Standard Trail Suspended and Suspension Bridges
Volumes A and B

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H.M.G. OF NEPAL MINISTRY OF WORKS AND TRANSPORT, ROADS DEPARTMENT

SATA, SWISS ASSOCIATION FOR TECHNICAL ASSISTANCE

PART A

PLANNING, DESIGN AND SURVEY OF

STANDARD TRAIL SUSPENDED AND SUSPENSION BRIDGES

Part A: Planning design and survey

1. Types of trail suspension or suspended bridges
2. Bridge design
3. Structural analysis
4. Survey of bridge sites
5. Construction work
6. Machines and tools

330 Steel drawings for the standard suspended and suspension bridges are available from the Suspension Bridge Division of HMG Roads Department

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Part B: Execution and maintenance

7. Cost estimate
8. Lay out
9. Construction
10. Bridge erection
11. Trail improvement
12. Maintenance
13. Photos of standard steel parts

330 Steel drawings for the standard suspended and suspension bridge are available from the Suspension Bridge Division of HMG Roads Department

PREFACE to the second enlarged edition

The manual for construction of suspension bridges will be quite helpful to the engineers who will construct suspension bridges in Nepal. It contains the details of methods of surveying, calculations and design procedures. Previously we did not have any such manual having so much in detail. I have no doubt that this manual will help all the engineers who will construct suspended and suspension bridges, specially those who will be newcomers and work for construction of trail suspension bridges.
At the same time I must appreciate the commendable work done by Mr. H. Pfaffen, civil engineer with SATA.

C. B. Pradhanang
Superintending Engineer

Kathmandu, March 1977

The manual for Trail Suspension Bridges which first appeared in autumn 1975 has now been reedited for this second enlarged edition. The contents were increased at the wish of many for an extensive treatment of the deliberation and analysis necessary to plan, design, estimate and construct standardized bridges.
The suspended bridge (bridge without pylons) was completely accepted as an equally valid solution to the suspension bridge, its standardized design has also been taken into full consideration.
We have not attempted to cover the entire field of the bridge construction work, but rather to select some of the most important sections for unstiffened suspension bridges and their foundation constructions with a special reference to a practical and economical engineering work. It has been assumed that our readers already have a basic knowledge of engineering work and we hope that they will find this book both instructive and covering the matters for execution of trail bridges.
For further assistance we recommend the standardized designs of steelwork for suspended and suspension bridges of HMG' Roads Department compiled with SATA, Swiss Association for Technical Assistance. The quantity of work has, however, been such, that the 330 plans for the unit - construction bridge systems could not be included in this manual. These drawings have been worked out and are available from the Suspension Bridge Division.
This edition was financed by SATA. At the same time I would like to thank all at the Suspension Bridge Division for their helpful comments, especially the SATA engineers Leo Condrau and Robert Groeli for their unvaluable help to complete this manual.

Hans Pfaffen
SATA

Kathmandu, March 1977

PREFACE to the first edition

The descriptions given in this book will be quite helpful specially to those who will be working for suspension bridge projects for the first time. The tables and formulas given will enable the surveyors to work out the calculations on site itself. The instructions to be followed during the construction period will help all the bridge builders to avoid the mistakes that may even lead to the failure of bridges.

C. B. Pradhanang
Superintending Engineer
Suspension Bridge
Division

Kathmandu, September 1975

The Suspension Bridge Division should construct more than 50 foot - trail suspension bridges throughout the country during the 5th Plan (1975 - 1980) period. Past experience has shown that little technical training was provided for newcomers in the field of suspension bridge design and construction work. The Manual as presented now, is in a preliminary phase and should g[illegible] a basis for future technical training. In advance I would like to thank those who will give critical suggestions, and help for adding new pages.

H. Aschmann
SATA

Kathmandu, September 1975

PART A

PLANNING, DESIGN AND SURVEY

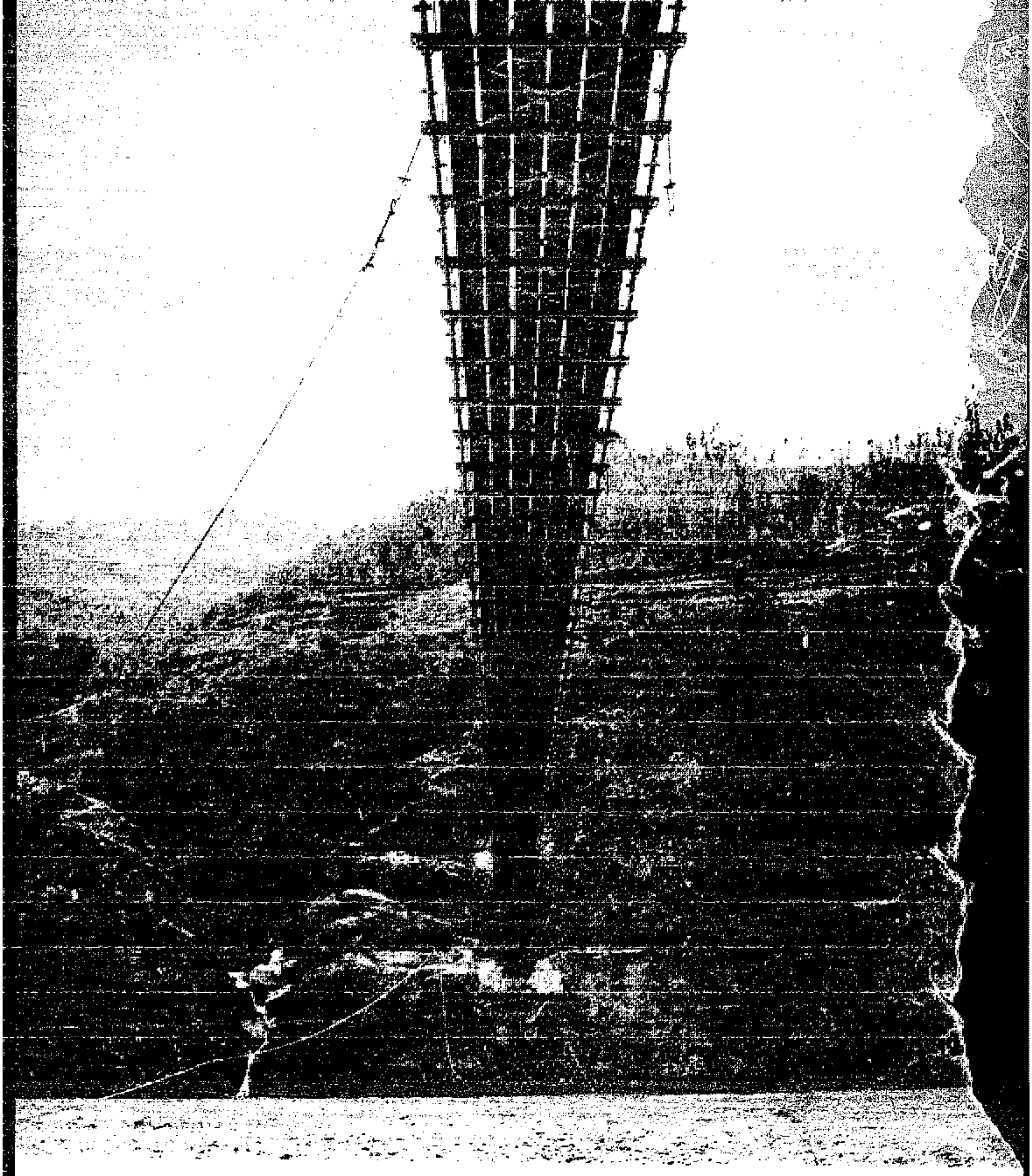
EXECUTION AND MAINTENANCE REFER TO PART B

CONTENTS

5. CONSTRUCTION MATERIAL

6. MACHINES AND TOOLS

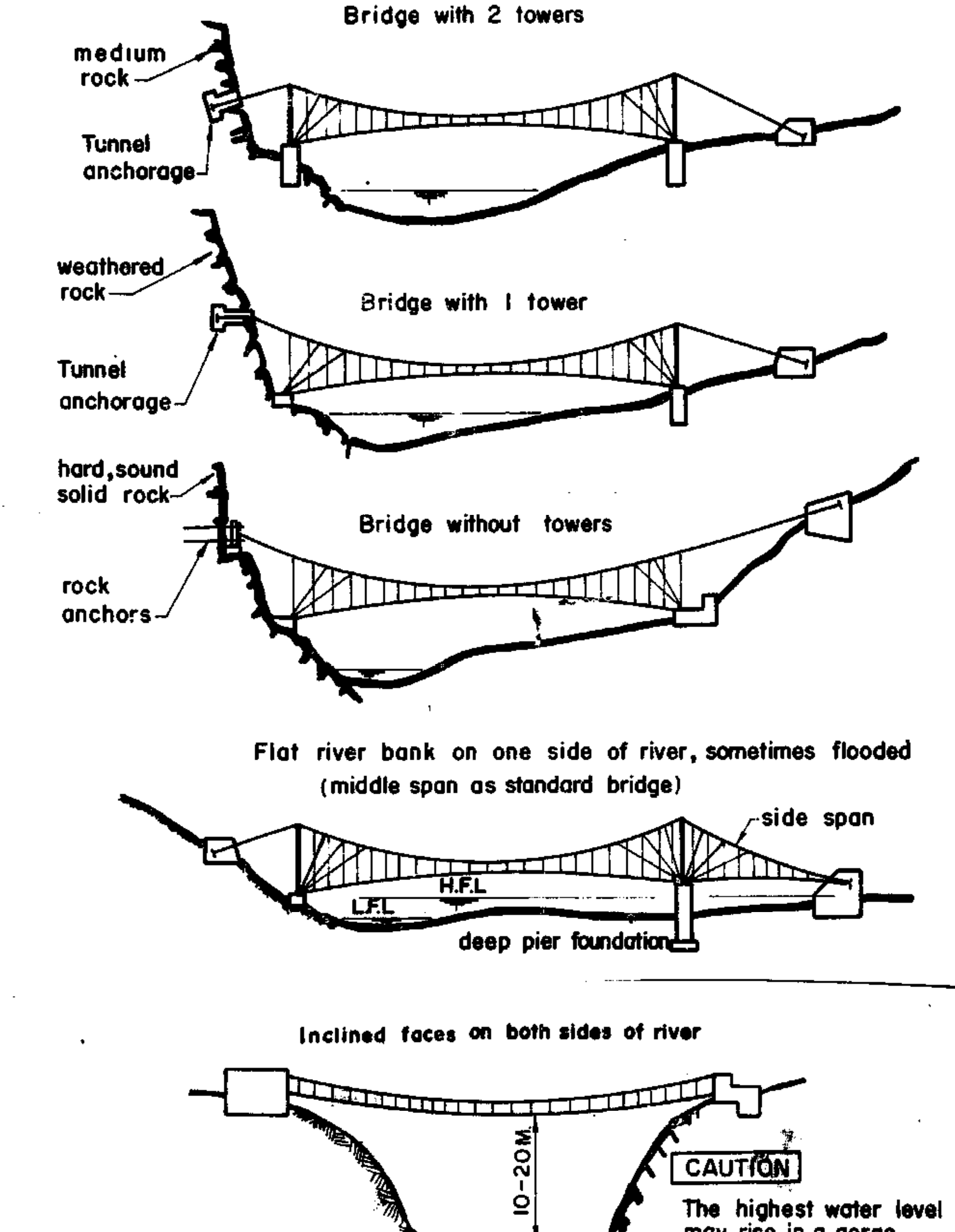
7. COST ESTIMATE



I. TYPES OF TRAIL SUSPENSION OR SUSPENDED BRIDGES

TYPES OF TRAIL SUSPENSION OR SUSPENDED BRIDGES	No. 1.101
GENERAL DESIGN. Variations depending on cross section and soil	Date: 30th Dec 76
	Sig.: [signature]

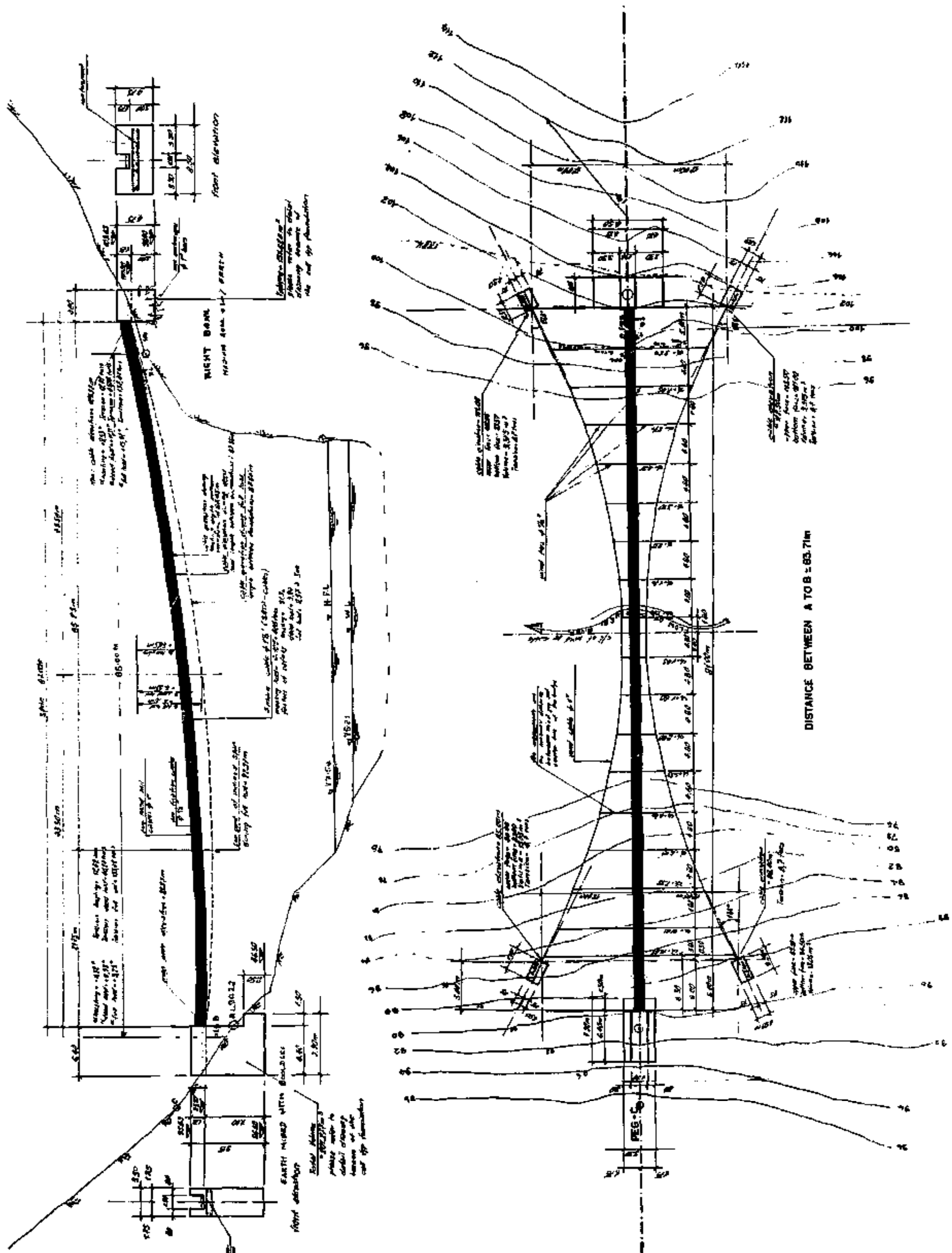
For further information and references please refer to the chapter 2. Bridge Desig



SOURCES: Design Section of Suspension Bridge Division.

TYPES OF SUSPENSION OR SUSPENDED BRIDGES General Design (e.g. 512 Dhaunebagar Suspended Bridge of 87 m span)	No. : 1.102 Date : 13th Dec. 76 Sig : [signature]

Noteworth : The main anchor blocks are placed at different levels. This system is known as a inclined span. For the type of a suspension bridge with two pylons either a huge excavation or a high foundation would have been necessary on one river bank. This solution would be much costlier than the choise of a suspended Bridge without pylons.



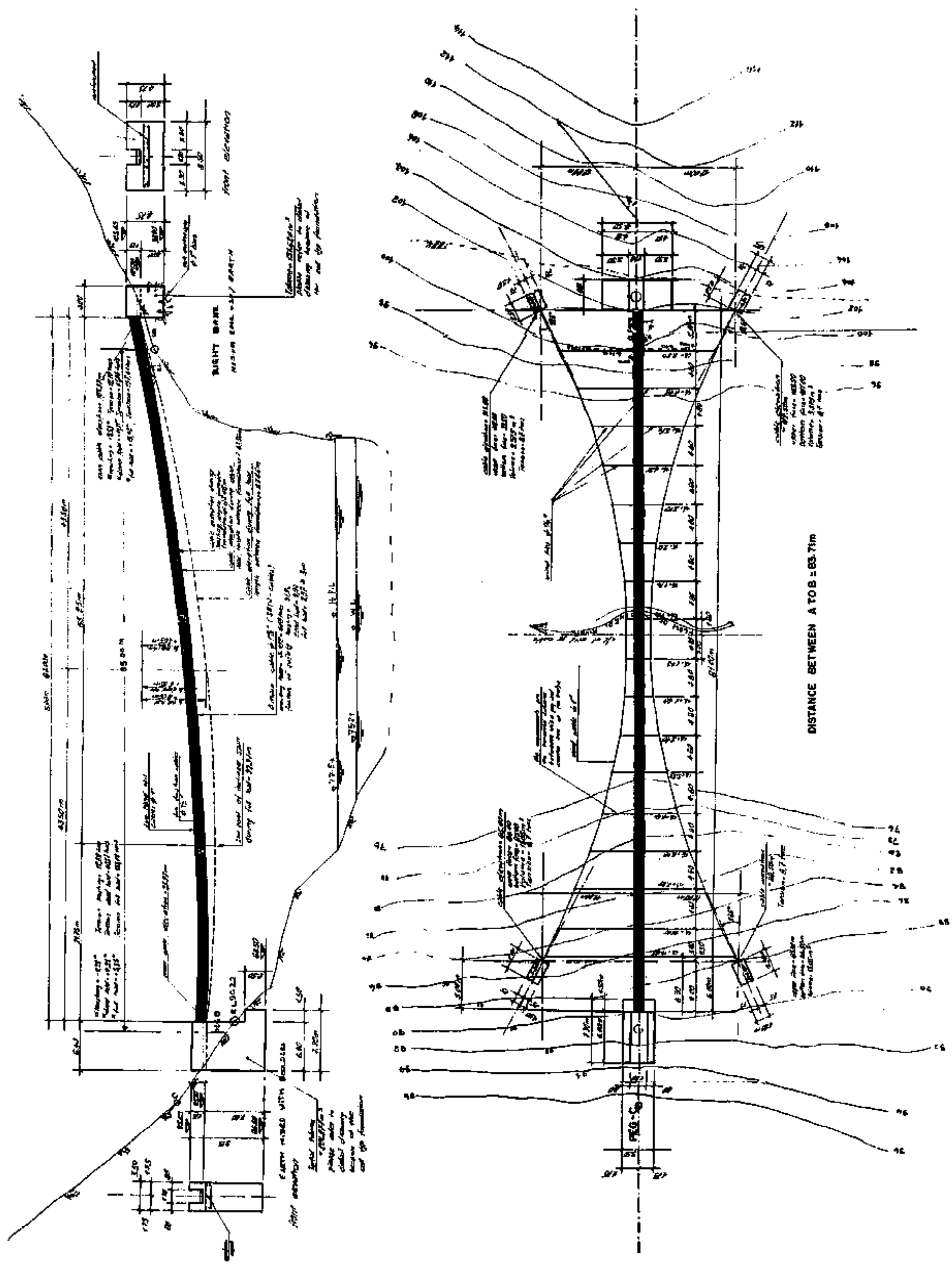
TYPES OF SUSPENSION OR SUSPENDED BRIDGES

General Design

(e.g. 512 Dhaunebagar Suspended Bridge of 87 m span)

No.	: 1.102
Date	: 13th Dec. 76
Sig	: [signature]

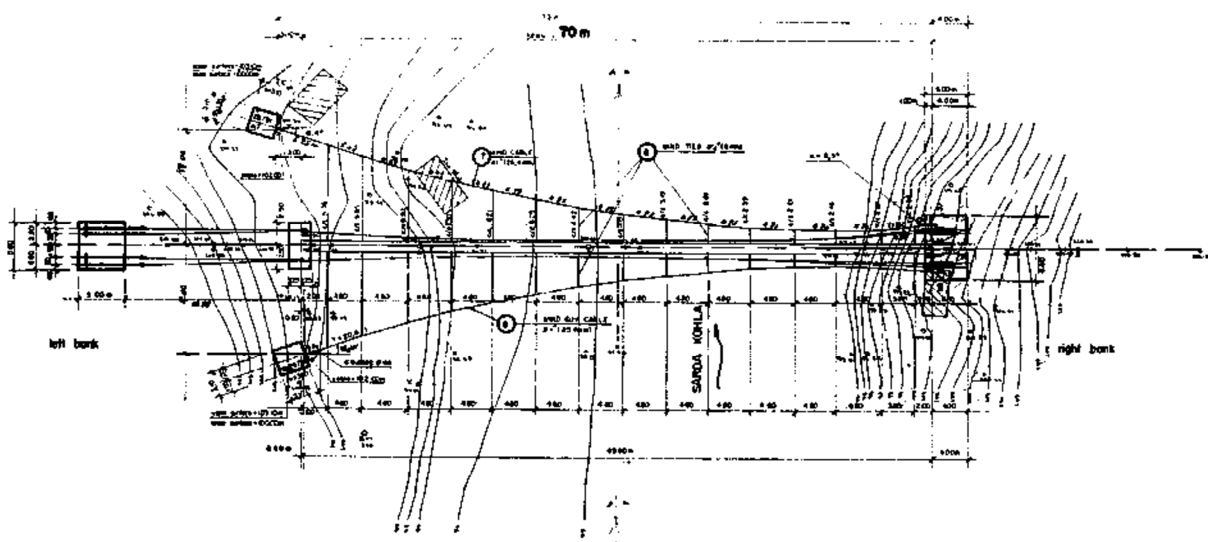
Noteworth : The main anchor blocks are placed at different levels. This system is known as a inclined span. For the type of a suspension bridge with two pylons either a huge excavation or a high foundation would have been necessary on one river bank. This solution would be much costlier than the choise of a suspended Bridge without pylons.

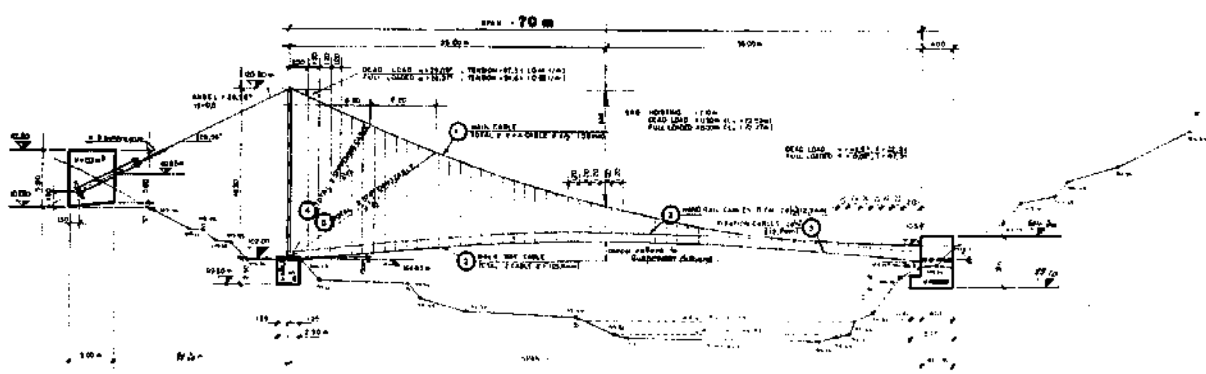


TYPES OF TRAIL SUSPENSION OR SUSPENDED BRIDGES General Design (e.g. 507 Chacklighat Bridge of 70 m Span with one Pylon)	No. : 1.103 Date : 13th Dec. 76 Sig :

Noteworth : It has been proved that this is only economical for short spans, as the pylons get to high, or a relatively high tensile force has to be anchored. It should and must be mentioned, that this type might only be chosen if the costs can be expected lower than the normal solution with two pylons.

PLAN

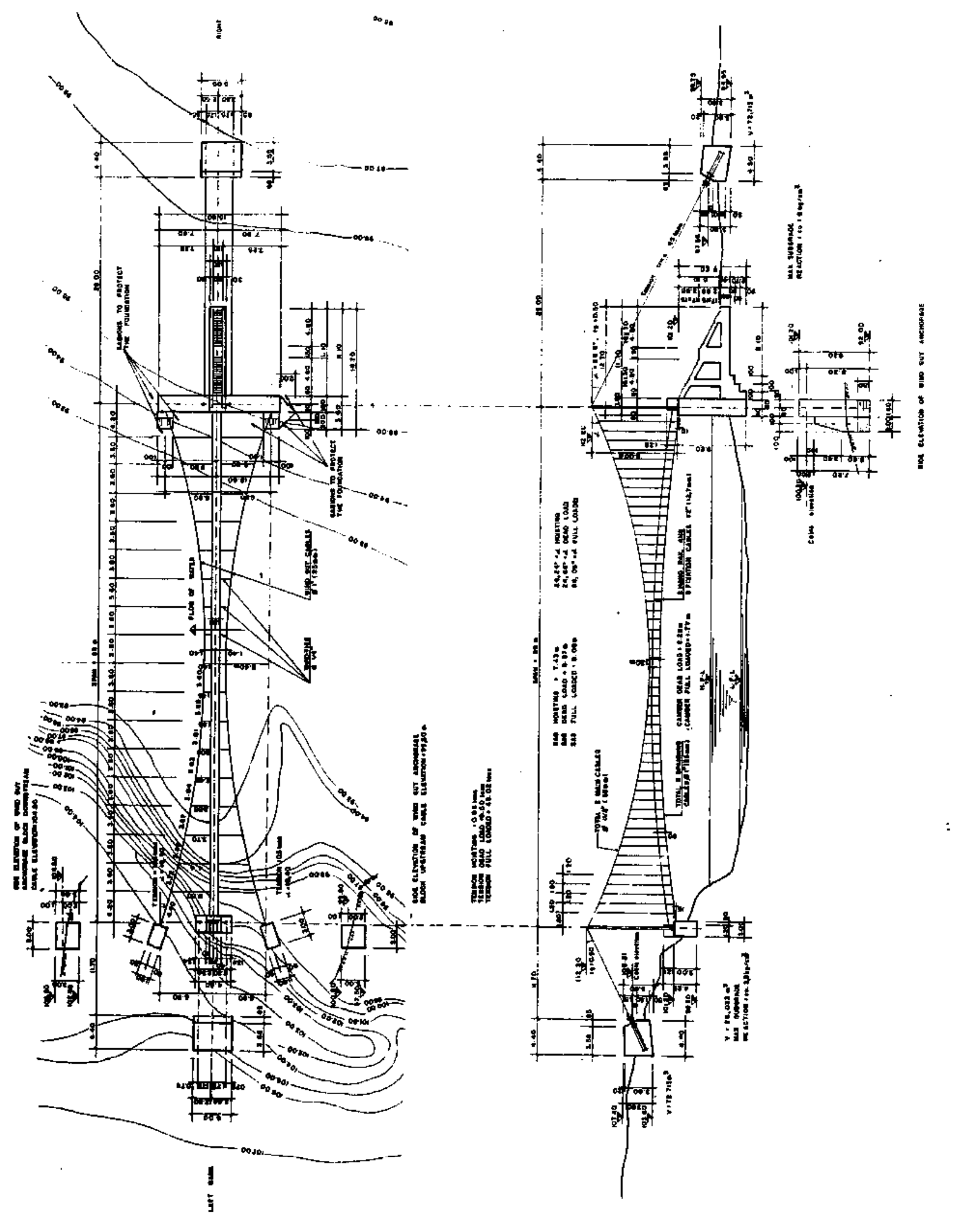




ELEVATION

S A T A , Swiss Association for Technical Assistance

TYPES OF TRAIL SUSPENSION BRIDGES General Arrangement for a Suspension Bridge (e.g. 517 Chutra Besi Bridge of 66 m Span)	No. : 1.104
	Date : 1st. Dec. 76
	Sig :



HMG Nepal	Roads Departmentnt	Suspension Bridge Division

SATA, Swiss Association for Technical Assistance

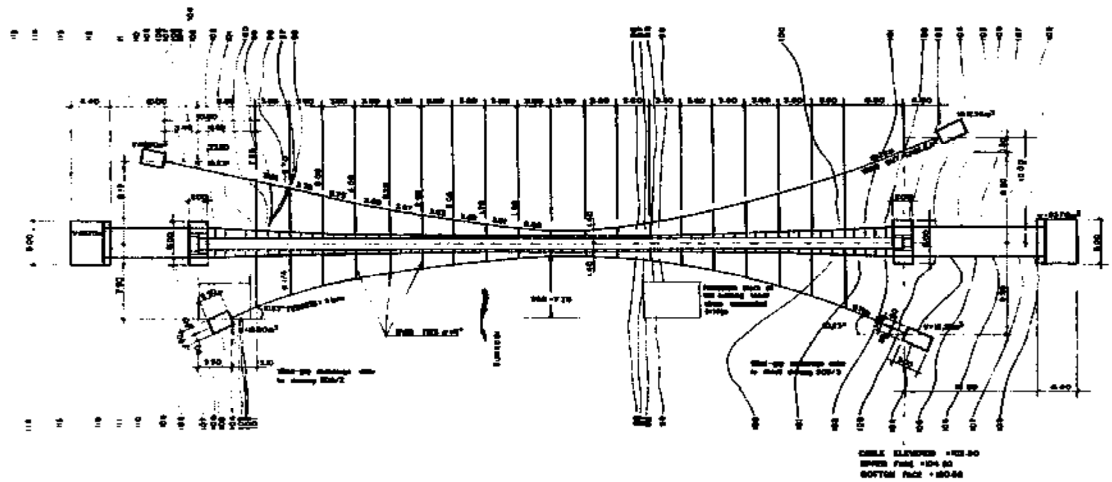
TYPES OF TRAIL SUSPENSION OR SUSPENDED BRIDGES

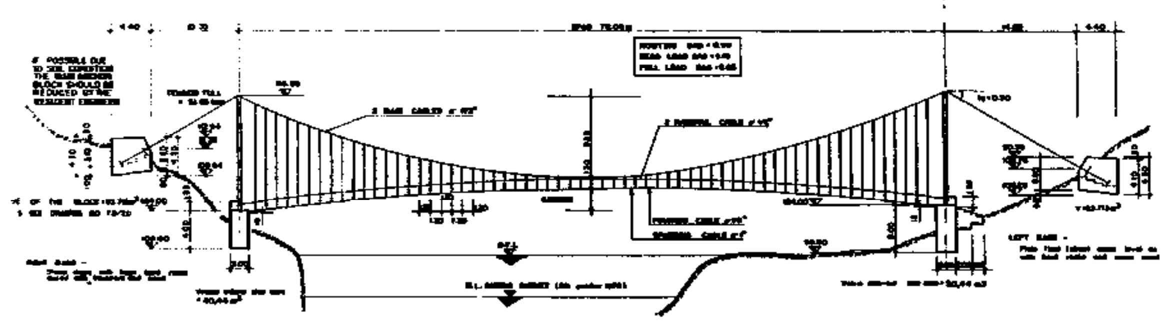
General Design

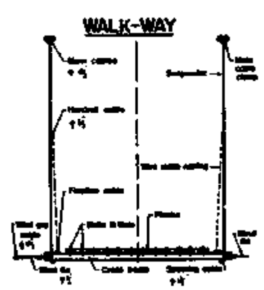
(e.g. 508 Kothe Bridge of 78 m span)

No.	: 1.105
Date	: 13th. Dec. 76.
Sig	: [signature]

Noteworth: The span is chosen with 78 m because the free board line with at least five (5) metres above the known high flood level has to be taken into account.



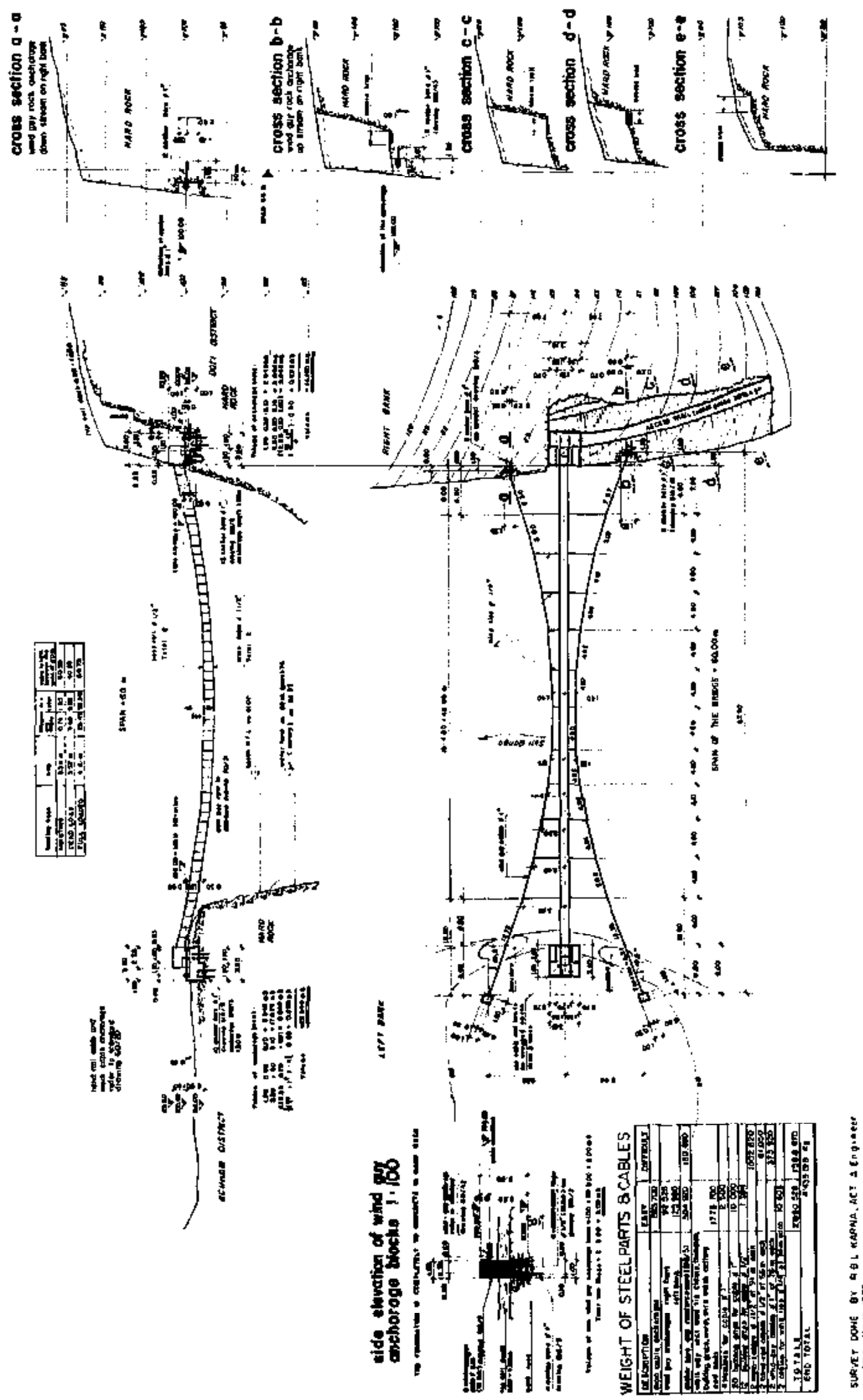




SATA, Swiss Association for Technical Assistance

TYPES OF TRAIL SUSPENSION OR SUSPENDED BRIDGES General Design (e.g. 518 Maurasain Bridge of 60 m span)	No. : 1.106 Date : 13th Dec. 76 Sig : for [signature]

Noteworth: On one side the hard sound rock is used as ancherage. The needed volume of about 48 m3 for the whole bridge makes the bridge cheap. For the main anchorag 1 : 3: 6 mass cencrete, and for the wind guy anchorage on the left bank 1 : 2: 4 mass cencrete is used.



TYPES OF TRAIL SUSPENSION OR SUSPENDED BRIDGES	No. : 1.106
General Design	Date : 13th Dec. 76
(e.g. 518 Maurasain Bridge of 60 m span)	Sig : [signature]

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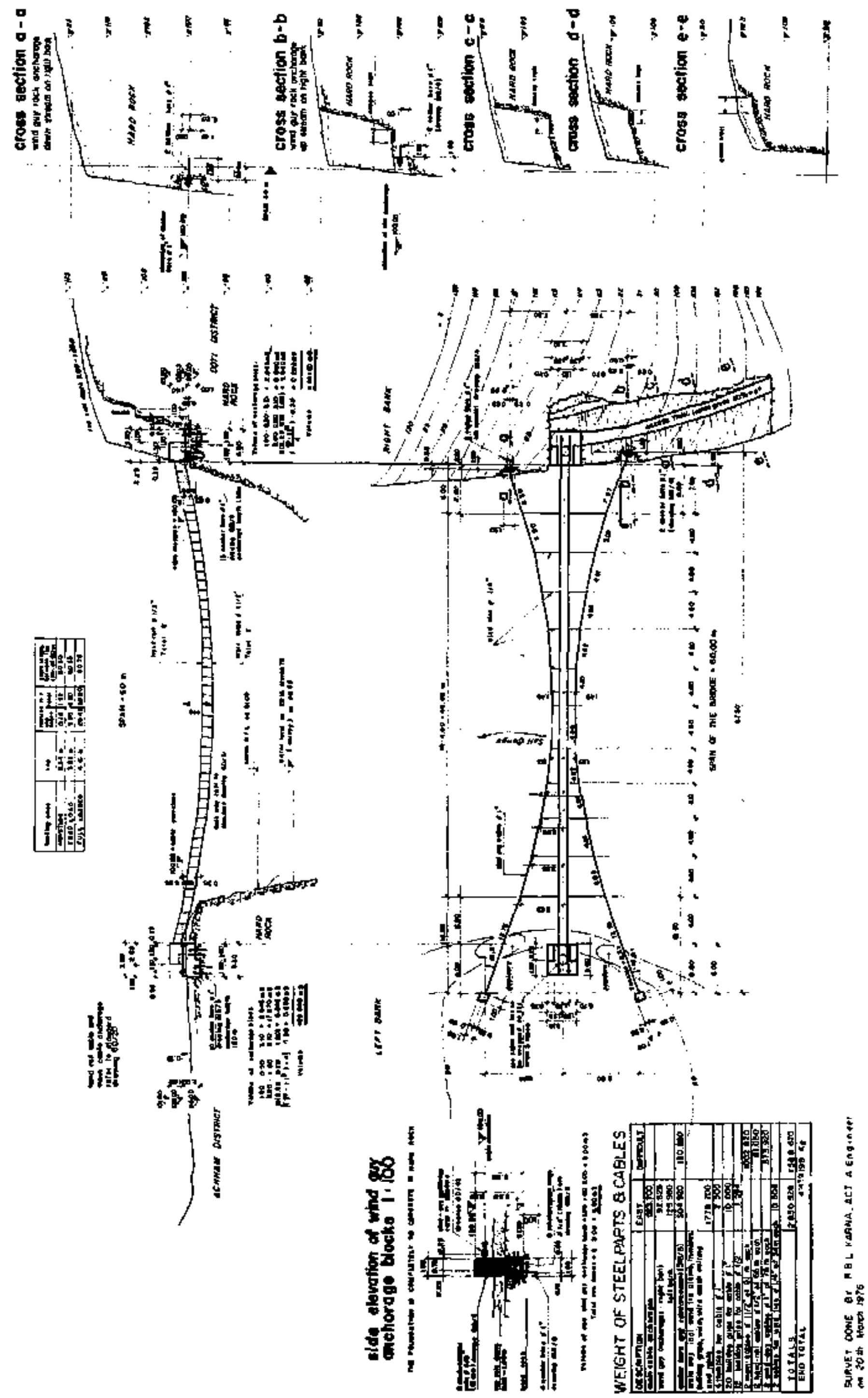
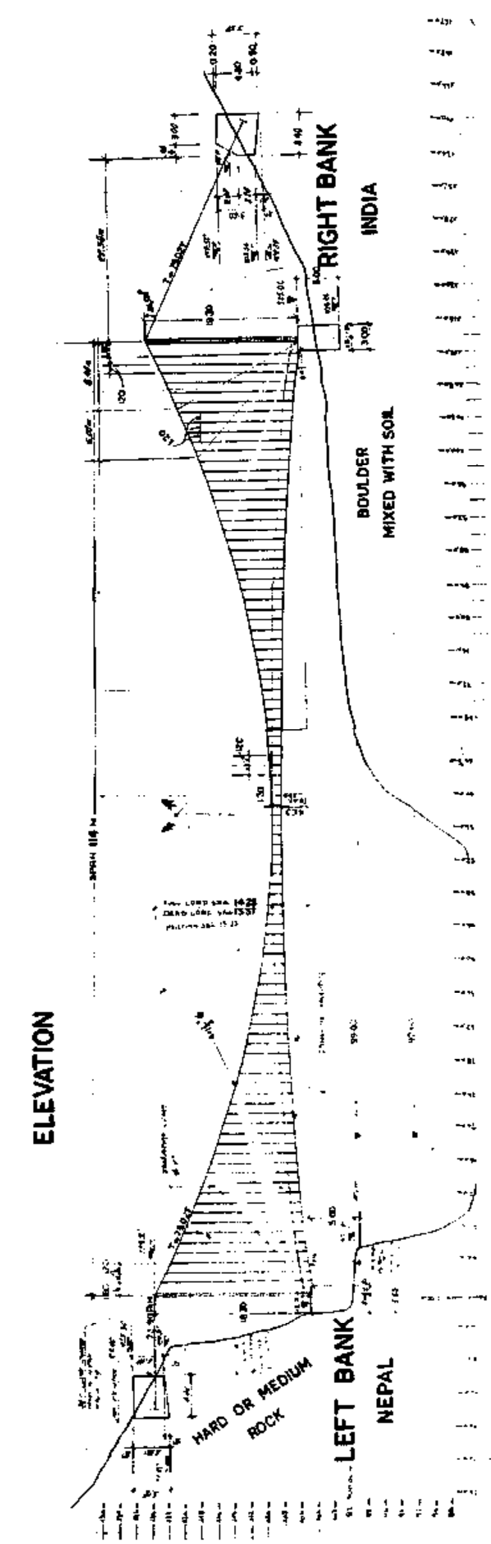


TYPES OF TRAIL SUSPENSION OR SUSPENDED BRIDGES General Design (e.g. 506 Jauljibi Suspension Bridge of 114 m Span)	No. : 1.107 Date : 13th Dec. 76 Sig : [signature]

Noteworth : On the left river bank the back stay cables are nearly horizontal. The pylon is a hinge type, i.e. no different in the horizontal force can be kept by the tower. To withstand the propensity to turn buck of the pylon a special clamp at the saddle has to be used. These clamps (on each saddle one) should be calculated by using a factor of sliding of 0.1 and a factor of safety with 1.5 .



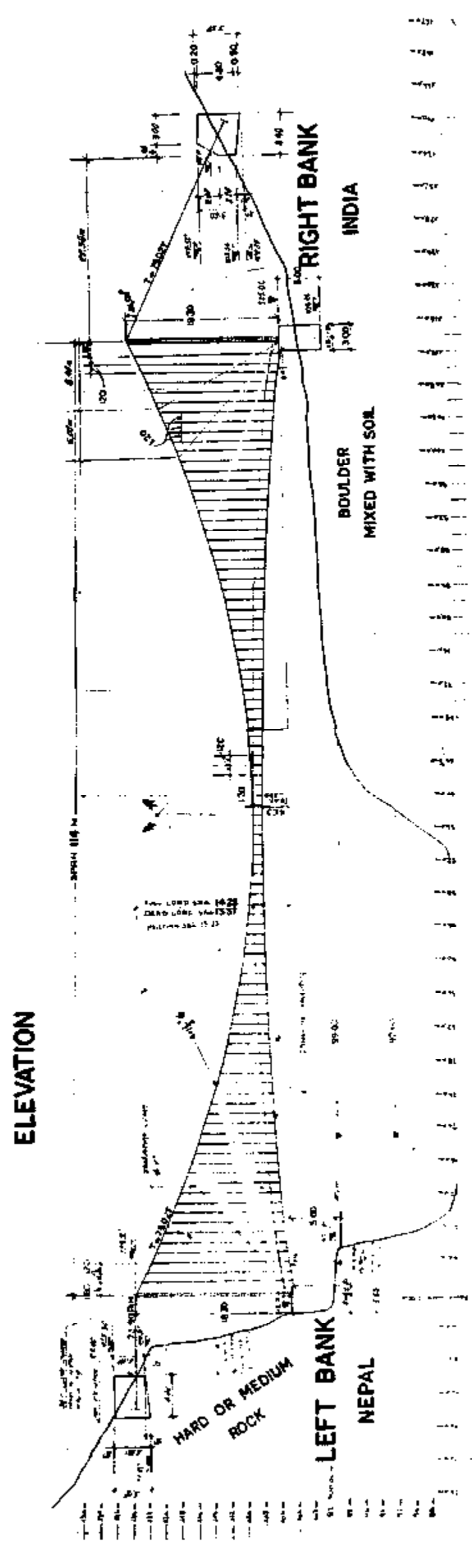
TYPES OF TRAIL SUSPENSION OR SUSPENDED BRIDGES

General Design

(e.g. 506 Jauljibi Suspension Bridge of 114 m Span)

No.	: 1.107
Date	: 13th Dec. 76
Sig	:

Noteworth : On the left river bank the back stay cables are nearly horizontal. The pylon is a hinge type, i.e. no different in the horizontal force can be kept by the tower. To withstand the propensity to turn buck of the pylon a special clamp at the saddle has to be used. These clamps (on each saddle one) should be calculated by using a factor of sliding of 0.1 and a factor of safety with 1.5 .



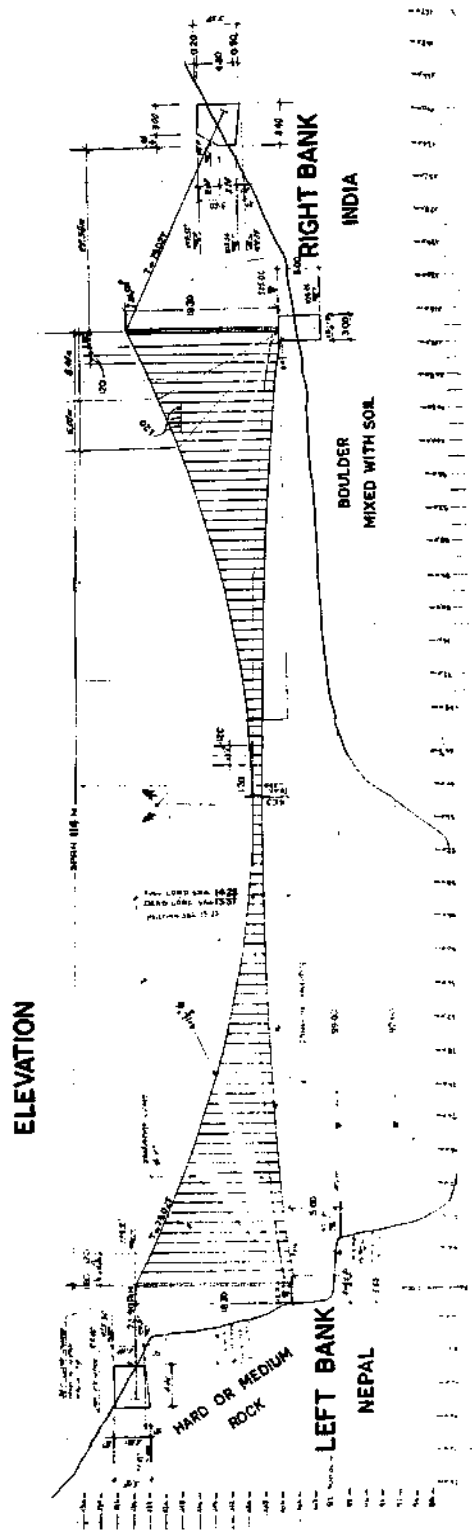
TYPES OF TRAIL SUSPENSION OR SUSPENDED BRIDGES

General Design

(e.g. 506 Jauljibi Suspension Bridge of 114 m Span)

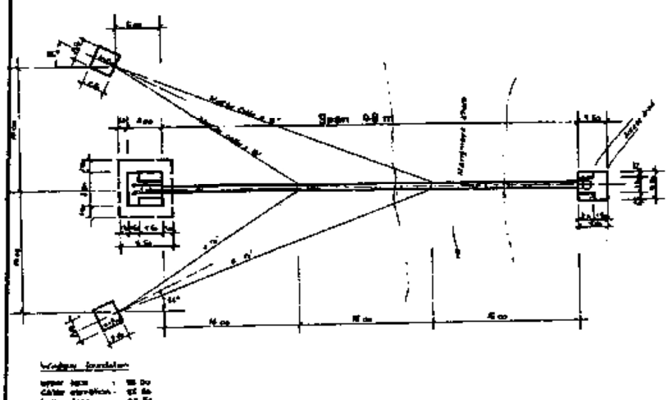
No.	: 1.107
Date	: 13th Dec. 76
Sig	: [signature]

Noteworth : On the left river bank the back stay cables are nearly horizontal. The pylon is a hinge type, i.e. <u>no</u> different in the horizontal force can be kept by the tower. To withstand the propensity to turn buck of the pylon a special clamp at the saddle has to be used. These clamps (on each saddle one) should be calculated by using a factor of sliding of 0.1 and a factor of safety with 1.5 .



TYPES OF TRAIL SUSPENSION OR SUSPENDED BRIDGES General Design (e.g. 515 Mangmaya Khola Bridge of 48 m span)	No. : 1.108 Date : 13th Dec. 76 Sig : [signature]

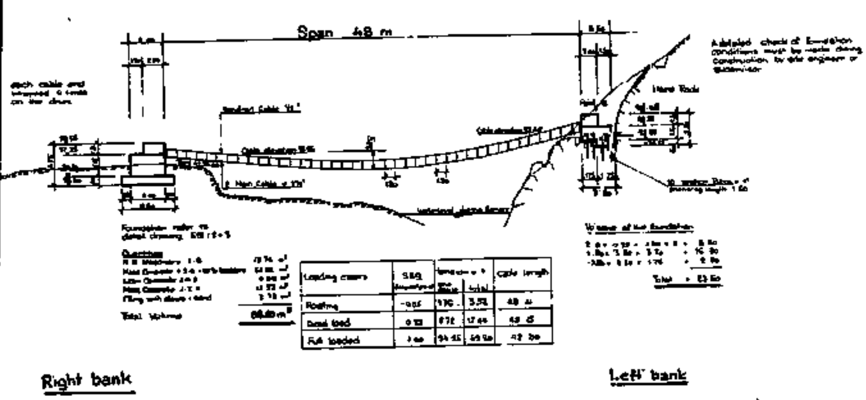
Noteworth : The first design has been a standard suspension bridge of 78 m span. After the Divisional Engineer and SATA Field Engineers have taken a field trip it was proved, that the proposed suspension bridge can be replaced with a standard suspended bridge of 48 m span only. This latter typ of bridge will save about two thirds of the amount to be spent on a suspension bridge. The new site of the 48 m suspended bridge is only about 25m upstream from the first proposed site. It must and should be said, that such errors should be prevented by the survey team which is conducting the site selection.

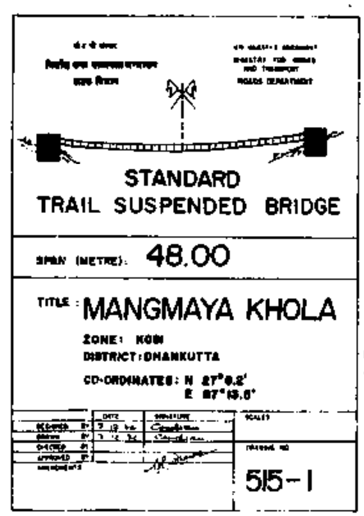


Weight of Steelparts and Cables

Description	Copy	Difficult	Supplied by
main cable anchorage	947.07	796.76	Workshop
windguy anchorage	754.94		Workshop
anchor bars and reinforcement	[illegible]		Workshop
windtie cable clamp	[illegible]		Workshop
[illegible]	[illegible]		Workshop
[illegible]	[illegible]		Workshop
1 Main cable [illegible]		774.40	S.B.D.
2 Handrail cable [illegible] 55 m each	[illegible]		S.B.D.
2 Windtie cable [illegible] 45 m each	[illegible]		S.B.D.
2 Windtie cable [illegible] 35 m each	[illegible]		S.B.D.
totals	[illegible]	[illegible]	
END TOTAL	[illegible] kg		

Reinforcement Steel refers to drawings no. 515/3 and 4 [illegible]
This drawing is to be read in conjunction with drawing no. :
[illegible]





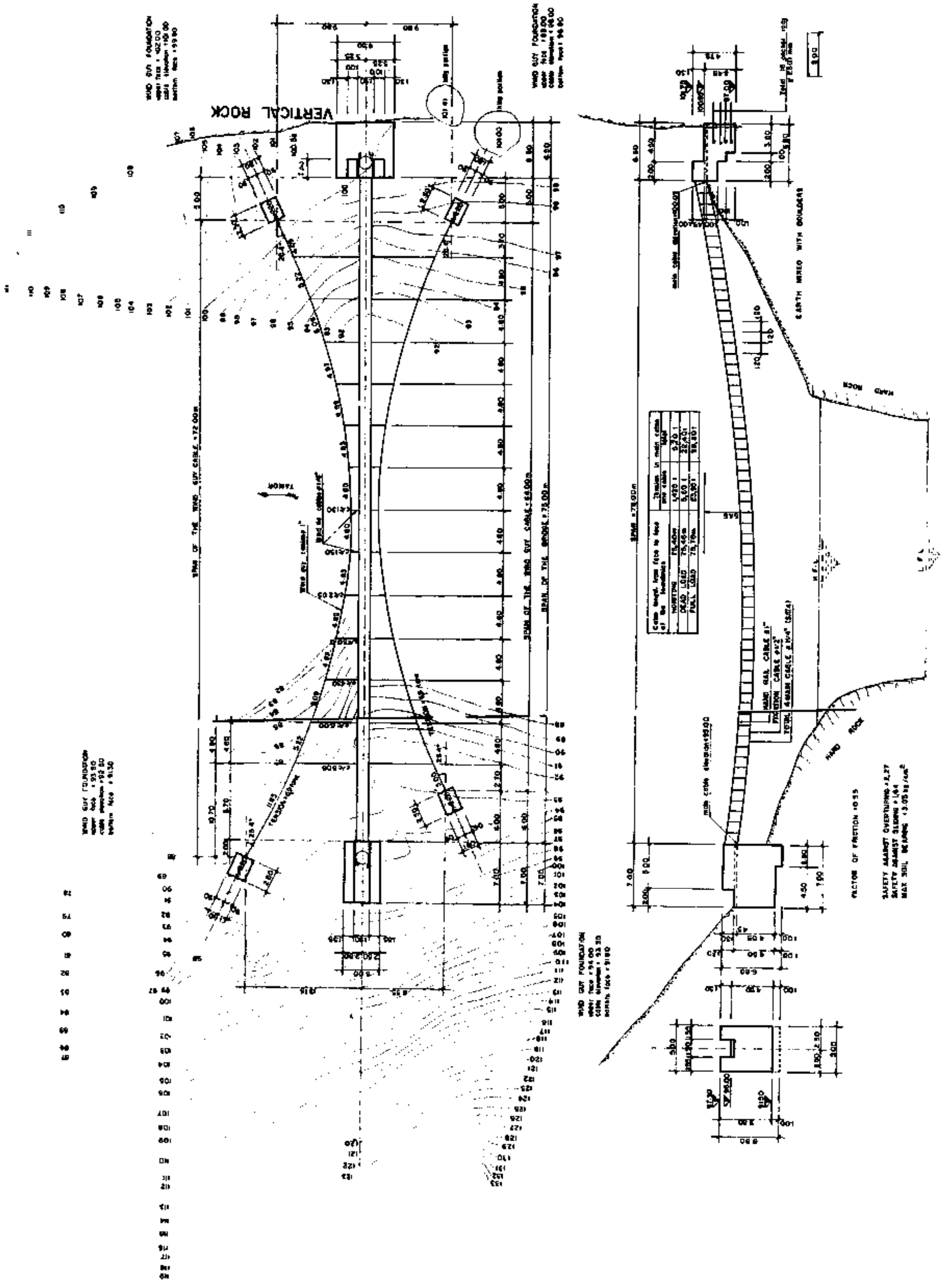
TYPES OF TRAIL SUSPENSION BRIDGES

General Design

(e.g. 523 Sekhathum Suspended Bridge of 75 m Span)

1.109

1st March 77



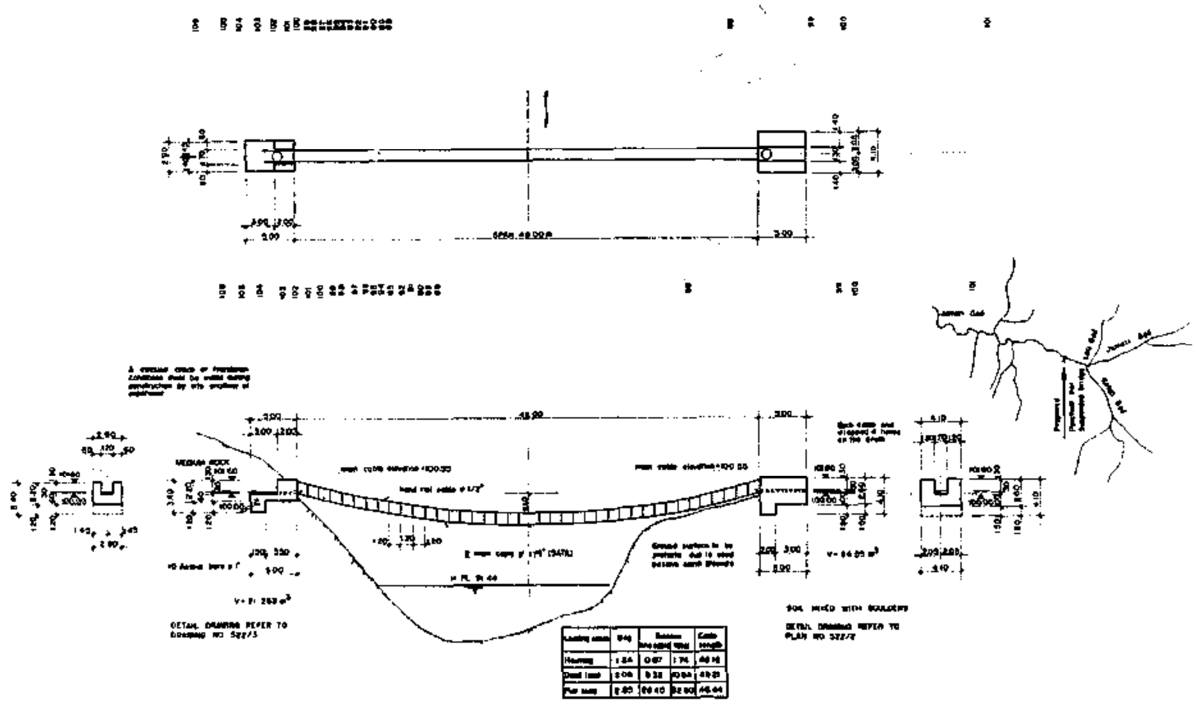
HMG Nepal Roads Department Suspension Bridge Division

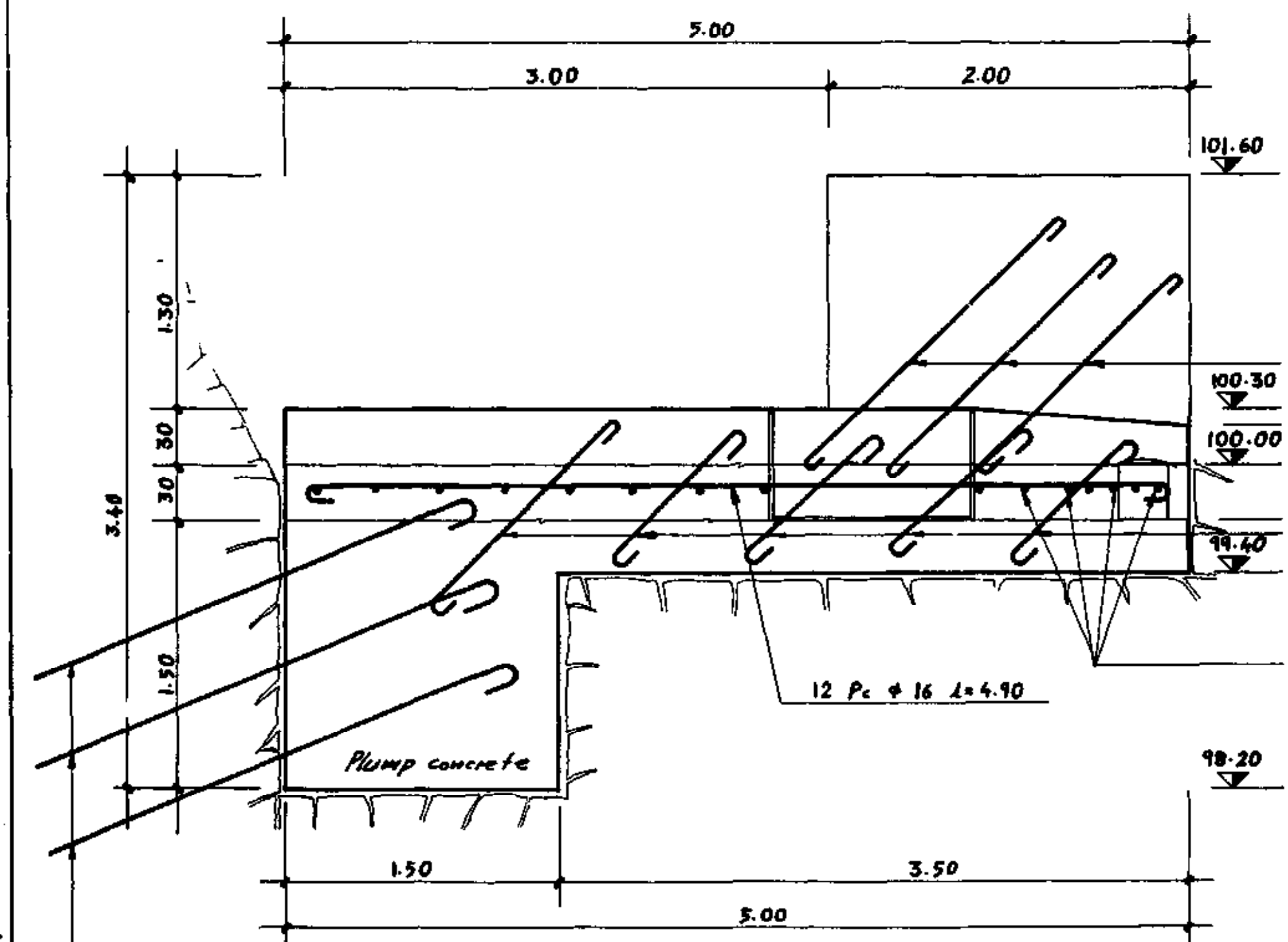
TYPES OF TRAIL SUSPENSION BRIDGES

General Design

(e.g. 522 Purchudi Hat Suspended Bridge of 48 m Span)

1.110
1st March 77





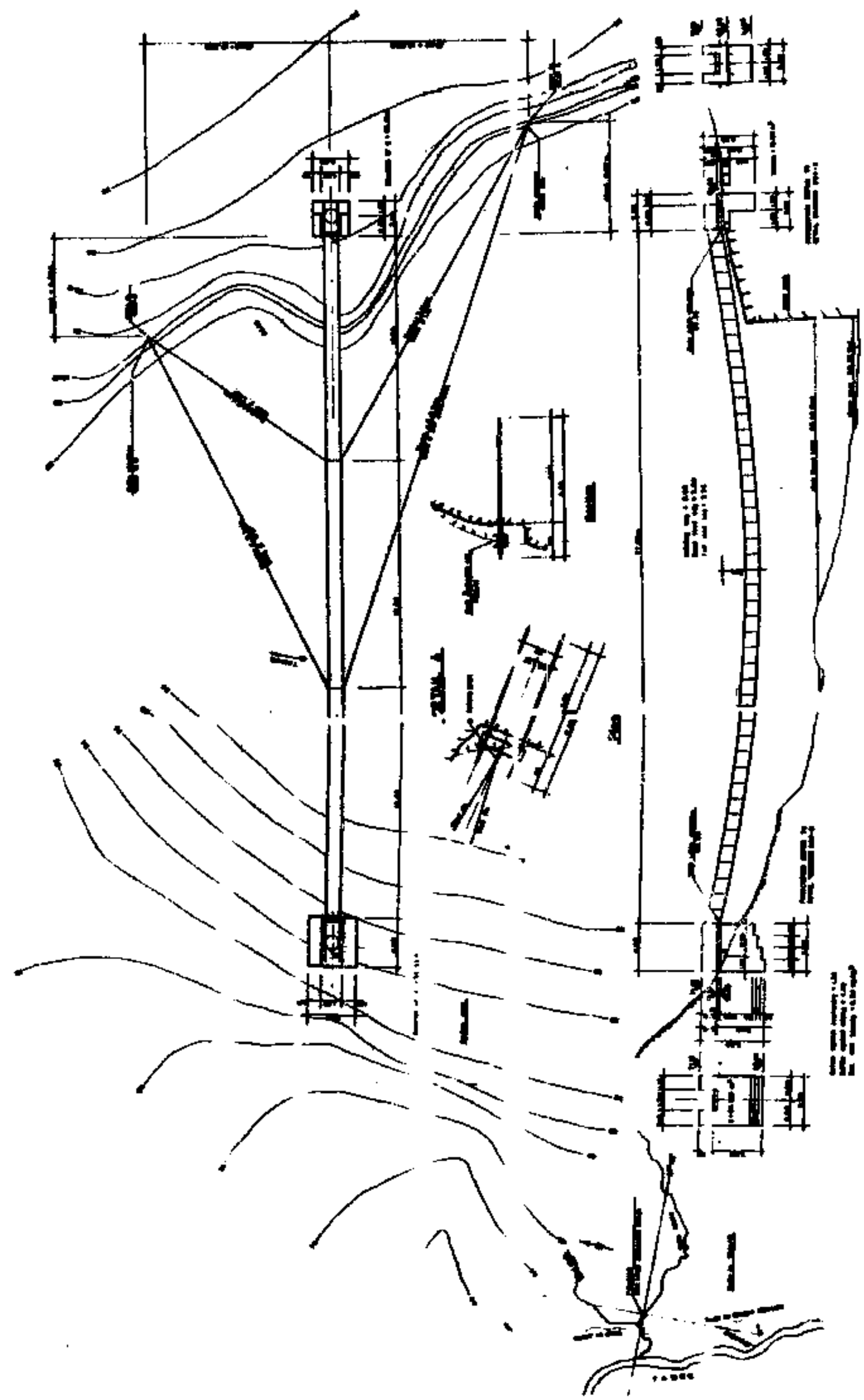
TYPES OF TRAIL SUSPENSION OR SUSPENDED BRIDGES

General Design

(e.g. 524 Nibu Khola Suspended Bridge of 57 m Span)

1.111

1st March 77



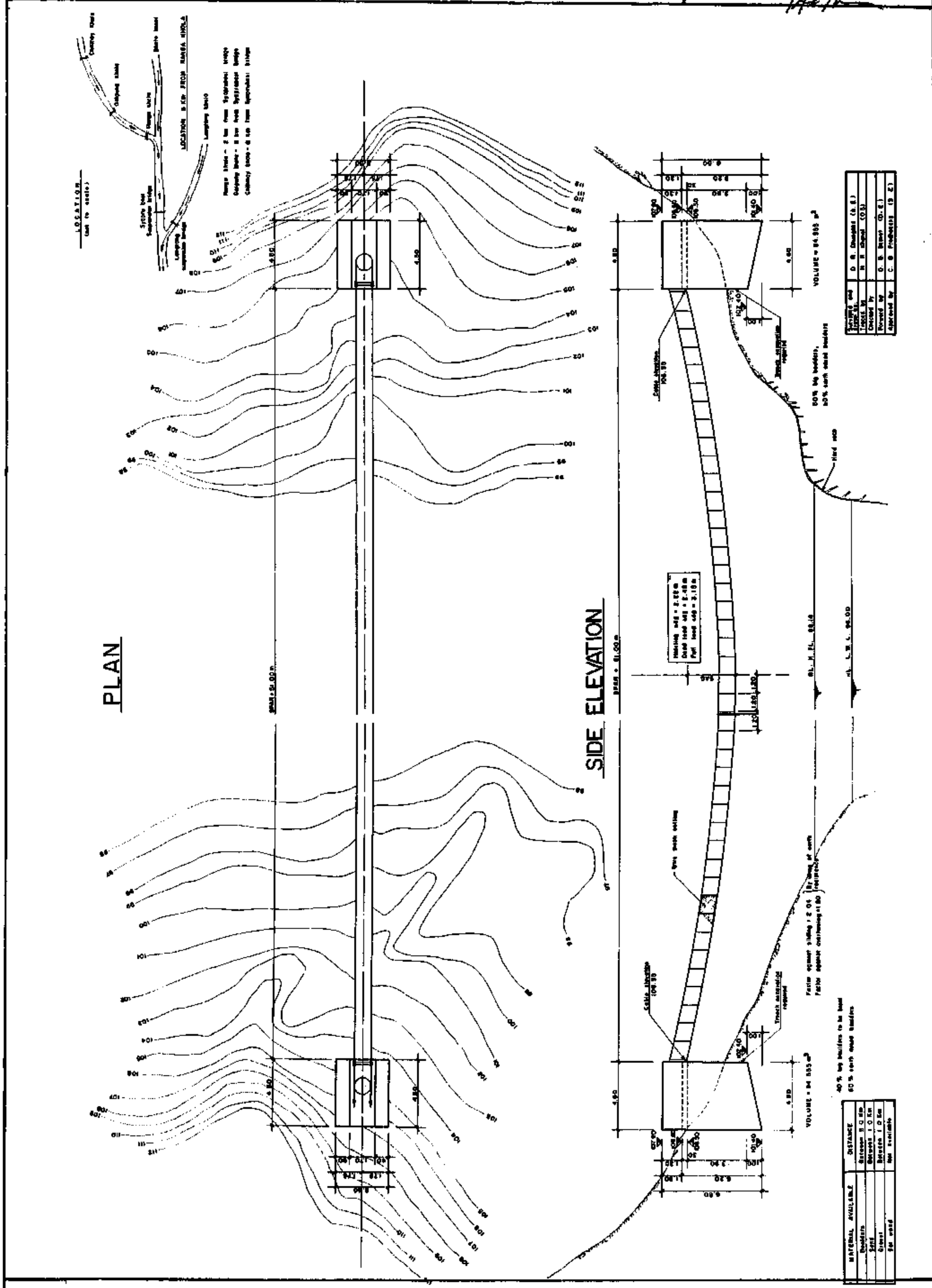
TYPES OF TRAIL SUSPENSION OR SUSPENDED BRIDGES

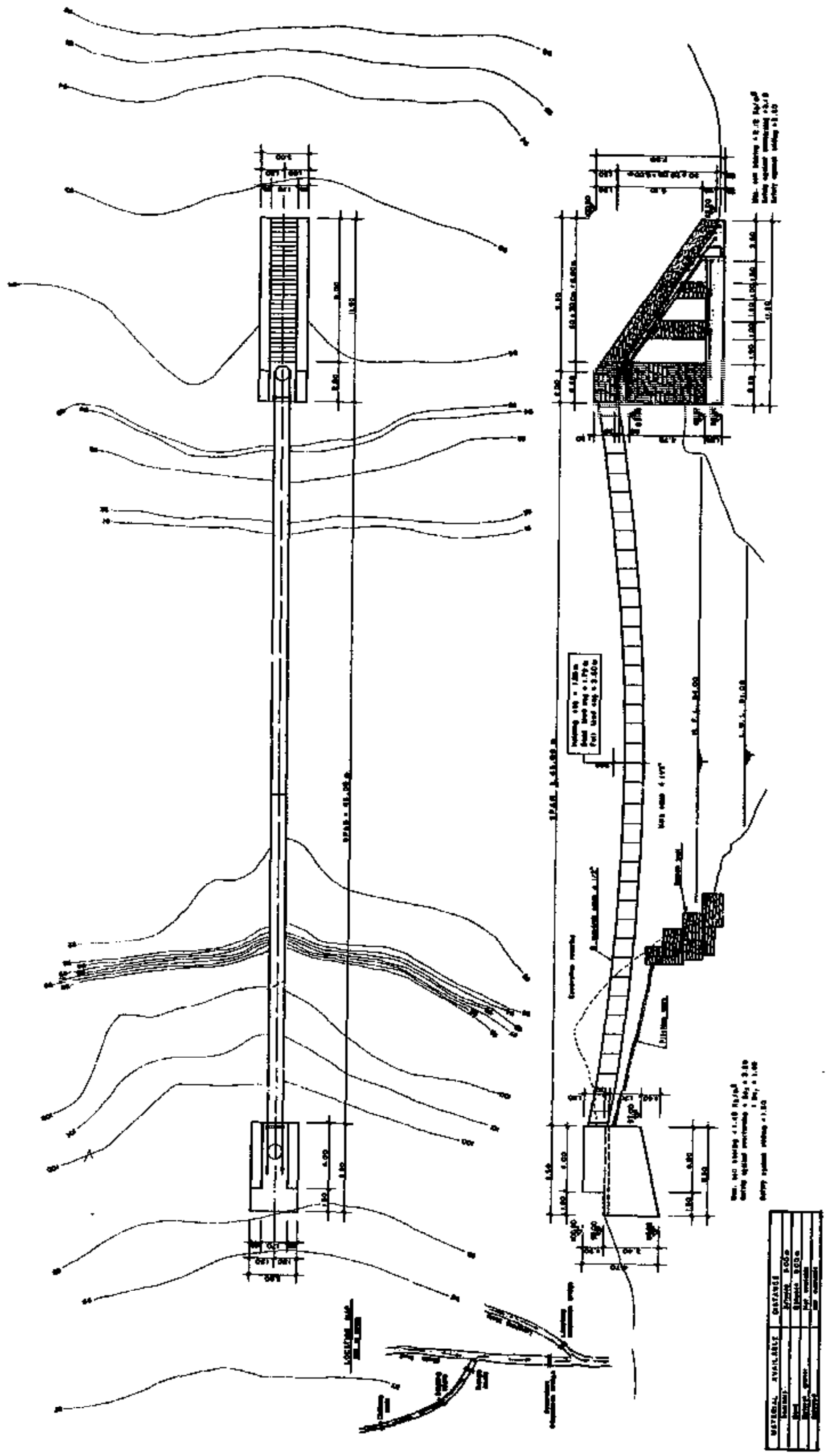
General Design

(e.g. 510 Chilimay Khola Suspended Bridge of 51 m Span)

1.112

1st March 77





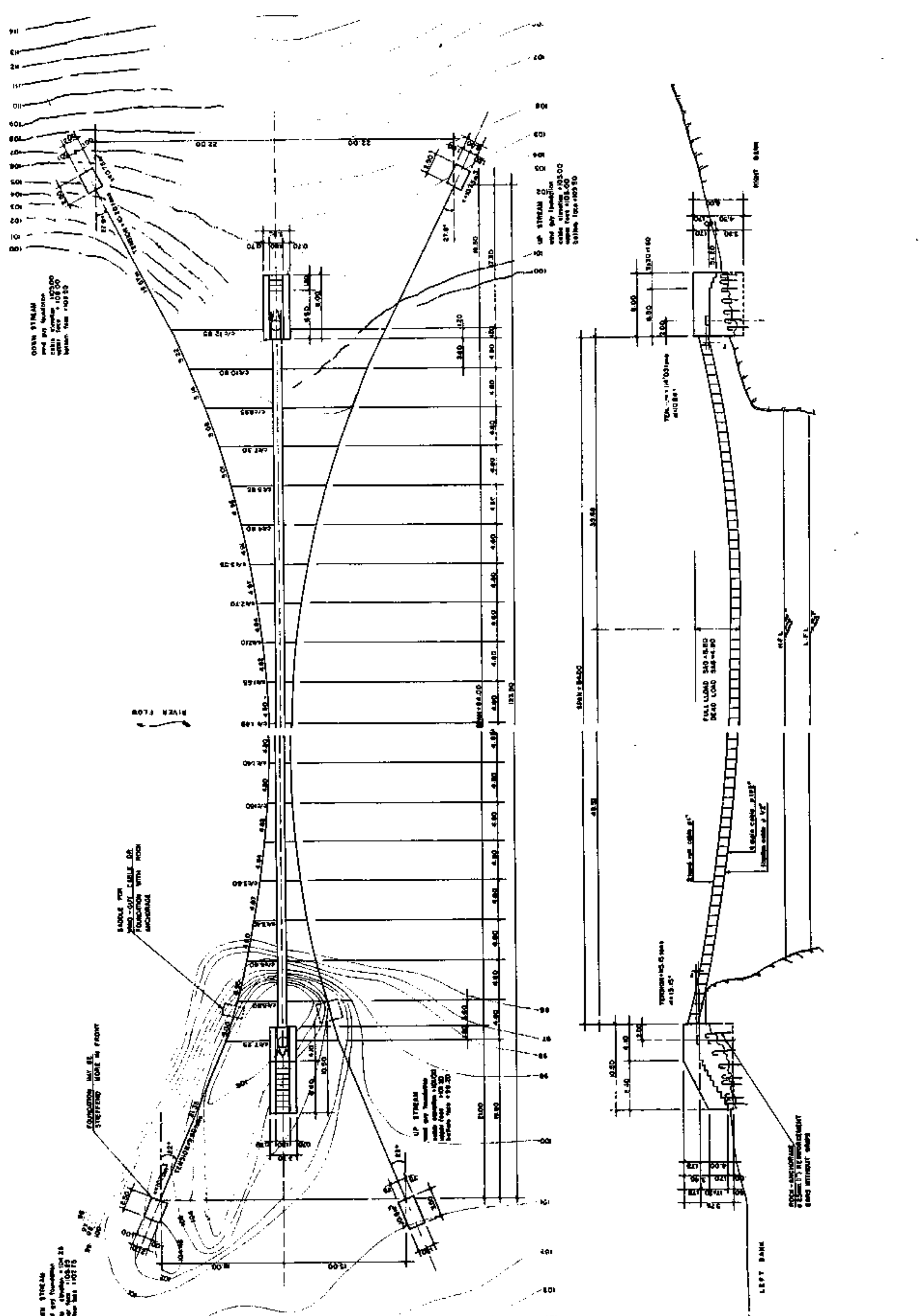
TYPES OF TRAIL SUSPENSION OR SUSPENDED BRIDGES

General Design

(e.g. 513 Sukadhik Bouldik Suspended Bridge of 84 m Span)

1.114

1st March 77

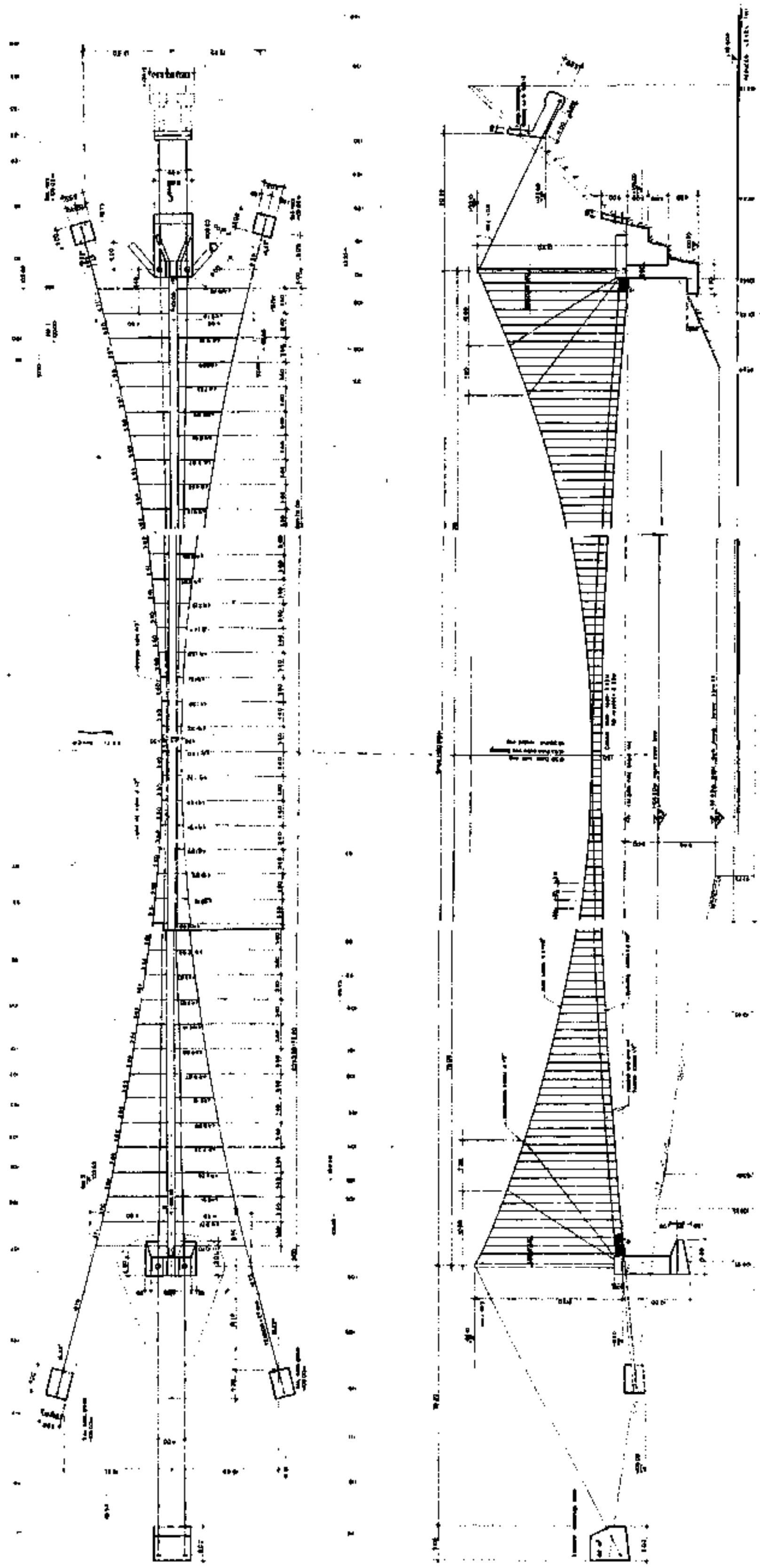


SATA, Swiss Association for Technical Assistance

General Design

(e.g. 521 Lodey Ghat Suspension Bridge of 150 m span)

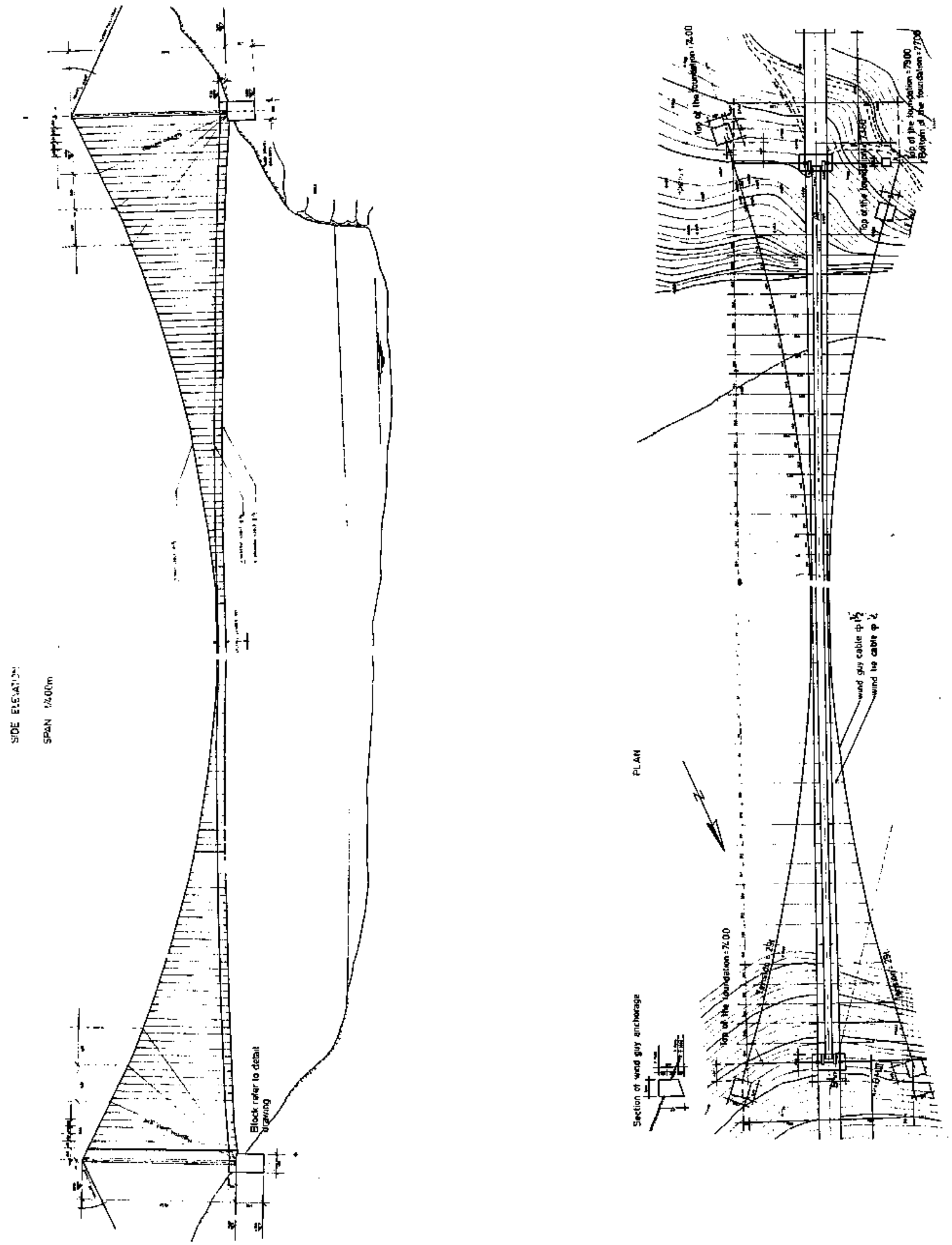
1st March 77



TYPES OF SUSPENSION OR SUSPENDED BRIDGES

General Design

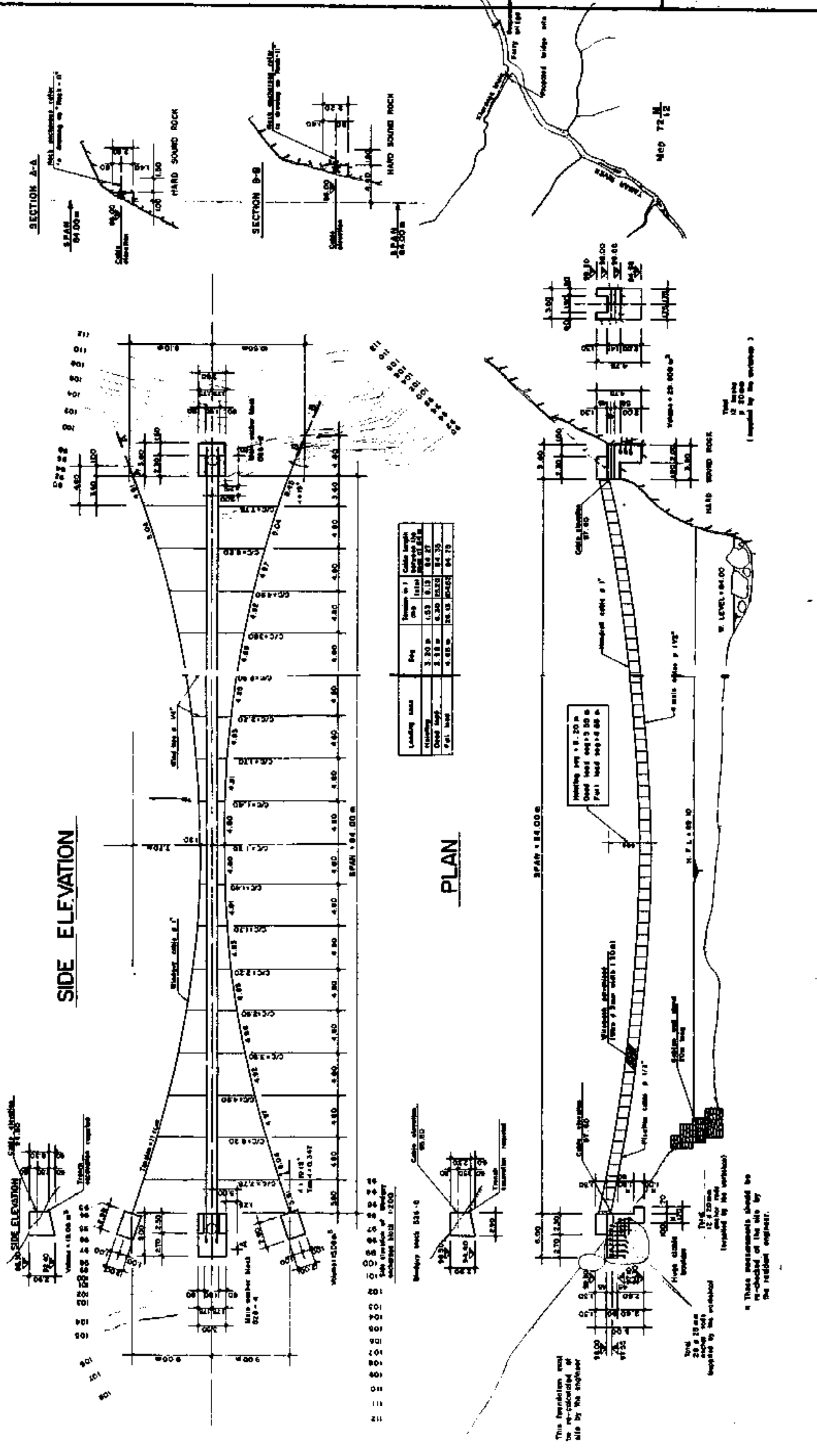
(e.g. 525 Pikuwa Khola Suspension Bridge of 174 m span)



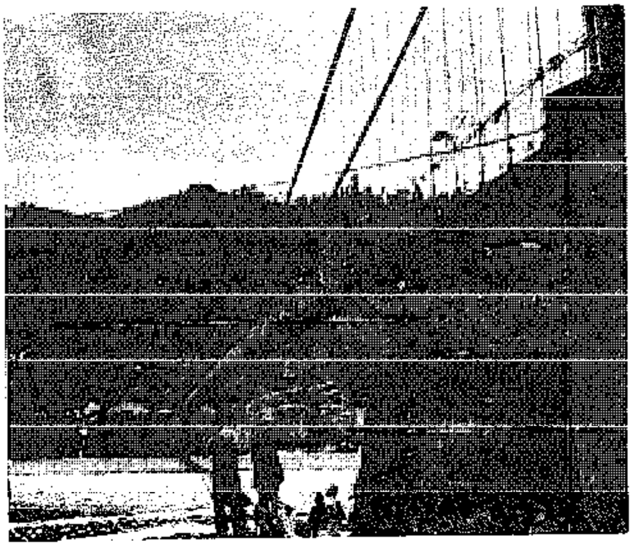
TYPES OF SUSPENSION OR SUSPENDED BRIDGES

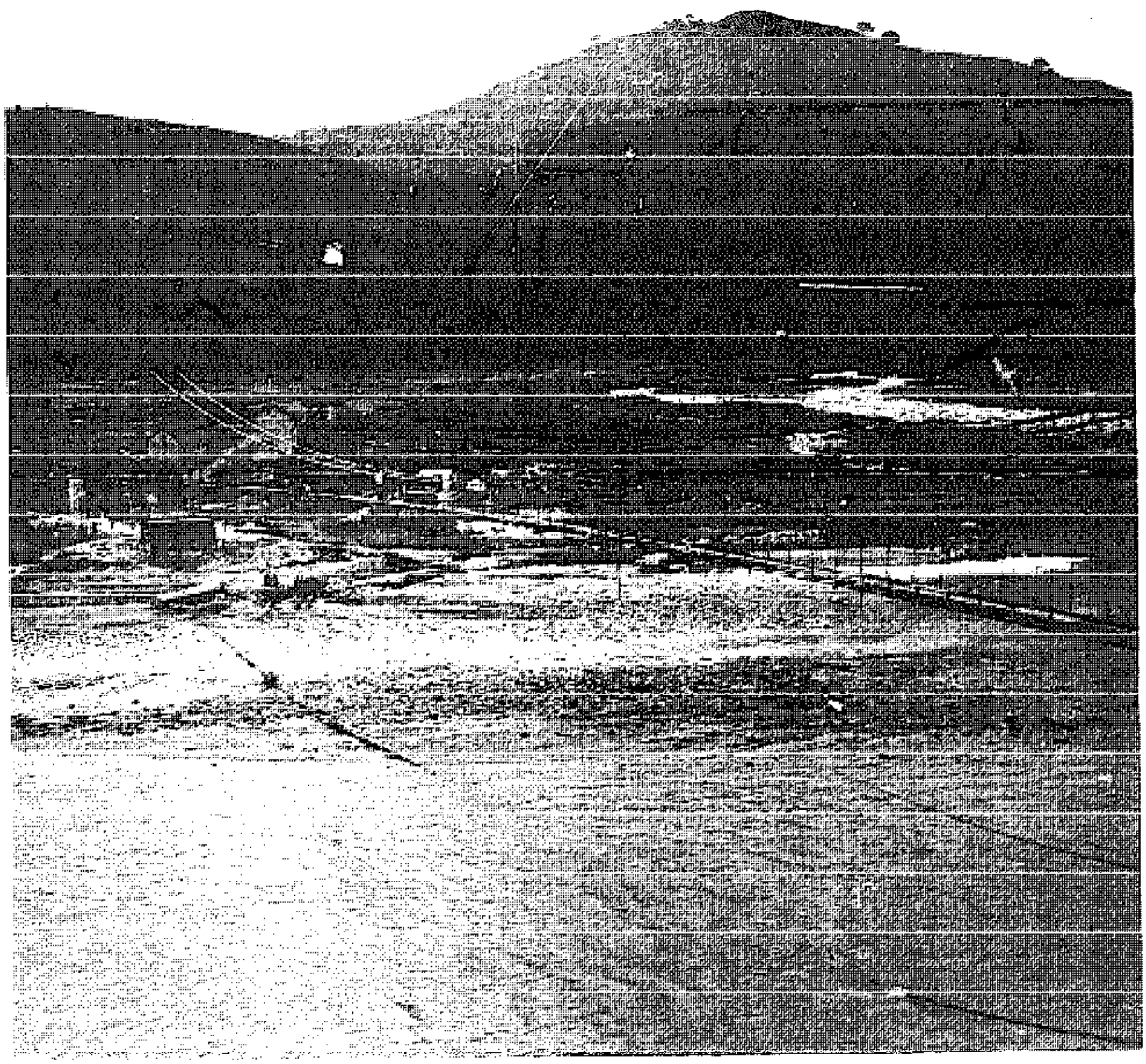
General Design

(e.e. 526 Kheranga Khola Suspended Bridge of 84 m span)



TYPES OF TRAIL SUSPENSION OR SUSPENDED BRIDGES	No. :1.201
Suspension Bridges	Date :23rd Febr. 77
	Sig :





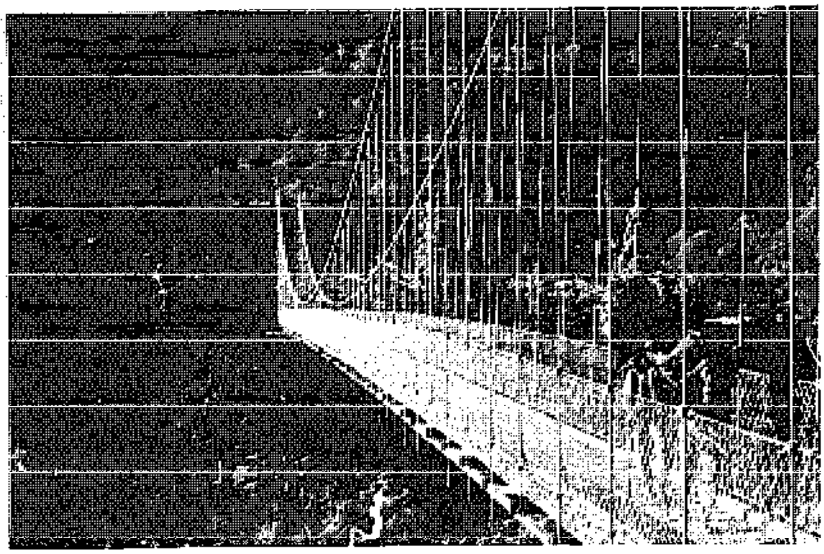
TYPES OF TRAIL SUSPENSION OR SUSPENDED BRIDGES

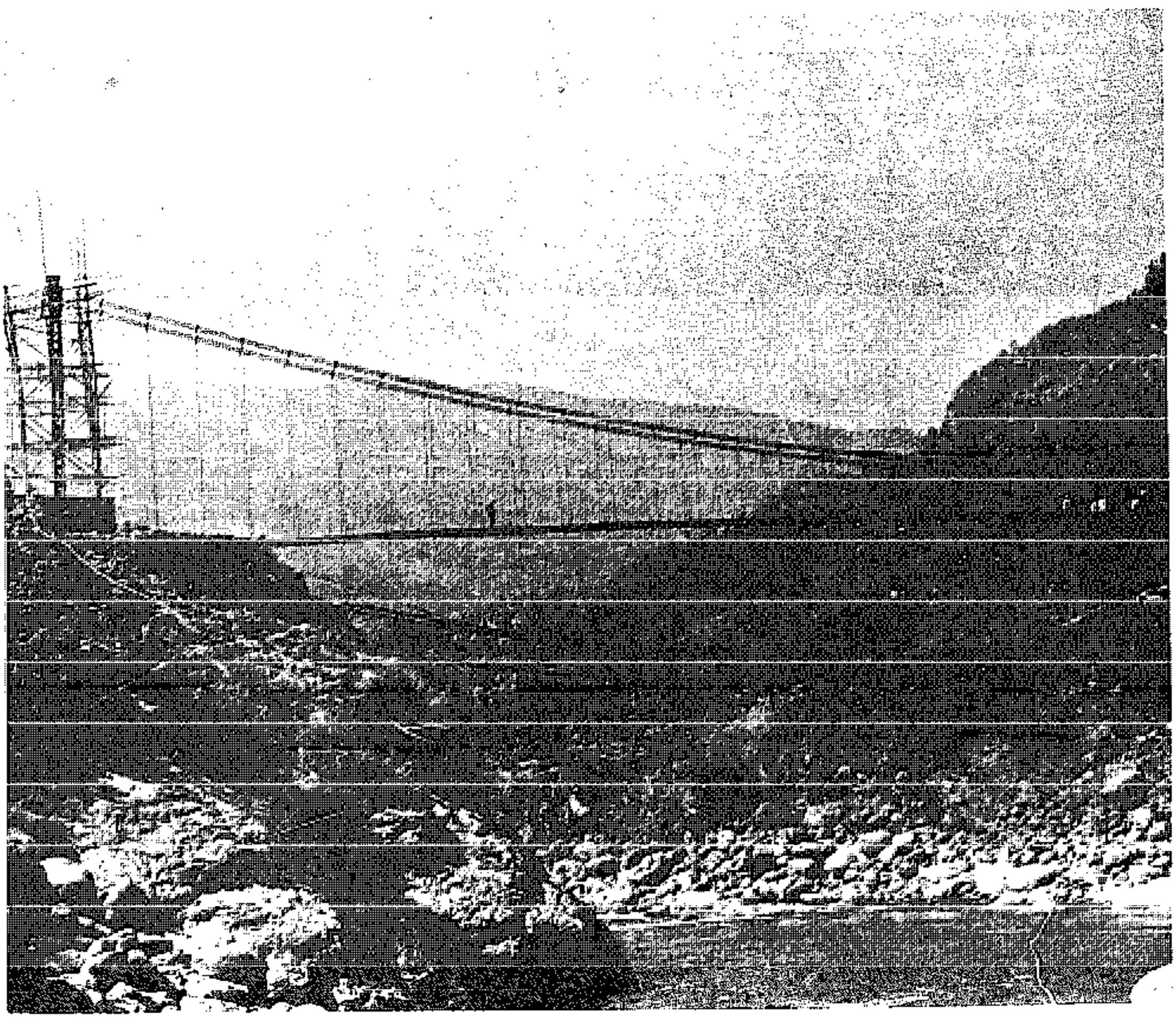
Suspension Bridges

No : 1.202

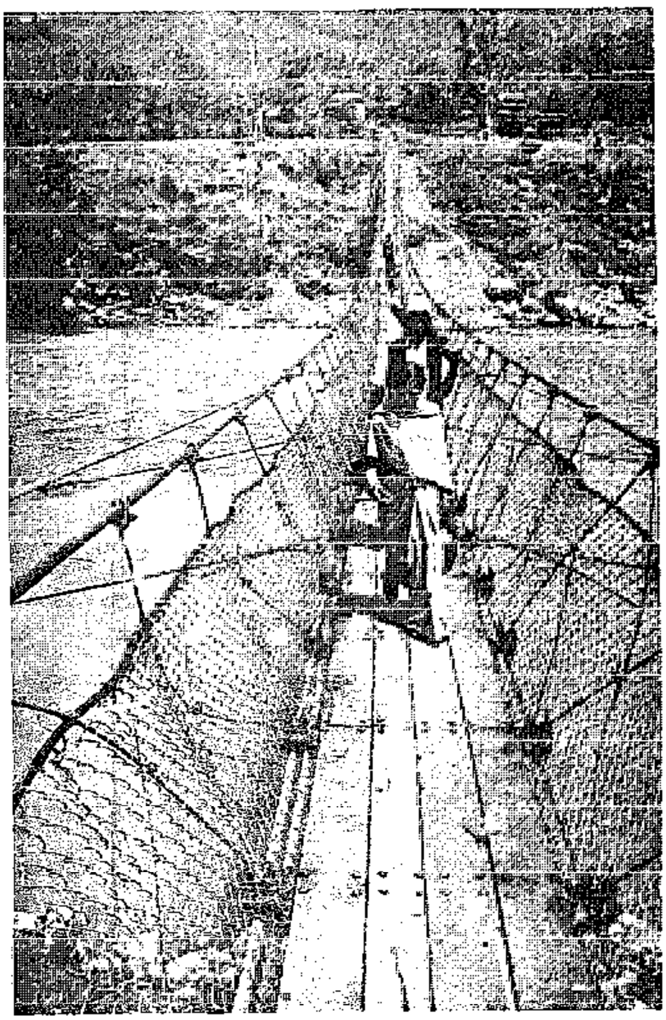
Date : 23rd Febr. 77

Sig :



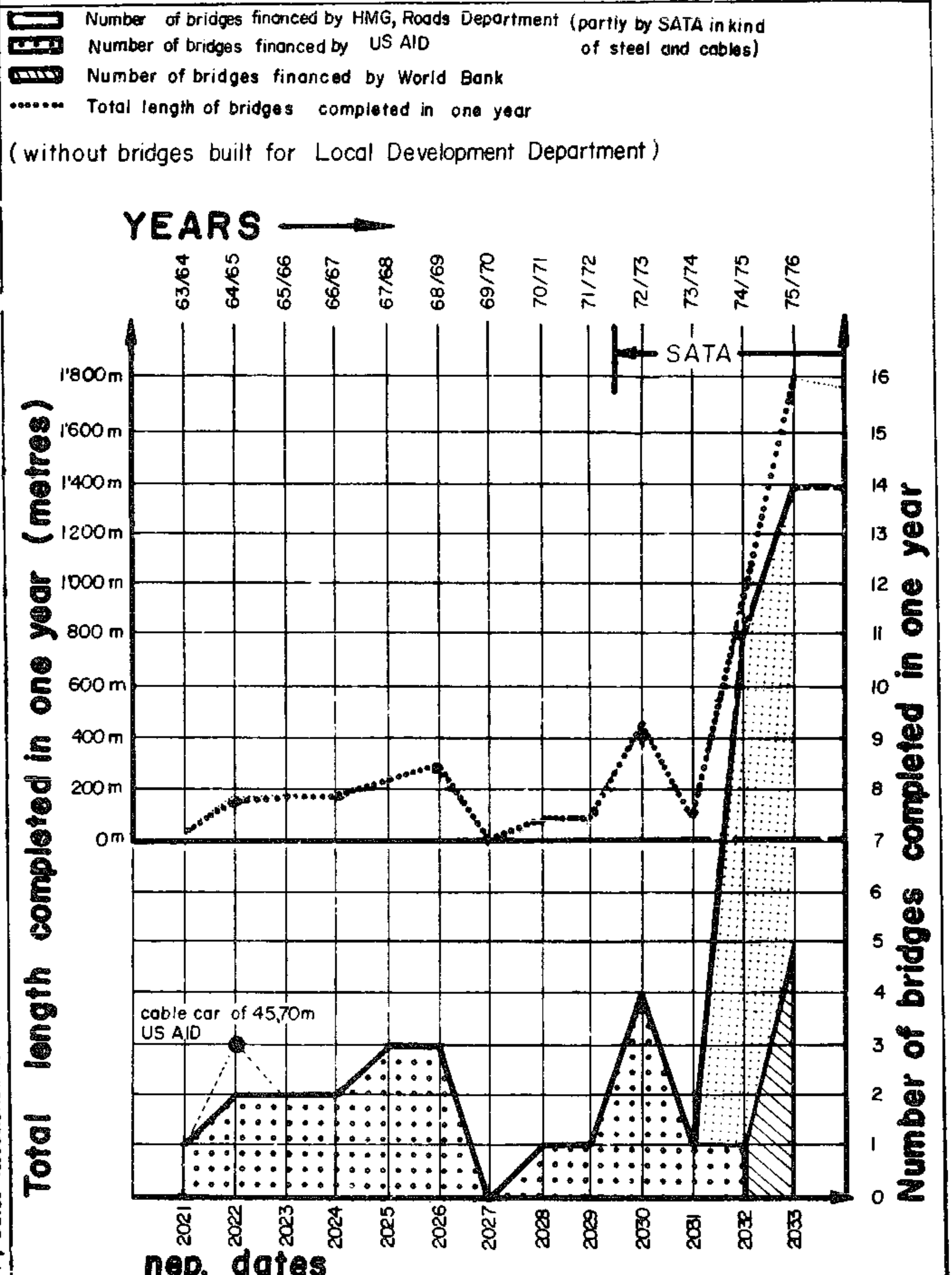


TYPES OF TRAIL SUSPENSION OR SUSPENDED BRIDGES Suspended Bridges	No : 1.203 Date : 4.10.75 Sig : [signature]



The pictures are showing the Devighat Suspended Bridge of 108 m span (Trishuli)

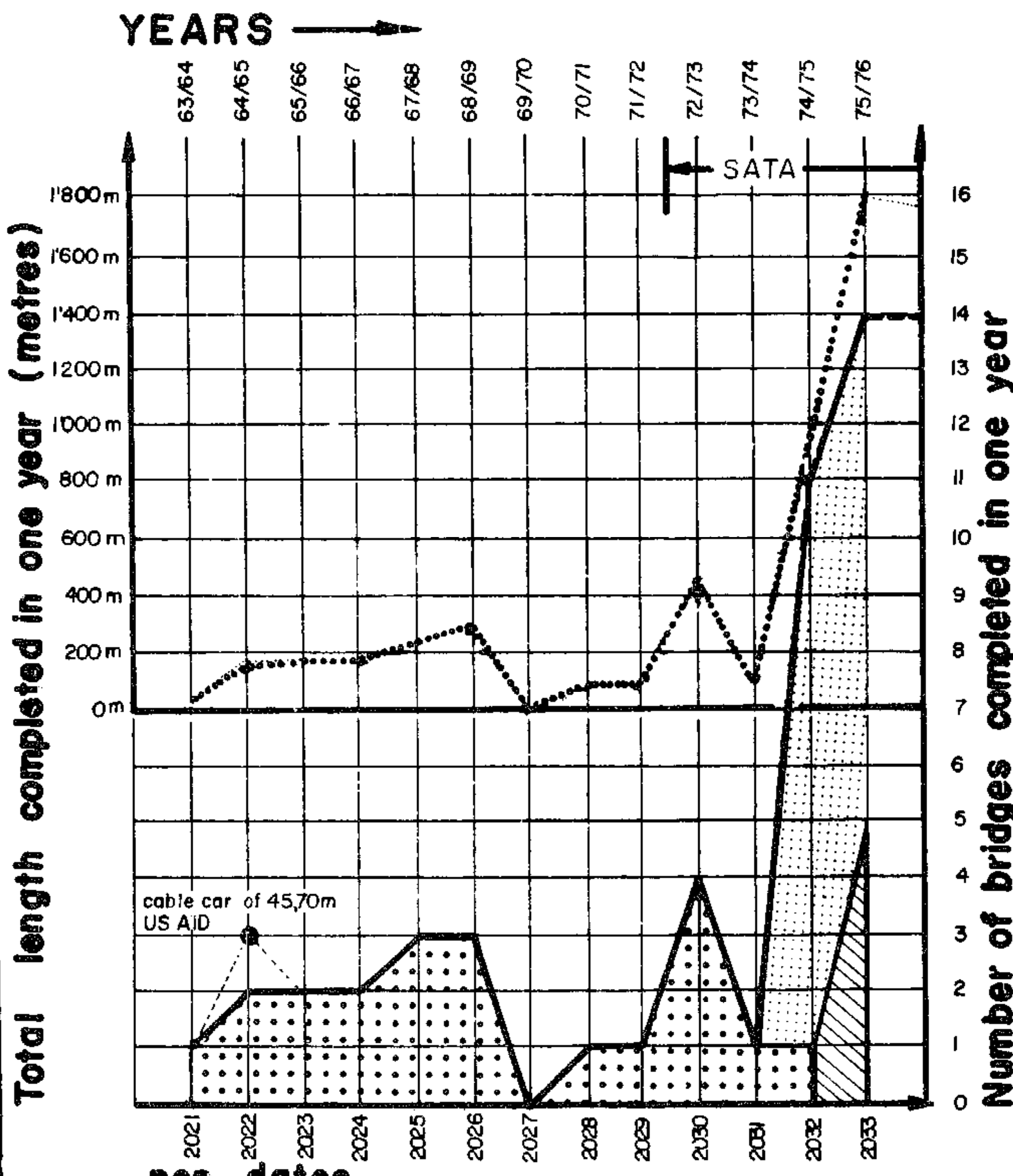
PLANNING WORK OF THE SUSPENSION BRIDGE DIVISION	No : 1.301
Completed Pedestrian Bridges within the Period 1963 - 1976 (without Bridges built for the LDD)	Date : 1.Dec. 76
	Sig : [signature]



PLANNING WORK OF THE SUSPENSION BRIDGE DIVISION Completed Pedestrian Bridges within the Period 1963 - 1976 (without Bridges built for the LDD)	No : 1.301 Date : 1.Dec. 76 Sig : [signature]

- Number of bridges financed by HMG, Roads Department (partly by SATA in kind of steel and cables)
- Number of bridges financed by US AID
- Number of bridges financed by World Bank
- ······· Total length of bridges completed in one year

(without bridges built for Local Development Department)



S A T A . Swiss Association for Technical Assistance

PLANNING WORK OF THE SUSPENSION BRIDGE DIVISION

Planning, design and execution work on current and proposed suspension and suspended bridges at the end of March 1977

1.302

31st March 77

Remaining construction sites

- to be completed 76/77

# 1	Tallogaon	Suspended Bridge	97 m
+ 2	Similighat	Suspension Bridge	78 m
+ 3	Purtighat	Suspension Bridge	114 m
4	Keladighat	Suspension Bridge	151 m
+ 5	Puchighat	Stay Cable Bridge	186 m
# 6	Raighat	Suspension Bridge	172 m
+ 7	Rasuwa Dobhan	Suspension Bridge	78 m
# 8	Sabha Khola	Suspension Bridge	115 m

- to be completed 77/78

9	Lubughat 2 span	Suspension Bridge	150 m

Key :
+ completed until March 1977
# almost complete
¢ only start of collection of material in 1976/77

New started bridge sites 76/77

- to be completed 76/77

# 502	Rawa Khola	Suspended Bridge	72 m
503	Likhu Khola	Suspension Bridge	70 m
504	Pareweghat	Suspension Bridge	126 m
# 507	Chackli Ghat	Suspension Bridge	70 m
# 509	Ranga Khola	Suspended Bridge	42 m
512	Dhaunebagar	Suspended Bridge	87 m
# 515	Mangmaya Khola	Suspended Bridge	48 m
+ 516	Lungri Khola	Suspended Bridge	37 m
522	Purchudi Hat	Suspended Bridge	48 m
527	Korchabang	Suspended Bridge	48 m

- to be completed 77/78

501	Nawalpur Ghat	Suspension Bridge	198 m
505	Ranighat	Suspension Bridge	126 m
514	Pipalmudha	Suspended Bridge	72 m
518	Maurasain	Suspended Bridge	60 m
519	Shailigad	Suspended Bridge	69 m
520	Punjuko Naya	Suspended Bridge	84 m

- to be completed 78/79

◄ 521	Lodey Ghat	Suspension Bridge	150 m

Proposed bridge sites (to be started 77/78)

- to be completed 77/78

506	'auljibi	Suspension Bridge	114 m
508	Iothe	Suspension Bridge	78 m
510	Chilimay Khola	Suspended Bridge	51 m
511	Gilgung Khola	Suspended Bridge	45 m
517	Chutra Besi	Suspension Bridge	66 m
523	Sekhatum	Suspended Bridge	75 m
524	Nibhu Khola	Suspended Bridge	57 m
526	Khoranga Khola	Suspended Bridge	84 m

to be completed either 77/78 or 78/79

513	Sukadik	Suspended Bridge	84 m
525	Pikuwa Khola	Suspension Bridge	174 m
528	Buriganga	under survey	
529	Tharsyang Ghat	under survey	
530	Nibuz Khola	under survey	
531	Charchare Tinau	under survey	
532	Tawa Khola	under survey	
533	Kharpu	soon under survey	

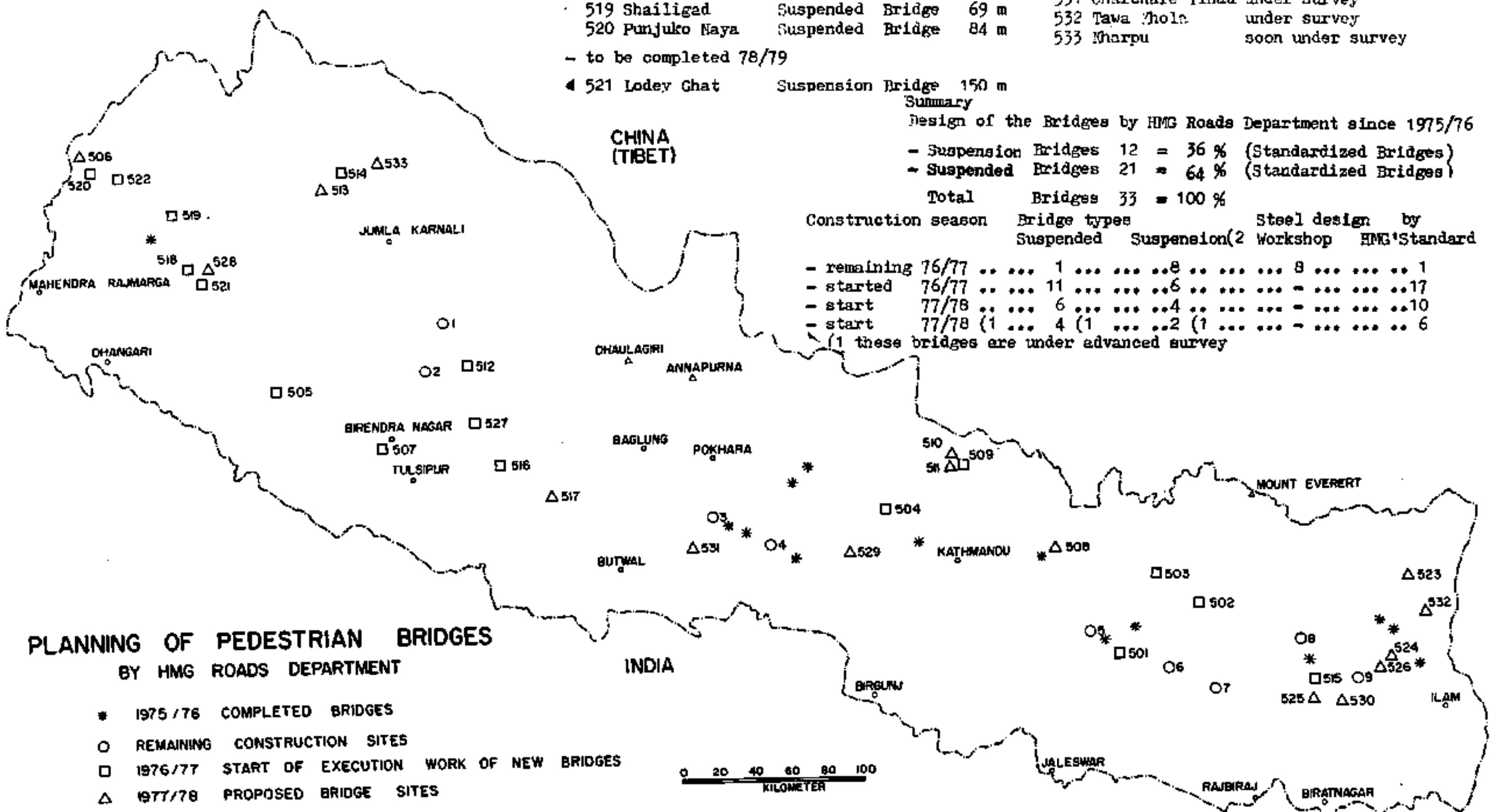
Summary

Design of the Bridges by HMG Roads Department since 1975/76

- Suspension	Bridges	12 =	36 %	(Standardized Bridges)
- Suspended	Bridges	21 =	64 %	(Standardized Bridges)
Total	Bridges	33 =	100 %	

Construction season		Bridge types Suspended	Suspension(2	Steel design Workshop	by HMG'Standard
- remaining	76/77	1	8	8	1
- started	76/77	11	6	-	17
- start	77/78	6	4	-	10
- start	77/78 (1	4 (1	2 (1	-	6

(1 these bridges are under advanced survey

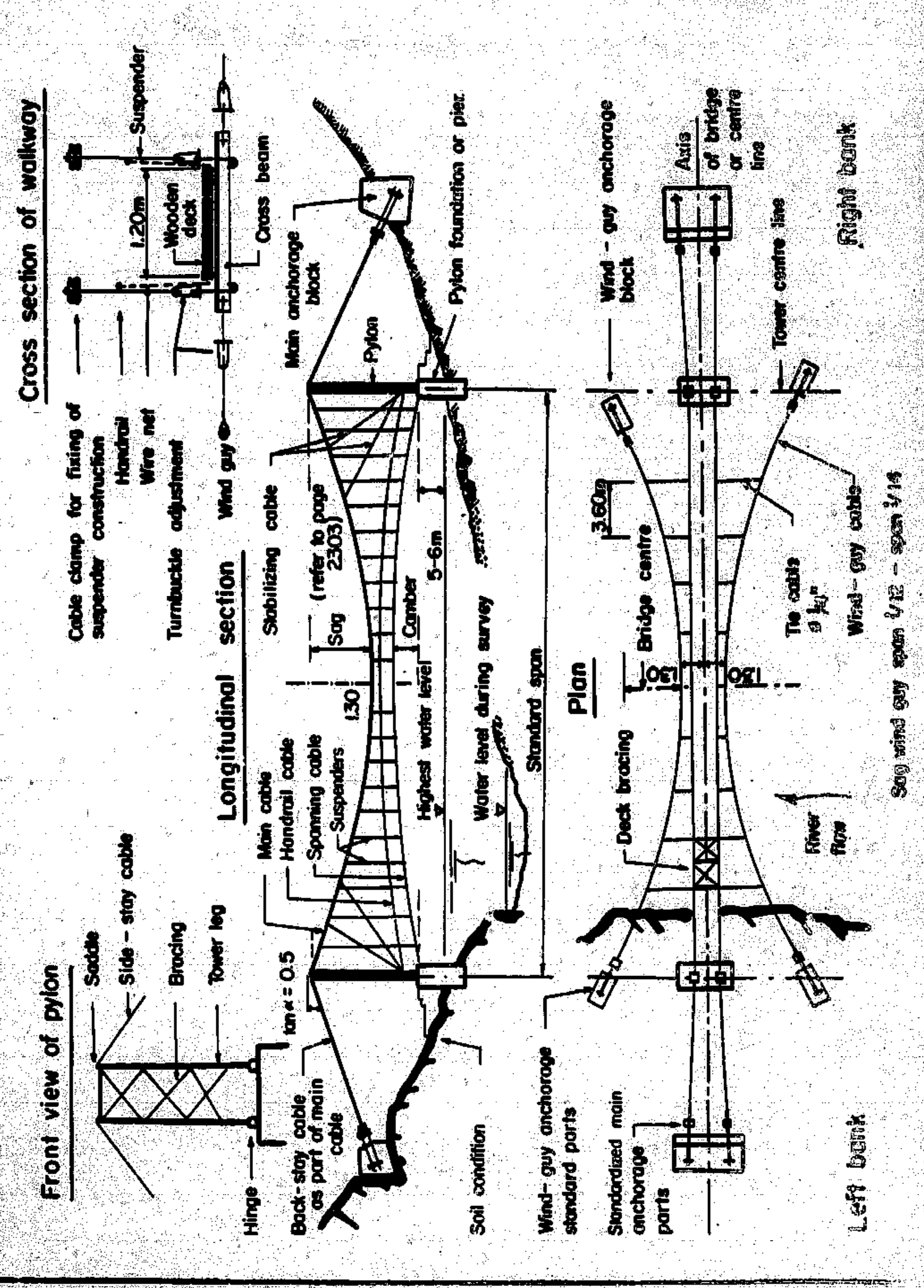


2. BRIDGE DESIGN

BRIDGE DESIGN

Nomenclature for Suspension Bridge

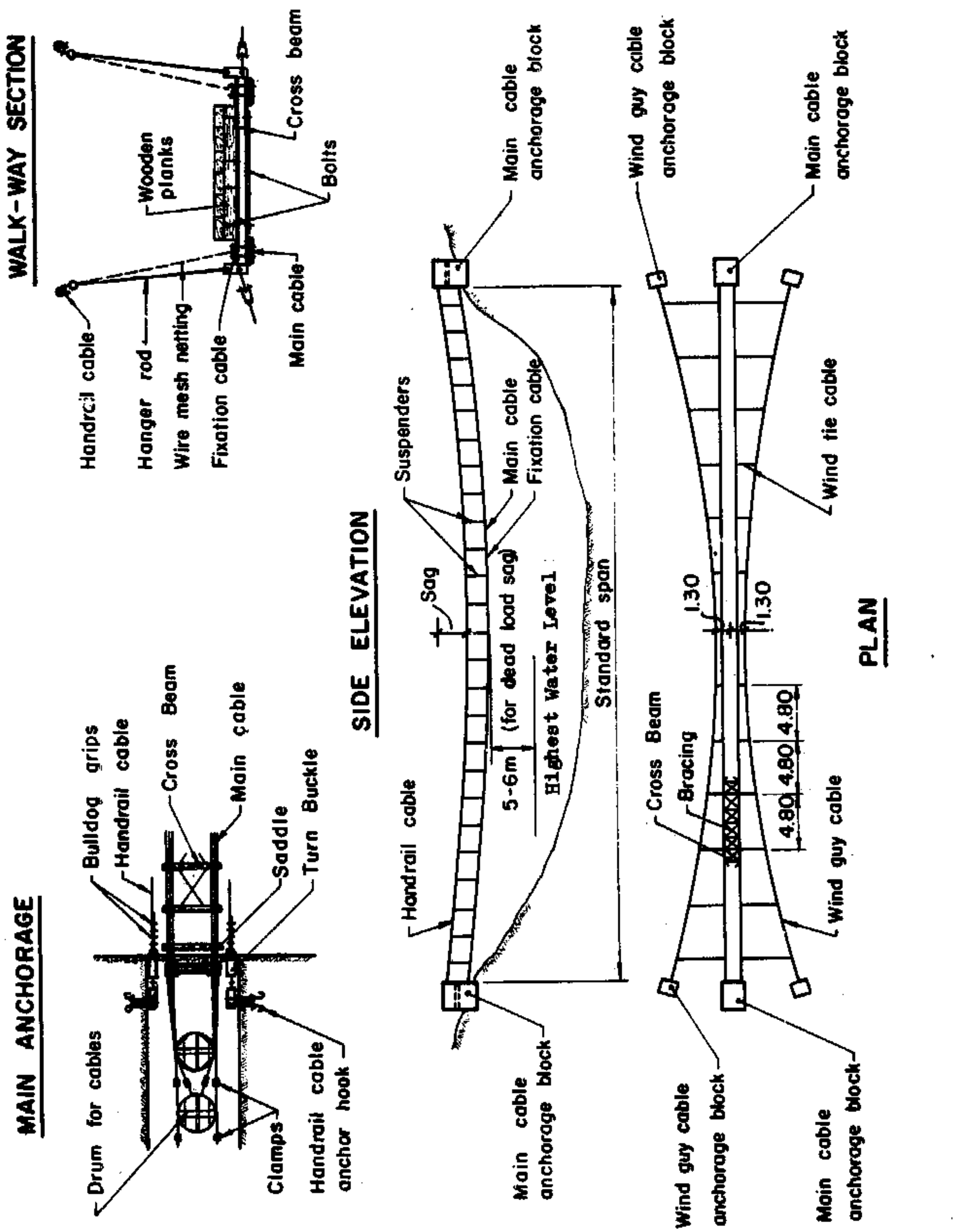
No.	2.101
Date :	14/2/1977
Sig	[signature]



BRIDGE DESIGN

Nomenclature for Suspended Bridge

No.	:2.102
Date	:14th Febr. 77
Sig	:



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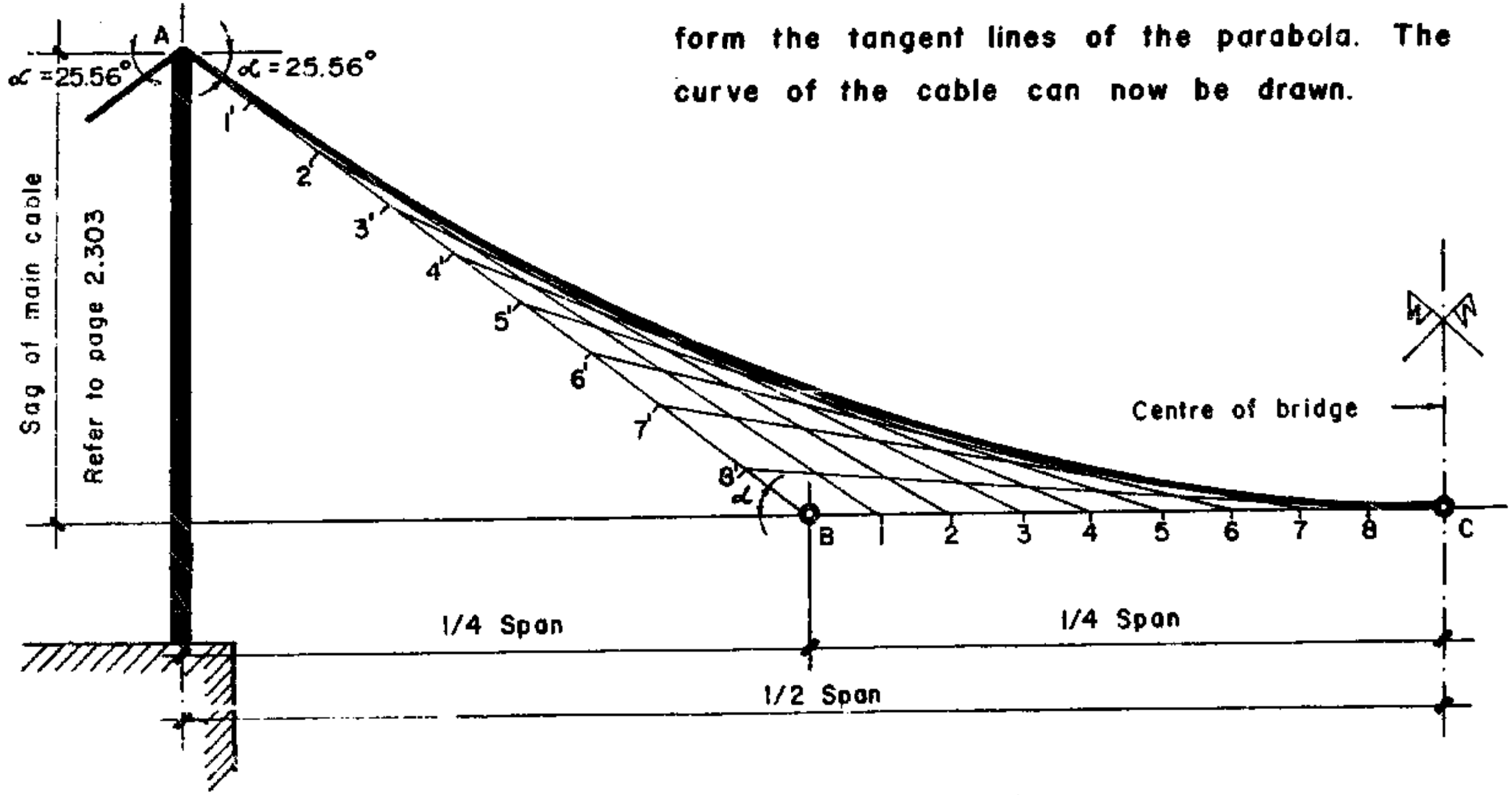
When a cable is supported at each end to hang freely under its weight, it forms a curve which is part of a catenary or chain line. The parabola line is only slightly different to the catenary and can be used for easy design work.

Example: Divide A–B into 9 equal parts and B–C into 9 equal parts. Connect the points 1' with 1, 2' with 2.......... and so on. These lines form the tangent lines of the parabola. The curve of the cable can now be drawn.



BRIDGE DESIGN

Parabola construction, α - factor method

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Date : 14th Febr. 77
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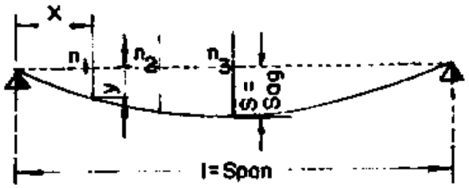


According to **Parabola form:** I) In general $y = \frac{4x}{l}\left(1-\frac{x}{l}\right)s$.

Example: Given l = 15.0 m; x = 5.0 m; S = 150 mm.

It is: $y = \frac{4 \times 5.00}{15.00}\left(1-\frac{5.00}{15.00}\right) \times 0.150 = \frac{200}{225} \times 0.150$

$= 0.889 \times 0.150 = 0.13335$ = approx. 133 mm.

II) For the beam, divided into n **equal parts**, the value of x y at the point n x will be

$$y_{n_x} = \frac{4 n_x (n-n_x)}{n^2} s = \alpha s$$

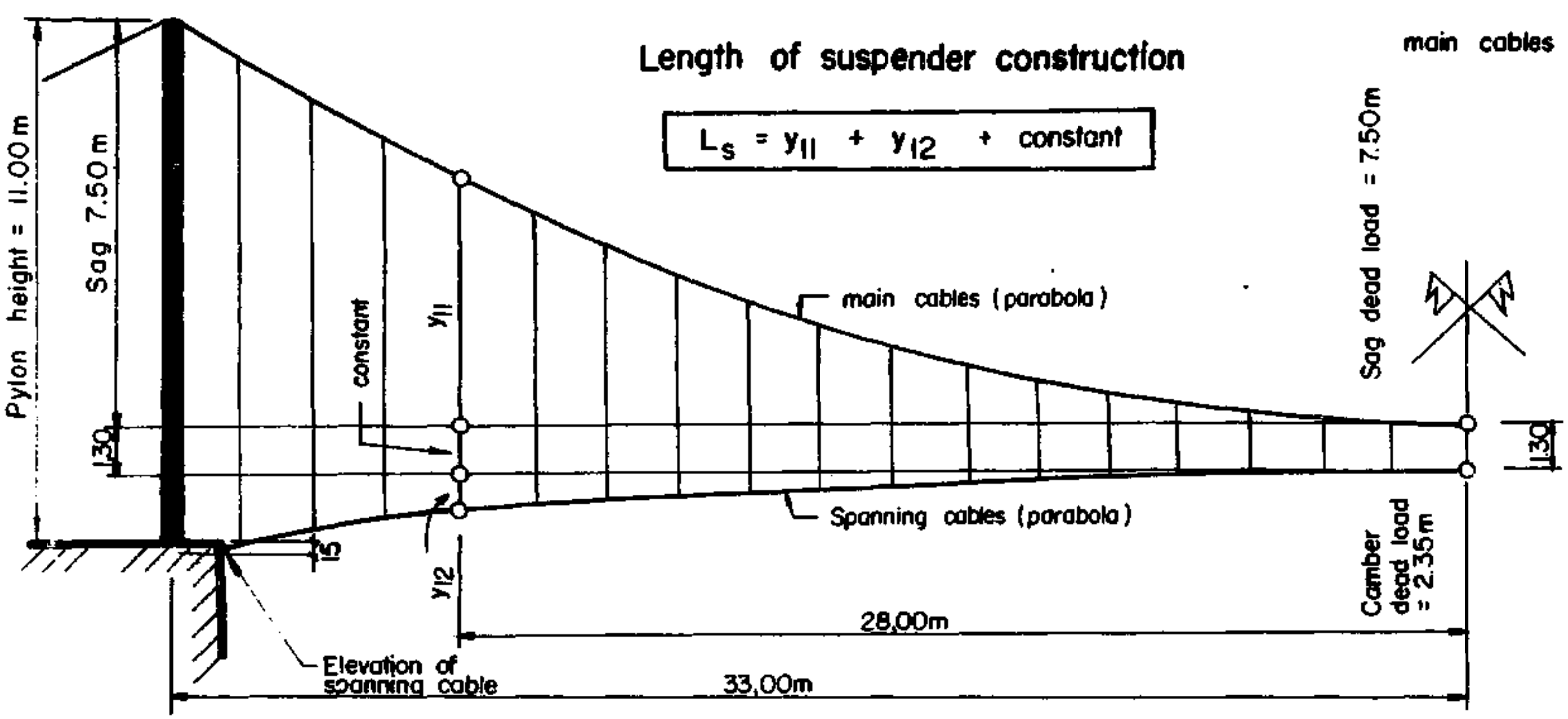
n_x = Index for the end position of the beam panel within the beam-ray, i.e. for n_1, n_2, n_3 .... up to $\frac{n}{2}$ for which the dimension of the Parabolic superelevation y is to be determined.

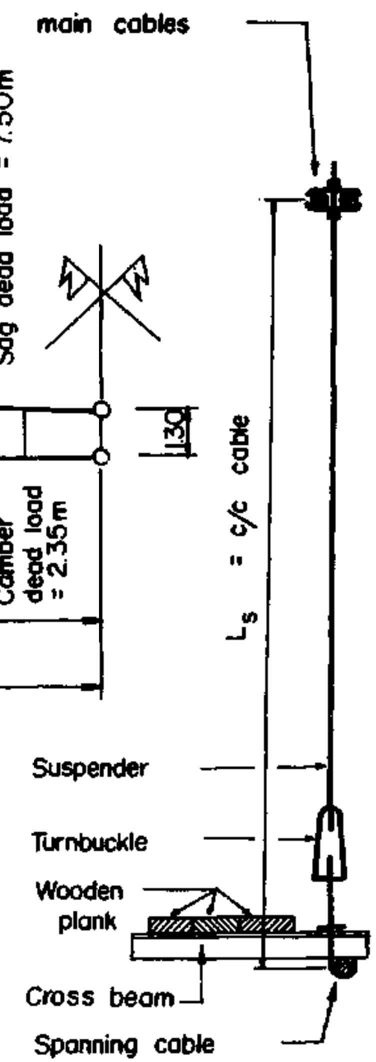
The corresponding values of α are given in the following table: (Sources: Stahl im Hochbau, 13. Auflage 1969)

Total no. of panels	α-Factor to calculate the ordinate height y at the end of the .... n_x =															Total no. of panels
	n_1	n_2	n_3	n_4	n_5	n_6	n_7	n_8	n_9	n_{10}	n_{11}	n_{12}	n_{13}	n_{14}	n_{15}	
4	0.750	1.00	—	—	—	—	—	—	—	—	—	—	—	—	—	4
5	0.640	0.960	—	—	—	—	—	—	—	—	—	—	—	—	—	5
6	0.556	0.889	1.00	—	—	—	—	—	—	—	—	—	—	—	—	6
7	0.490	0.816	0.980	—	—	—	—	—	—	—	—	—	—	—	—	7
8	0.438	0.750	0.938	1.00	—	—	—	—	—	—	—	—	—	—	—	8
9	0.395	0.691	0.889	0.988	—	—	—	—	—	—	—	—	—	—	—	9
10	0.360	0.640	0.840	0.960	1.00	—	—	—	—	—	—	—	—	—	—	10
11	0.331	0.595	0.793	0.926	0.992	—	—	—	—	—	—	—	—	—	—	11
12	0.306	0.556	0.750	0.889	0.972	1.00	—	—	—	—	—	—	—	—	—	12
13	0.284	0.521	0.710	0.852	0.947	0.994	—	—	—	—	—	—	—	—	—	13
14	0.265	0.490	0.673	0.816	0.918	0.980	1.00	—	—	—	—	—	—	—	—	14
15	0.249	0.462	0.640	0.782	0.889	0.960	0.996	—	—	—	—	—	—	—	—	15
16	0.234	0.438	0.609	0.750	0.859	0.938	0.984	1.00	—	—	—	—	—	—	—	16
17	0.221	0.415	0.582	0.720	0.830	0.913	0.969	0.996	—	—	—	—	—	—	—	17
18	0.210	0.395	0.556	0.691	0.802	0.889	0.951	0.988	1.00	—	—	—	—	—	—	18
19	0.199	0.377	0.532	0.665	0.776	0.864	0.931	0.975	0.997	—	—	—	—	—	—	19
20	0.190	0.360	0.510	0.640	0.750	0.840	0.910	0.960	0.990	1.00	—	—	—	—	—	20
21	0.181	0.344	0.490	0.617	0.726	0.816	0.889	0.944	0.980	0.998	—	—	—	—	—	21
22	0.174	0.331	0.471	0.595	0.702	0.793	0.867	0.926	0.967	0.992	1.00	—	—	—	—	22
23	0.166	0.318	0.454	0.575	0.680	0.771	0.847	0.907	0.953	0.983	0.998	—	—	—	—	23
24	0.160	0.306	0.438	0.556	0.660	0.750	0.826	0.889	0.938	0.972	0.993	1.00	—	—	—	24
25	0.154	0.294	0.422	0.538	0.640	0.730	0.806	0.870	0.922	0.960	0.986	0.998	—	—	—	25
26	0.148	0.284	0.408	0.521	0.621	0.710	0.787	0.852	0.905	0.947	0.976	0.994	1.00	—	—	26
27	0.142	0.274	0.395	0.505	0.604	0.691	0.768	0.834	0.889	0.933	0.966	0.988	0.999	—	—	27
28	0.138	0.265	0.383	0.490	0.587	0.673	0.750	0.816	0.872	0.918	0.954	0.980	0.995	—	—	28
29	0.133	0.257	0.371	0.476	0.571	0.656	0.732	0.799	0.856	0.904	0.942	0.970	0.989	0.999	—	29
30	0.129	0.249	0.360	0.462	0.556	0.640	0.716	0.782	0.840	0.889	0.929	0.960	0.982	0.996	1.00	30

Length of suspender construction

$$L_s = y_{11} + y_{12} + \text{constant}$$





Spanning cable elevation to main cable elevation = Pylon height + 15cm = 11.15m.

$y_{11} = a \times 28.00^2 \qquad a_{11} = \dfrac{7.5}{33.00^2} = 0.00689 \qquad y_{11} = 5.40\text{m}$

$y_{12} = a_{12} \times 28.00^2 \qquad a_{12} = \dfrac{2.35}{33.00^2} = 0.00216 \qquad y_{12} = 1.69\text{m}$

Constant = 1.30m

L_s = 8.39m

L_s can also be calculated by: $y_{Total} = \dfrac{(7.5+2.35)}{33.00^2}\, 28^2 = 7.09\text{m}.$

Constant = 1.30m

L_s = 8.39m

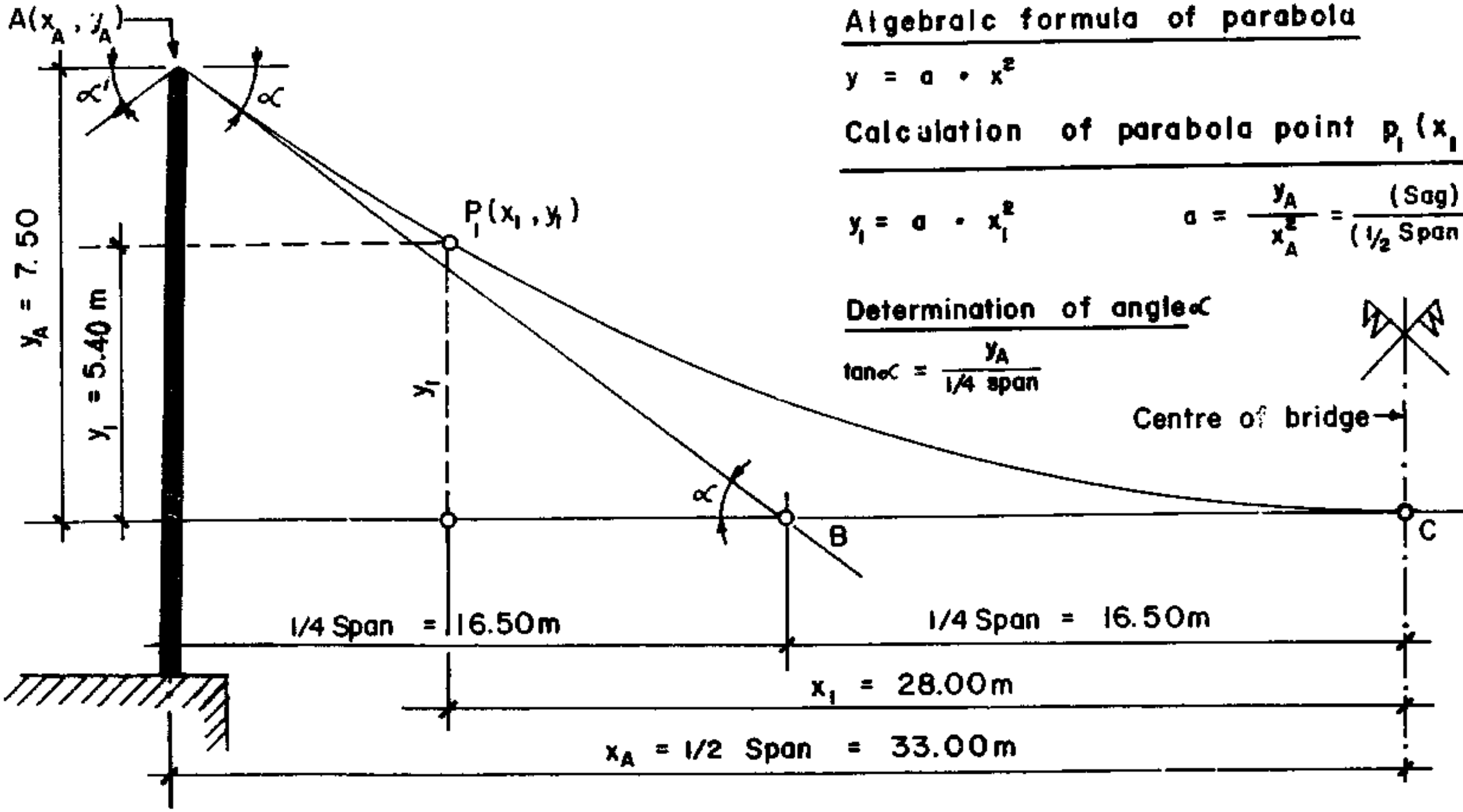
BRIDGE DESIGN

Parabola construction, analytical method

No.: 2.204

Date: 26th Febr. 77

Sig.:



Algebraic formula of parabola

$$y = a \cdot x^2$$

Calculation of parabola point $p_1(x_1\ y_1)$

$$y_1 = a \cdot x_1^2 \qquad a = \frac{y_A}{x_A^2} = \frac{(Sag)}{(1/2\ Span)^2}$$

Determination of angle α

$$\tan\alpha = \frac{y_A}{1/4\ span}$$

Example:

Given : x_1 = 28.00 m

x_A = 33.00 m

y_A = 7.50 m

To find: y_1 , α

$$a = \frac{7.50}{33.00^2} = 0.00689$$

$$y_1 = 0.00689 \cdot 28.00^2 = 5.40 m$$

$$\tan\alpha = \frac{7.50}{16.50} = 0.455 ; \alpha = 24.45°$$

Suspension Bridge

The Standard Suspension Bridge is a light suspension bridge, chiefly meant for pedestrian and pack animal traffic. The walk way (gangway) is unstiffened.

This bridge Typ is normally constructed with two pylons and the suspended walkway has an arched profile. The suspension bridge design is normally applied for river cross section with flat banks and is more expensive than the Suspended Bridge (without pylons). It is recommended in cases where the required free-board line cannot be achieved with the suspended bridge (cat walk).
The grafic on page 4.101 shows, that a suspension bridge is between 28 to 80 % expensiver than a suspended bridge.
The main design characteristics of the suspension bridge are as follows :

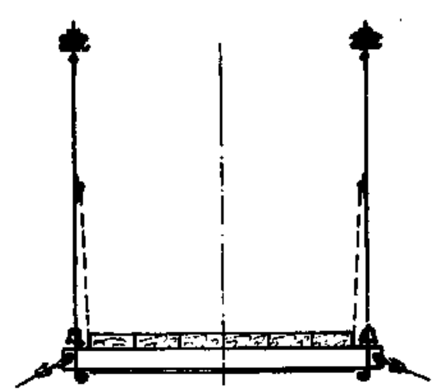
- Standard spans available ... ... 66 – 222 m
- Span intervals of ... ... 12 m
- Sag ratio (full loaded) ... ... 1/8 to 1/9
- Width of the wooden deck (walkway) ... 1.20 m
- Live load ... ... 400 kg/m2 or 480 kg/m1
- Wind load (exposed area) 150 kg/m2
- Available standardized drawings ... ... page 2.305
- Further technical data ... ... pages 2.303 and 2.304

Walkway and Suspenders

The walk way cross-section for a suspension bridge is shown below. The walkway is supported by adjustable m.s. bar suspenders attached to the main cables at 1.20 m centres. The spanning cables are pretensioned to minimise longitudinal oscillations. The following spanning cables are used :

Span in m	cable ∅ (inches)
66 – 102	1 "
114 – 186	1¼ "
198 – 222	1½ "

Walk-way



The walk way deck is supported on cross beams made of two m.s. angles. The cross beams are spaced at 1.20 m centres and connected together with cross – bracing of m.s. flat section. The wooden deck is bolted directly to the cross beams. The walkway papapets are constructed in wire netting (3mm wire, galvanized, 9o cm width) which is fastened top and bottom to ½ " diametre cables (handrail- and fixation cable).

Pylons

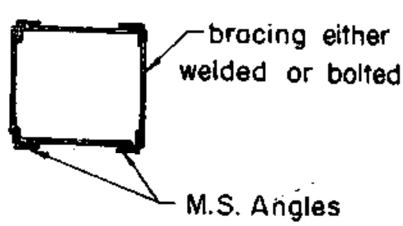
Pylons are required for suspension bridges. The structural analysis of pylons for single spans up to 222 m and for multiple spans, using a standard 'middle' span, up to about 400 m length, was undertaken at the request of the Suspension Bridge Division by a Swiss Computer Static firm in Zurich. The structural analysis has been based on Indian Standards.

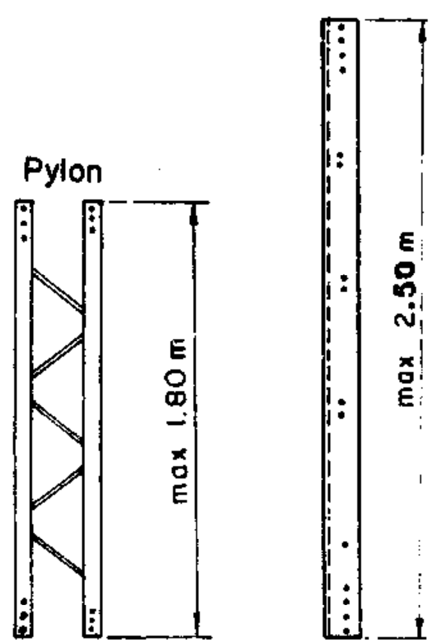
The pylons are constructed using standard units with two main colums consisting of m.s. angles battened together, the colums being connected together by m.s. angle bracing. For spans of 162 m and beyond side stay cables are used to prevent side sway. The front and backstay cables (main cable) should have the same angels for the full loaded bridge. On the standardized Suspension Bridges the increasing of the back-stay cable angle - increasing of slope - of about $\tan_a = 0,05$ shows, that the total load on the pylon increases with about 5%.

tan of back stay cable	tan of front stay cable	total vertival load on the pylon
0.500 (26,56°)	0.500 (26,56°)	100 %
0.550 (28,81°)	0.500 "	105 %
0.600 (30,96°)	0.500 "	110 %
0.650 (33,02°)	0.500 "	115 %
0.700 (34,99°)	0.500 "	120 %
0.750 (36,87°)	0.500 "	125 %
1.000 (45,00°)	0.500 (26,56°)	150 %

The above numbers make it clear, that the back stay angel must be correct or the pylons will be overloaded.

The standardized Pylons are constructed as moveable, e.g. they have hinges at the bottom.





Further information are available on page 2.304

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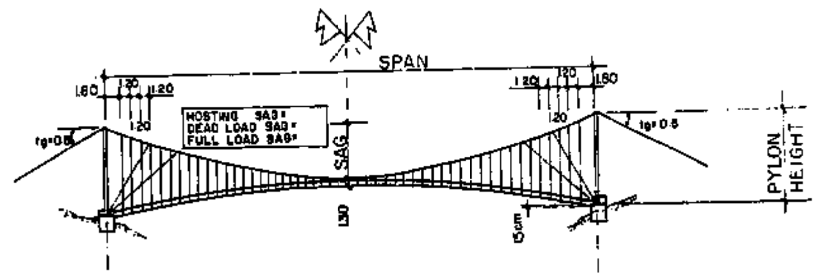
सडक विभाग

HIS MAJESTY'S GOVERNMENT
MINISTRY FOR WORKS AND TRANSPORT
ROADS DEPARTMENT

STANDARD SUSPENSION BRIDGES 66–222 m
Technical data



-modulus of elasticity = 10'500kg/mm² — Specification for steel wire ropes for general purpose Table I: 6x19(12/6/1) with w.s.c. (wire strand core). Tensile strength of wire 160kg/mm² (according to Indian Standard)

SPAN	pylon	main cables			loading cases (t/m)			sags (m)			total tension (t)			total breaking load (t)	factor of safety		
m	height	ø	Nos	Total area mm²	hoisting	dead	full	hoisting	dead	full	hoisting	dead	full		hoisting	dead	full
66	11.00	1/2"	2	962	0.011	0.12	0.60	7.43	7.57	8.08	0.88	9.50	45.02	154	175.00	16.20	3.42
78	12.80	1/2"	2	962	0.011	0.12	0.60	8.99	9.18	9.85	1.02	10.99	51.90	154	175.98	14.01	2.97
90	14.70	1/4"	4	1360	0.016	0.12	0.60	10.81	10.99	11.60	1.66	12.30	58.92	217.6	131.08	17.69	3.69
102	16.50	1/4"	4	1360	0.016	0.12	0.60	11.72	11.96	12.75	1.95	14.44	68.42	217.6	111.59	15.10	3.18
114	18.30	1/2"	4	1924	0.022	0.12	0.60	13.29	13.51	14.25	2.97	15.96	76.47	308	103.70	19.30	4.02
126	18.30	1/2"	4	1924	0.022	0.12	0.60	13.65	13.94	14.88	3.49	18.68	88.50	308	88.25	16.49	3.48
138	21.90	1/2"	4	1924	0.022	0.12	0.60	15.19	15.54	16.64	3.77	20.16	95.30	308	81.70	15.28	3.23
150	21.90	1/2"	4	1924	0.022	0.12	0.60	16.93	17.30	18.50	4.01	21.48	101.71	308	76.81	14.34	3.03
162	25.50	1/4"	6	2040	0.024	0.14	0.60	18.74	19.20	20.50	4.63	26.47	107.61	326.4	70.50	12.33	3.03
174	25.50	1/2"	6	2886	0.033	0.14	0.62	20.25	20.65	21.75	6.80	28.40	120.61	462	67.94	16.27	3.83
186	29.10	1/2"	6	2886	0.033	0.14	0.62	21.62	22.10	23.40	7.28	30.33	128.27	462	63.46	15.23	3.60
198	29.10	1/2"	6	2886	0.033	0.15	0.62	23.25	23.80	25.20	7.68	34.27	135.29	462	60.10	13.48	3.41
210	32.70	1/2"	6	2886	0.033	0.15	0.62	23.98	24.65	26.25	8.33	37.06	145.57	462	55.46	12.47	3.17
222	32.70	1/2"	6	2886	0.033	0.15	0.62	24.96	25.70	27.50	8.93	39.62	155.01	462	51.73	11.66	2.98

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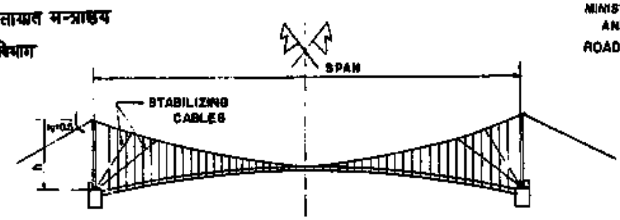
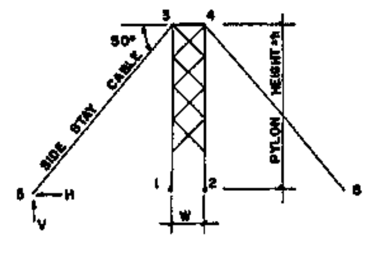
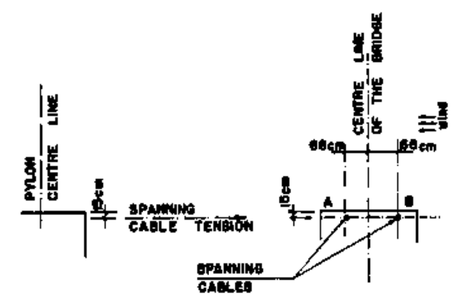






REACTION ON THE PYLON BASE AND SIDE STAY CABLE

– modulus of elasticity = 10'500 kg/mm² – Specification for steel wire ropes for general purposes Table 1: 6 x 19 (12/6/1) with w.s.c. (wire strand core). Tensile strength of wire 160 kg/mm² (according to Indian Standard)

GEOMETRY SPAN	height = of shaft		SIDE STAY CABLE		REACTIONS (column bases) DEAD + WIND				TOTAL (some wind)			
m	h	w	ø	pretention	1V	1H	2V	2H	1V	1H	2V	2H
66	11.00	3.50	—	—	-10.12*	-1.46*	+0.22*	1.14*	-20.80*	-0.40*	-20.70*	—
78	12.80	3.50	—	—	-16.372	-1.803	+4.172	1.823	-25.987	-0.440	-23.613	-0.014
90	14.70	3.50	—	—	-22.68*	-2.14*	+8.12*	2.50*	-31.18*	-0.48*	-26.62*	-0.26*
102	15.50	3.50	—	—	-28.676	-2.470	+12.076	-3.169	-36.370	-0.509	-29.43	-0.499
114	18.30	4.00	—	—	-25.12*	-2.65*	+9.53*	-2.88*	-45.38*	-0.88*	-32.32*	-1.17*
126	18.30	4.00	—	—	-31.977	-2.812	+9.577	-3.024	-46.794	-0.626	-36.006	-0.937
138	21.90	4.00	—	—	-38.63*	-2.904	+9.63*	-3.16*	-48.20*	-0.37*	-39.70*	-0.70*
150	21.90	4.00	—	—	-45.673	-3.136	+9.673	-3.295	-49.613	-0.107	-43.387	-0.468
162	25.50	4.00	ø 1"	2 tone	-55.90*	-3.04*	+0.03*	-3.30*	-55.15*	-0.13*	-47.55*	-0.57*
174	25.50	4.00	ø 1"	2 tons	-56.008	-3.184	+6.434	-3.414	-60.873	-0.095	-52.909	-0.577
186	29.10	4.00	ø 1"	2 tons	-56.22*	-3.32*	+12.43*	-3.52*	-66.59*	-0.06*	-58.27*	-0.59*
198	29.10	4.00	ø 1"	2 tone	-56.429	-3.453	+18.432	-3.635	-72.029	-0.022	-63.628	-0.898
210	32.70	4.00	ø 1 1/4"	2,5 tons	-61.88*	-3.50*	+18.18*	-4.02*	-74.46*	-0.016*	-65.85*	-0.77*
222	32.70	4.00	ø 1 1/4"	2,5 tons	-69.246	-3.898	+23.821	-4.095	-79.046	-0.017	-68.905	-0.612
m	m	m	in.	tons	tons	tons	tons	tons	tons	tons	tons	tons

SPAN	REACTIONS (side stay anchorage) DEAD + WIND				TOTAL (some wind)				STABILIZING CABLE			TENSION (side stay cable) DEAD + WIND		Total (some wind)	
m	5V	5H	6V	6H	5V	5H	6V	6H	No.	Total No.	ø	3–5	4–6	3–5	1–6
66	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
78	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
90	—	—	—	—	—	—	—	—	2	8	1/2"	—	—	—	—
102	—	—	—	—	—	—	—	—	2	8	1/2"	—	—	—	—
114	—	—	—	—	—	—	—	—	2	8	1/2"	—	—	—	—
126	—	—	—	—	—	—	—	—	2	8	1/2"	—	—	—	—
138	—	—	—	—	—	—	—	—	2	8	1/2"	—	—	—	—
150	—	—	—	—	—	—	—	—	2	8	1/2"	—	—	—	—
162	2.11*	2.19*	3.36*	2.82*	2.82*	2.41*	2.98*	2.50*	3	12	1/2"	3.40*	4.38*	5.13*	3.89*
174	2.506	2.102	3.469	-2.912	2.828	2.374	2.954	-2.479	3	12	1/2"	3.27	4.529	4.692	3.856
186	2.90*	2.02*	3.56*	-3.01*	2.79*	2.34*	2.93*	-2.46*	3	12	1/2"	3.14*	4.68*	4.14*	3.83*
198	3.301	1.930	3.696	-3.101	2.747	2.306	2.910	-2.441	3	12	1"	3.003	4.824	3.589	3.798
210	2.61*	2.34*	4.59*	-4.03*	3.91*	3.02*	3.49*	-3.19*	3	12	1"	3.14*	6.21*	4.47*	4.78*
222	2.496	2.094	4.930	-4.131	3.340	2.810	3.602	-3.018	3	12	1"	3.268	6.431	4.371	4.699
m	tons	tons	tons	tons	tons	tons	tons	tons	—	—	—	tons	tons	tons	tons

SPAN	TENSION SPANNING CABLE DEAD + WIND		Total (some wind)		Spanning cables
m	A – B	Total	A – B	Total	ø
66	3+5	8	1+1.2	2.2	1"(2)
78	3+5.5	8.5	1+1.25	2.25	1"(2)
90	3+6.5	9.5	1+1.35	2.35	1"(2)
102	3+6.5	9.5	1+1.35	2.35	1"(2)
114	4+8	12	1.5+1.9	3.4	1 1/4"(2)
126	4+9	13	1.5+2.0	3.5	1 1/4"(2)
138	4+9	13	1.5+1.9	3.4	1 1/4"(2)
150	4+11	15	1.5+2.2	3.7	1 1/4"(2)
162	5+11	16	2+2.1	4.1	1 1/4"(2)
174	5+14	19	2+2.9	4.9	1 1/4"(2)
186	5+11	16	2+2.6	4.6	1 1/4"(2)
198	6+15	20	2+3.0	5.0	1 1/2"(2)
210	6+13	19	3.5+4.2	7.7	1 1/2"(2)
222	6+16	22	3.5+4.5	8.0	1 1/2"(2)
m	tons	tons	tons	tons	in.

* approximately.

Source: Calculated by computer stress programme (DIGISTAT AG, Zurich, Switzerland)

BRIDGE DESIGN

Available Standard Drawings for Suspension Bridges

No. : 2.305

Date : 14th Febr. 77

Sig : [signature]

AVAILABLE DRAWINGS FOR STANDARD SUSPENSION BRIDGES

TITLE	NO. \ SPAN	66 (2 cables)	78 (2 cables)	90 (4 cables)	102 (4 cables)	114 (4 cables)	126 (4 cables)	138 (4 cables)	150 (4 cables)	162 (6 cables)	174 (6 cables)	186 (6 cables)	198 (6 cables)	210 (6 cables)	222 (6 cables)
Lay out	/10														
Main anchorage block	/20														
Main Cable anchorage parts	/31														
Walk way and pylon anchorage	/32														
Wind guy anchorage Ø 1" Cable	/33				*	*	*	*	*	*	*	*	*	*	*
Wind guy anchorage Ø 1¼" Cable	/34														
Wind guy anchorage Ø 1½" Cable	/35	*	*	*	*										
Pylon details and Steelpartlist	/51														
Pylon assembly drawing	/52														
Side stay Cable parts Ø 1"	/61	*	*	*	*	*	*	*	*					*	*
Side stay Cable parts Ø 1¼"	/62	*	*	*	*	*	*	*	*	*	*	*	*		
Walk-way (gang way)	/71														
Suspender	/72														
Stabilizing Cable clamps for Ø ½"-4main Cables	/81	*	*							*	*	*	*	*	*
Stabilizing Cable clamps for Ø ½"-6main Cables	/82	*	*	*	*	*	*	*	*				*	*	*
Stabilizing Cable clamps for Ø 1"-6main Cables	/83	*	*	*	*	*	*	*	*	*	*	*			
Wind tie Cable clamps for Ø 1"	/91				*	*	*	*	*	*	*	*	*	*	*
Wind tie Cable clamps for Ø 1¼"	/92														
Wind tie Cable clamps for Ø 1½"	/93	*	*	*	*										
Total drawings		12	12	13	11	13	13	13	13	14	14	14	14	14	14

If Rock-anchor parts are required please refer to Standard drawing **"ROCK"**

* means drawings <u>not required.</u>

Suspended Bridge (cat walk cable bridge)

This bridge typ is designed for pedestrian and pack animal traffic and is a modern version of Nepal's age old traditional bridge, the Jholunge, which was built using bamboo ropes, chains or used ropeway cables. The bridge cables are anchored directly to the anchor blocks, thus avoiding the necessity of expensive structures of the pylon. The walkway (gangway) is unstiffened and directly fixed to the main support structure and has a slight sag profile. The sag of the main support structure is small and as experienced already on several bridges in Nepal, built with HMG'Standard Design, longitudinal and lateral oscillations are surprisingly low. Being much lower in the cost than the suspension bridge with pylons, the suspended bridge design has been strongly applied within the bridge programme of the Roads' Department since fall 1975, whenever the required free-board could be achieved.

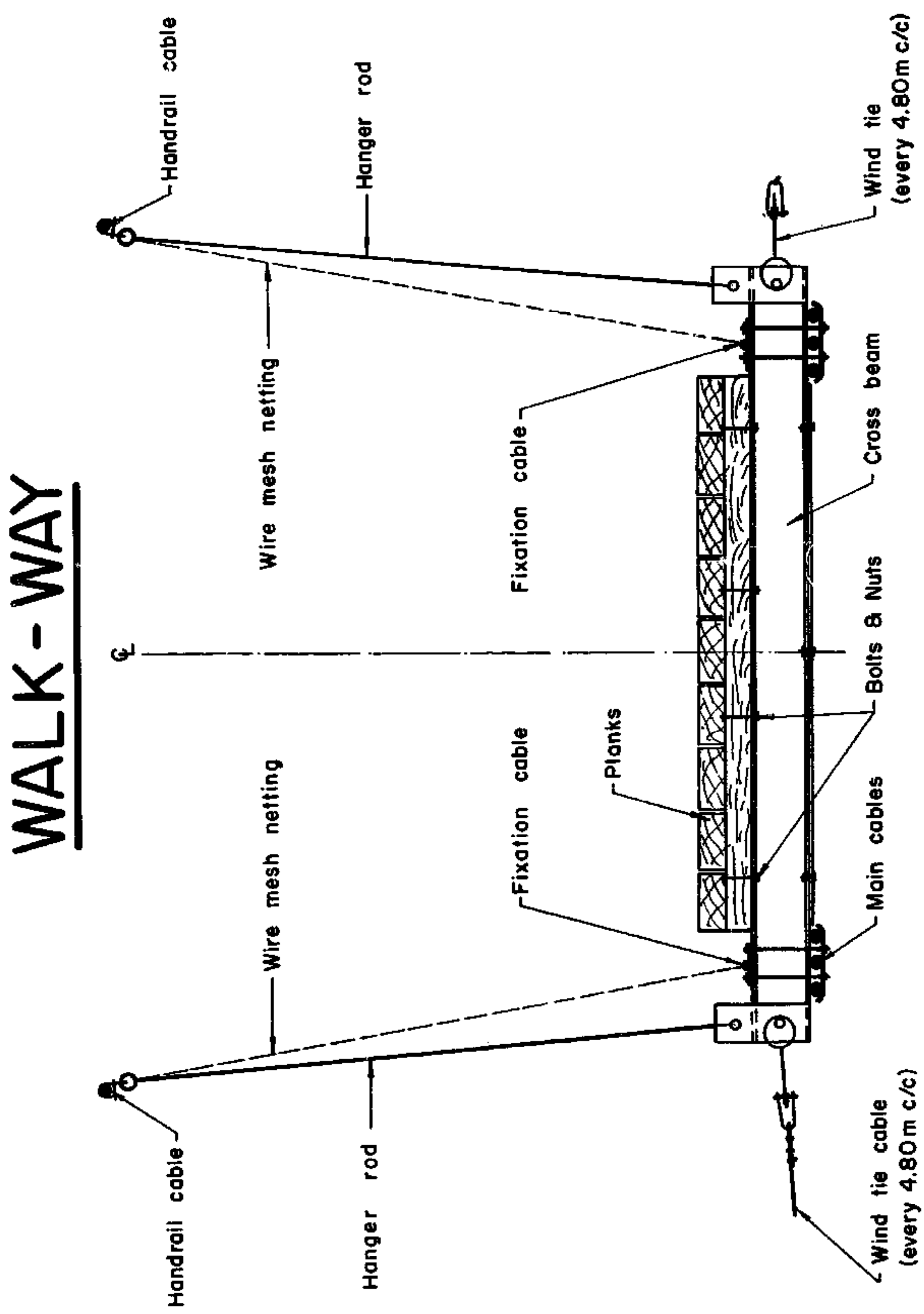
The main design characteristics of the suspended bridge are as follows :

- Standard spans available ... ... 39 - 126 m
- Span intervals of ... ... 3m (39 to 96 m)
6m (102 to 126 m)
- Width of the timber deck (gangway) ... ... 1.10 m (39 to 60 m)
0.97 m (63 to 87 m)
0.98 m (90 to 126m)
- Live load ... ... 425 kg/m1 (39 to 51 m)
410 kg/m1 (54 to 60 m)
460 kg/m1 (63 to 126m)
- Wind load (exposed area) 150 kg/m2
- Available standard drawings ... ... page 2.404
- Further dechnical data ... ... page 2.403

Walkway (Gangway)

The walk way cross section for a suspended bridge is shown on the next page. The walkway is supported directly on the main bridge cable on channel section cross beams at 1.20 m centres, the cross beams being connected together with cross bracing of m.s. flat section. The timber decking is nailed to nailing strips which are bolted to the cross beams. The handrails are formed by cables and the following diameters are used : 39 to 60 m span ____ ø ½ " cable
63 to 126 m span ____ ø 1 " cable

Differential movement between the handrail and main cables is prevented by m.s. bar connectors. The papapet is constructed of wire netting (3mm wire, galvanized, 120 cm width) which is fastened at the top to the handrail cable and at the bottom either nailed to the timber decking for spans 39 to 60 m or fastened to a ½ inch fixation cable for spans 63 to 126 m.


WALK-WAY
Handrail cable
Hanger rod
Wire mesh netting
Fixation cable
Wind tie
(every 4.80m c/c)
Cross beam
Bolts & Nuts
Planks
Main cables
Wire mesh netting
Fixation cable
Handrail cable
Hanger rod
Wind tie cable
(every 4.80m c/c)

BRIDGE DESIGN

Technical Data for Standard Suspended Bridges

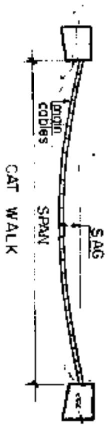
No. :2.403

Date :14th Febr. 77

Sig :

STANDARD SUSPENDED BRIDGES 39–126m

Technical data



–modulus of elasticity = 10'500 kg/mm² – Specification for steel wire ropes for general purposes Table I: 6x19(12/6/1) with w.s.c.(wire strand core). Tensile strength of wire 160kg/mm² (according to Indian Standard)

SPAN	main cables			loading cases (t/m)			sags (m)			total tension (t)			total breaking load (t)	factor of safety			length of cable between the faces of foundation		
m	ø	Nos	area total mm²	hoisting	dead	full	hoisting	dead	full	hoisting	dead	full		hoisting	dead	full	hoisting	dead	full
39	1/2"	2	962	0.011	0.075	0.50	1.12	1.34	2.00	1.89	10.74	48.52	154	81.48	14.34	3.17	39.05	39.09	39.27
42	1/2"	2	962	0.011	0.075	0.50	1.28	1.48	2.20	1.91	11.28	51.20	154	80.63	13.65	3.01	42.07	42.11	42.31
45	1/2"	2	962	0.011	0.075	0.50	1.55	1.79	2.50	1.81	10.74	51.86	154	85.08	14.34	2.97	45.11	45.16	45.37
48	1/2"	2	962	0.011	0.075	0.50	1.84	2.06	2.80	1.74	10.64	5281	154	88.51	14.47	2.92	48.16	48.21	4844
51	1/2"	2	962	0.011	0.075	0.50	2.22	2.42	3.15	1.63	10.26	53.16	154	94.48	15.01	2.90	51.23	51.28	51.52
54	1/2"	2	962	0.011	0.090	0.50	2.63	2.81	3.55	1.52	11.67	51.34	154	101.02	13.29	3.00	54.29	54.39	54.62
57	1/2"	2	962	0.011	0.090	0.50	3.00	3.20	3.95	1.49	11.42	51.41	154	103.41	13.48	3.00	57.36	57.48	57.73
60	1/2"	2	962	0.011	0.090	0.50	3.44	3.66	4.40	1.44	11.07	51.14	154	10694	13.91	3.01	60.50	60.57	60.86
63	1/2"	4	1924	0.022	0.100	0.56	1.68	2.03	3.15	6.53	24.64	89.95	308	47.17	12.50	3.42	63.06	63.12	63.42
66	1/2"	4	1924	0.022	0.100	0.56	1.75	2.14	3.30	6.88	25.66	94.41	308	44.77	12.00	3.26	66.06	66.13	66.44
69	1/2"	4	1924	0.022	0.100	0.56	1.80	2.21	3.45	7.31	27.15	98.51	308	42.13	11.34	3.13	69.06	69.13	69.46
72	1/2"	4	1924	0.022	0.100	0.56	1.92	2.33	3.60	7.47	28.04	102.80	308	41.23	10.98	3.00	72.07	72.14	72.48
75	1/2"	4	1924	0.022	0.100	0.56	2.11	2.60	3.90	7.34	27.30	103.12	308	41.96	11.28	2.99	75.09	75.18	75.54
78	1/2"	4	1924	0.022	0.100	0.56	2.51	2.91	4.20	6.72	26.42	103.75	308	45.83	11.66	2.97	78.15	78.23	78.60
81	1/2"	4	1924	0.022	0.100	0.56	2.91	2.28	4.55	6.26	25.33	103.46	308	49.20	12.16	2.98	81.22	81.30	81.68
84	1/2"	4	1924	0.022	0.100	0.56	3.20	3.55	4.85	6.13	25.20	10452	308	50.24	12.22	2.95	84.27	84.35	84.75
87	1/2"	4	1924	0.022	0.100	0.56	4.21	4.44	5.30	5.04	21.75	102.90	308	61.10	14.16	2.99	87.54	87.60	87.86
90	1/2"	6	2886	0.033	0.120	0.58	2.36	2.89	4.50	4.24	42.39	133.08	462	32.44	10.90	3.47	90.08	90.17	90.60
93	1/2"	6	2886	0.033	0.120	0.58	2.48	3.00	4.65	14.47	43.60	137.52	462	31.93	10.60	3.36	93.09	93.18	93.62
96	1/2"	6	2886	0.033	0.120	0.58	2.53	3.11	4.80	15.11	44.82	141.96	462	30.58	10.31	3.25	96.09	96.19	96.04
102	1/2"	6	2886	0.033	0.120	0.58	2.72	3.30	5.10	15.87	47.87	150.83	462	29.11	9.65	3.06	102.10	102.20	102.68
108	1/2"	6	2886	0.033	0.120	0.58	3.17	3.76	5.60	15.28	46.98	15422	462	30.23	9.83	3.00	108.15	108.26	108.77
114	1/2"	6	2886	0.033	0.120	0.58	3.86	4.40	6.25	14.01	44.83	154.33	462	32.98	10.31	2.99	114.26	114.37	114.91
120	1/2"	6	2886	0.033	0.120	0.58	4.50	5.04	6.90	13.35	43.46	155.25	462	34.61	10.63	2.98	120.17	120.49	121.06
126	1/2"	6	2886	0.033	0.120	0.58	5.09	5.62	7.50	12.87	42.40	153.47	462	35.89	10.90	3.01	126.55	126.67	127.19

HIS MAJESTY'S GOVERNMENT MINISTRY FOR WORKS AND TRANSPORT ROADS DEPARTMENT

AVAILABLE DRAWINGS FOR STANDARD SUSPENDED BRIDGES

TITLE	NO	2 Main cables								4 Main cables									6 Main cables							
		39	42	45	48	51	54	57	60	63	66	69	72	75	78	81	84	87	90	93	96	102	108	114	120	126
Lay out (without any wind bracing)	Span/10							n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.
Lay out (Wind tie)	/11	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.			n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.
Lay out (Wind guy ø 1")	/12	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.					n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.
Lay out (Wind guy ø 1¼")	/13	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.																n.r.	n.r.
Lay out (Wind guy ø 1½")	/14	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.							
Main cable drum anchorage for 2 cables without clamps + Handrail cable anchorage	/20				n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.
Main cable drum anchorage for 2 cables with clamps + Handrail cable anchorage	/21									n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.
Main cable drum anchorage for 4 cables	/22	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.										n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.
Main cable drum anchorage for 6 cables	/23	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.								
Handrail cable anchorage ø 1" cable	/24	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.																	
Walk-way for 2 main cables without wind tie	/30									n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.
Walk-way for 4 main cables including wind ties ø ¼" every 4.80m	/31	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.										n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.
Walk-way for 6 main cables including wind ties ø ¼" every 4.80m	/32	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.								
Wind tie connecting clamps on the walk-way with 2 main cables	/33	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.			n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.
Wind tie anchorage for cables ø ½"	/41	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.			n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.
Wind guy anchorage for cables ø 1"	/42	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.					n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.
Wind guy anchorage for cables ø 1¼"	/43	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.																n.r.	n.r.
Wind guy anchorage for cables ø 1½"	/44	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.							
Total drawings		4	4	4	3	3	3	5	5	7	7	7	7	5	5	5	5	5	5	7	7	7	7	7	5	5

If Rock-anchor parts are required please refer to standard drawing "ROCK"

n.r. means drawings <u>not required</u>

Wind - Bracing

The Standard Design details of wind bracing are concerning the anchorage details for cable diametres. The detail shows, that adjustment to take up the pretension are proposed.

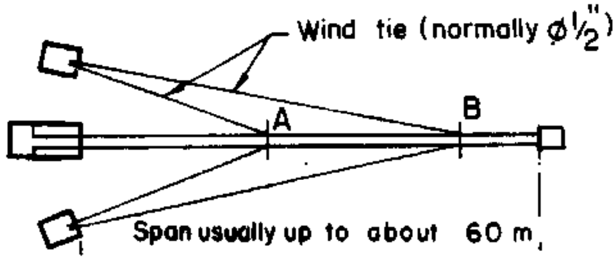
However, the actual layout of the windguy cables is dependent to a large extent on the bridge span and the topography of the bridge site, two main systems are employed as shown below.

The main characteristics of the wind - bracing systems are as follows :

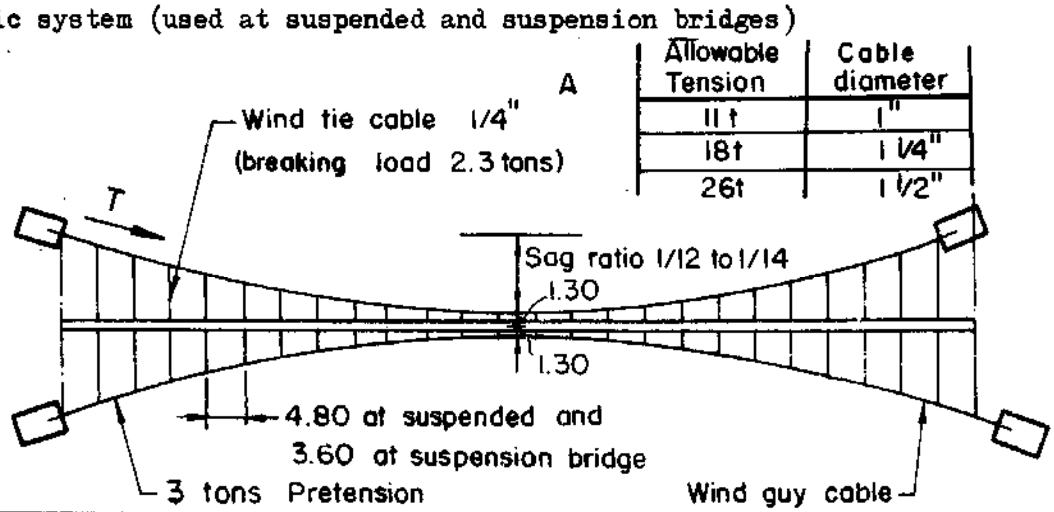
- Standard 'cable' (guy) ... ... ø 1", 1¼" and 1½" (6 x 19, 6/12/1)
- Standard wind tie ... ... ø ½" when tie only (below 60 m span)
  ø ¼ when wind guy cable used
- Wind tie intervals ... ... 3.60 m at Suspension Bridges
  4.80 m at Suspended Bridges
- Sag ratio ... ... 1/12 to 1/14
- Wind load (exposed area) 150 kg/m2
- Wind load supported by bracing 100 kg/m1
- Available standardized drawings ... ... pages 2.305 and 2.404

Diagonal system (used at short span suspended bridges)

For very short spans (up to about 51m) of suspended bridges only at real windy sites wind bracing should be proposed. For spans between 54 and 60 m the diagonal system is used.



Parabolic system (used at suspended and suspension bridges)



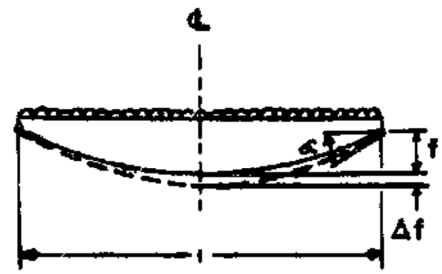
Allowable Tension	Cable diameter
11 t	1"
18t	1 1/4"
26t	1 1/2"

SINGLE CABLE UNDER UNIFORMLY DISTRIBUTED LOAD (level span)

A curved cable is a basic component of any suspension structure. Since the configuration corresponding to a unifoemly distributed load occurs quite often in suspension structures, an understanding of its behavior under static as well as dynamic loads is basic. The solid line in the sketch below represents the initial configuration of an unloaded hanging cable attached to immovable supports at its ends. Since the cable will assume a parabolic configuration under uniform load, the initial curve could be assumed to be parabola. The assumed initial configuration has no effect on further analysis. The problem is to find the deflection (dotted) configuration, the force in the cable, and the forces on the supports. The following notation is used.

No load (initial configuration):

- l = horizontal distance between supports
- L = developed length of cable
- f = sag of cable
- A = cross-sectional area of cable
- E = modulus of elasticity of cable



Loaded cable:

- T = tension in cable at support caused by superimposed loads
- q = weight of cable per unit length (assumed uniform)
- α = angle between horizontal and tangent to cable at support
- V = vertical component of T at support
- H = horizontal component of T at support
- ΔL = increase in length of cable due to T
- Δf = increase in sag of cable due to superimposed loads

It is assumed that the uniformly distributed load acts vertically and that the supports at each end of the cable are on the same horizontal line.

L of the cable $$L = l\left[1 + \frac{8}{3}\left(\frac{f}{l}\right)^2\right] \quad (1)$$

The tension T is given by $$T = \frac{ql^2}{8f}\sqrt{1+16\left(\frac{f}{l}\right)^2} \quad (2)$$

The approximate elastic elongation of the cable is $$\Delta L = \frac{TL}{EA} \quad (3)$$

$E = 10{,}500 - 16{,}000 \ \text{kg/mm}^2$

The increase in sag is $$\Delta f = \frac{\Delta L}{\frac{16}{15}(f/l)\left[5 - 24(f/L)^2\right]} \quad (4)$$

The angle α is given by $$\tan\alpha = \frac{4(f+\Delta f)}{l} \quad (5)$$

The vertical and horizontal reactions are

$$V = T\sin\alpha \quad (6)$$

$$H = T\cos\alpha \quad (7)$$

Reference : Structural Engineering Handbook : Edwin H. Gaylord, jr.
(McGraw-Hill Book Company) Charles N. Gaylord

SINGLE CABLE UNDER UNIFORMLY DISTRIBUTED LOAD (level span) continuation

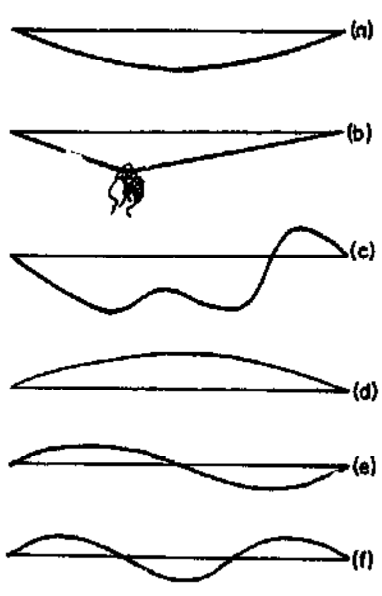
The figure below shows a suspended cable at rest (a), of any geometric configuration, with any assumed tension T. If the cable is plucked (for example, to the configuration in b and then released, it will vibrate. During such vibration it will assume various configurations. At some instant, it may assume a shape such as shown in Fig. c, which varies from instand, depending on the manner of plucking as well as on the properties of the cable and its initial tension. Whatever configuration the cable has at any instant can be represented by a summation of the ordinates of an infinite number of harmonic curves, the first three of which are shown in d, e, and f. Each harmonic has different amplitude, e.g., a_1, a_2, a_3 ...., a_n.

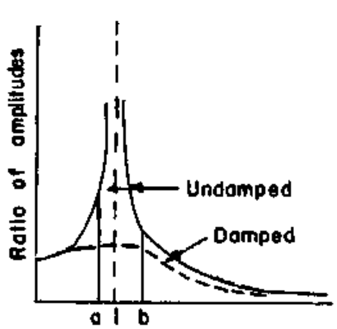
Dynamic Behavior. Additional notations are

- q = uniformly distributed load.
- g = acceleration of gravity (9.81m/Sec²).
- n = any integer.
- Wn = frequency of vibration of a harmonic.

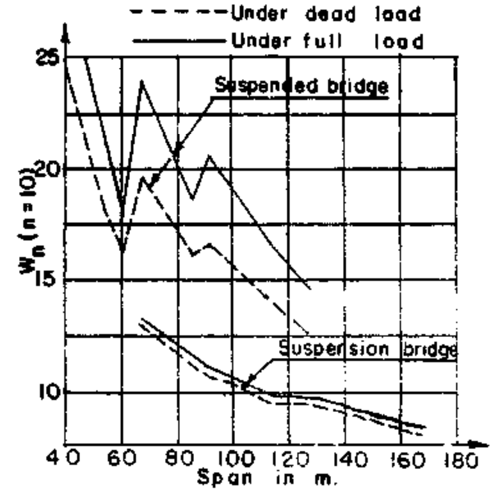
$$W_n = \frac{n\pi}{l}\sqrt{\frac{T}{q/g}}$$

The amplitudes are so prescribed that their summation results in the exact value of the ordinate of the actual configuration shown in c. The number of harmonics, and the amplitude of each, necessary to represent the configuration depends on the specific problem. It should be realized that each harmonic is not an imaginary component of a vibrating cable but is a physical entity. It should also be noted that the amplitude of each harmonic changes as the cable vibrates. Each component harmonic is called a mode vibration. The frequency of change of amplitude (i.e., the number of times per second that each harmonic assumes its maximum positiv and negativ amplitudes) is called a natural frequency of the cable. Thus, a cable can have an infinitive number of natural frequencies. The larger the number of waves in the mode the smaller the amplitude and the larger the frequency. Thus, from a practical viewpoint, the first few harmonics are sufficient to represent a vibrating cable. The first harmonic is called the fundamental mode of vibration and its frequency the natural frequency. One approach in designing suspension structures is to stay outside the range ab of the Fig. below middle. This can be made by increasing the mass q/g. The Fig. in the right below corner indicates the frequencies of the standard suspension and suspended bridges. It is easy understandable that the suspended bridge is stiffener than the suspension bridge.





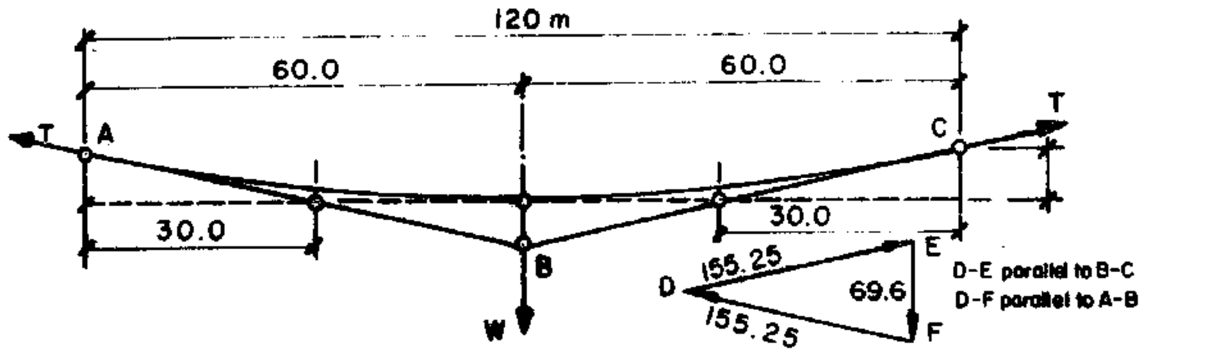
Ratio of natural frequencies.



Reference : Structural Engineering Handbook (McGraw-Hill Company) 1968

Given: Suspended bridge, span 120m, cable sag (full loaded) = 6.90 m, loading uniform, dead load 120 Kg/m + live load 460 Kg/m = total load 580 Kg/m.

To find: Force T in the main cables, diameter and number of cables.



Force Diagram Scale: 1cm = 50 tons

Procedure

1. Calculate total weight of the bridge
   W = 0.58 tons/m x 120m = 69.60 tons.
2. Support the weight W by the 2 forces T at either end of the cable.
3. Determine the forces T graphically with the force diagram.
4. Using $\phi 1\frac{1}{2}$" 6 x 19 (12/6/1) with W.S.C, breaking load 77 tons, factor of safety against rupture 3, calculate:

$$\text{Number of cables} = \frac{\text{Force T x Safety factor}}{\text{Breaking load of 1 cable}} = \frac{155.25 \times 3}{77} = 6.04$$

If in this case 6 cables are used, the factor of safety is reduced to 2.98 which would be acceptable. Total cable weight per meter = 6 x 5.53 = 33.18 kg/m

5. Alternative Solution

Using Bridge Wire (ϕ5mm) Required for equivalent strength, breaking strength 160 Kg/mm^2.

Allowable Strength 72 Kg/mm^2 (German Standard)

Area 19.6 mm^2 Weight per Wire 0.154 Kg/m

Allowable force per Wire = 1.41 t

Force = 155.25 tons

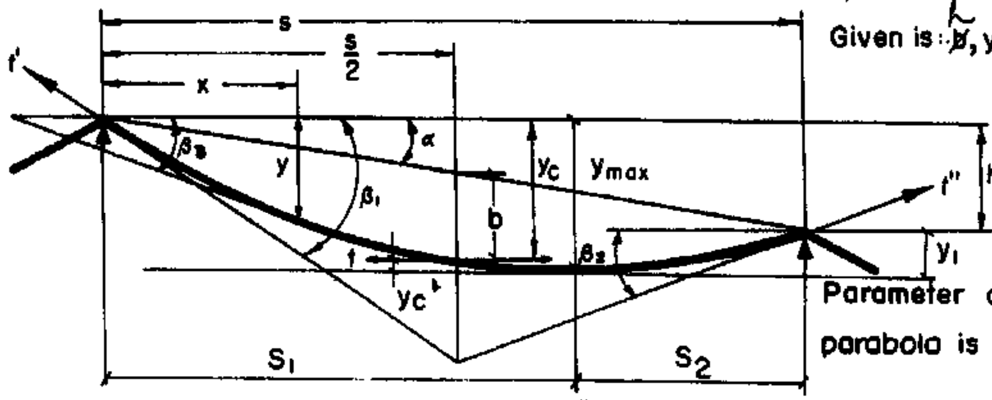
$$\text{Number of Wires required} = \frac{\text{Total Force}}{\text{Allowable force}} = \frac{155.25}{1.41} = 110.106$$

Say 112 Wires of ϕ 5mm (56 Wires on each side)

(Total wire weight per m = 112 · 0.154 = 17.248 kg/m')

SINGLE CABLE UNDER UNIFORMLY DISTRIBUTED LOAD (INCLINED SPAN)

The suspended walkway has however the advantage, that no extra problems crop up should the anchor block have to be placed at different heights. The layout of the wind guy cable sometimes calls also for an inclined parabola system.



Given is : h, y_1, $y_{max} = (h + y_1)$

Parameter a of this parabola is $a = \frac{(\sqrt{y_{max}} + \sqrt{y_1})^2}{l^2}$

The following formulas give increments of deflection and slope due to inclination of the chord.

"Down" slopes are usually considered as plus values and "Up" slopes as minus values.

$$y_c = \left(\frac{ws^2}{8t}\right) + \frac{h}{2}$$

$$S_1 = \sqrt{\frac{y_{max}}{a}} \; ; \; S_2 = \sqrt{\frac{y_1}{a}}$$

$$\tan\alpha = \frac{h}{s}$$

$$y_c' = a\left(S_1 - \frac{S}{2}\right)^2$$

At any point — $y = \frac{wx(s-x)}{2t} \pm x \tan\alpha$

$$y_c = y_1 - y_c' + h$$

$$\tan\beta_1 = \frac{ws}{2t} + \tan\alpha \; ; \quad \tan\beta_2 = \frac{ws}{2t} - \tan\alpha$$

$$b = y_c - \frac{h}{2}$$

$\tan\beta_3$ (at any point) $= \frac{w}{t}\left(\frac{s}{2} - x\right) \pm \tan\alpha$

When center deflection is known : $t = \frac{ws^2}{8y_c - 4h}$

$$t = \frac{ws^2}{8b}$$

Low point of an inclined span occurs when $\tan\beta_3 = 0$, $\therefore x = \frac{s}{2} + \frac{t}{w}\tan\alpha$

When deflection at any other point is known :

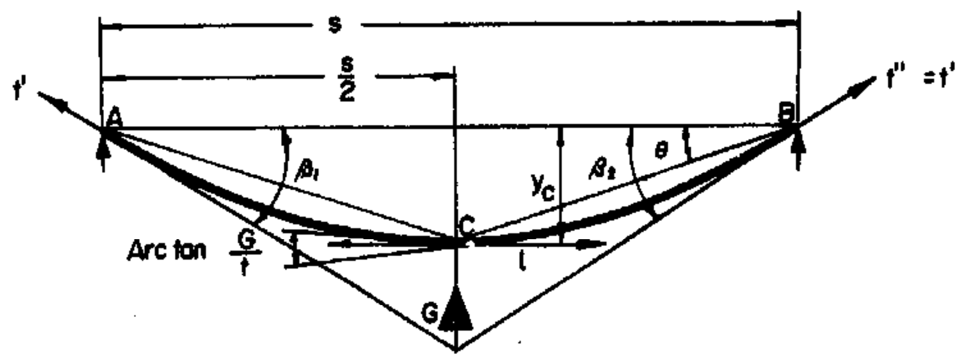
$$t = \frac{wx(s-x)}{2(y - x\tan\alpha)} \qquad t' = t\sec\beta_1 \qquad t'' = t\sec\beta_2$$

The lengths of cable in an inclined span is given by the formulas :

$$L_1 \text{ or } L = \sqrt{s^2 + h^2} + \frac{w^2 s^3 \cos^3\alpha}{24t^2} \text{ (approx)}; \quad L_1 \text{ or } L = \sqrt{s^2+h^2}\left(1 + \frac{8}{3}k^2 - \frac{32}{5}k^4 + \frac{256}{7}k^6\right)$$

$$K = \text{Ratio of deflection} = \frac{w \cdot s \cdot \cos^2\alpha}{8 \cdot t}$$

SINGLE CABLE UNDER CONCENTRATED SINGLE LOAD e.g CABLE CAR (LEVEL SPAN) (SIMPLIFIED CALCULATION)



The deflection produced by a concentrated load suspended midway between two fixed points A and B forms two equal sub-chords AC and CB. The cable assumes two catenary arcs which intesect at C. The following formulas are, however, based on the parabola, as the difference in results is negligible.

The center deflection is found from :

$$yc = \frac{Gs}{4t} + \frac{ws^2}{8t} = \frac{s(2G + ws)}{8t} \quad (1) \qquad \text{and} \quad t = \frac{s(2G + ws)}{8y_c} \quad (2)$$

$$t' = t \sec\beta_1 = t \sec\beta_2 = t'' \quad (3) \qquad \tan\beta_1 = \frac{G + ws}{2t} = \tan\beta_2 \quad (4)$$

Example

A rolling load weighing 600 Kg is to be supported in a level span 100m long by a cable anchored at both ends. The deflection must not exceed 3m. No wind or ice conditions.

Since this is a level span, $\alpha = 0$ and $w = w'$

W = 2.46 kg per m

From (2) $t = \frac{100(2 \times 600 + 2.46 \times 100)}{8 \times 3} = 6.025$ Kg

a) From (3) $t' = 6.025 \times 1.0025 = 6.040$ Kg

b) From (4) $\tan\beta_1 = \frac{600 + (2.46 \times 100)}{2 \times 6025} = 0.0702 \qquad \beta_1 = 4.02°$

Factor of safety $= \frac{\text{Breaking load}}{\text{max. tension}} = \frac{25.000}{6.040} = 4.14 > 4.0$

The maximum cable length occurs when load is at center of span

$s_1 = \sqrt{\left(\frac{s}{2}\right)^2 + y^2} = \sqrt{50^2 + 3^2} = 50.0899$ m $\qquad \tan\theta = \frac{3}{50} = 0.061\ \theta = 3.43°$

$$L = 2\left(s_1 + \frac{w^2\left(\frac{s}{2}\right)^3 \cos^3\theta}{24\,t^2}\right) = 2\left(50.0899 + \frac{2.46^2 \times 50^3 \times \cos^3 3.43°}{24 \times 6025^2}\right) = 100.18 \text{ m}$$

We assume the elongation due to load as 0.15%.

The hoisting (erection) length of the cable : $\Delta l = \frac{0.15 \cdot 100.18}{100} = 0.15$ m

c) Length (hoisting) = 100.18 − 0.15 = 100.03 m

$$y_{Hoisting} = \sqrt{\frac{\text{span} \cdot 3(\text{cable length} - \text{span})}{8}} = \sqrt{\frac{100 \cdot 3(100.03 - 100.00)}{8}} = 1.06\text{ m}$$

$$\tan\alpha = \frac{4 \cdot 1.06}{100} = 0.0424 \qquad \alpha = 2.43^\circ$$

d) Tension during hoisting (erection)

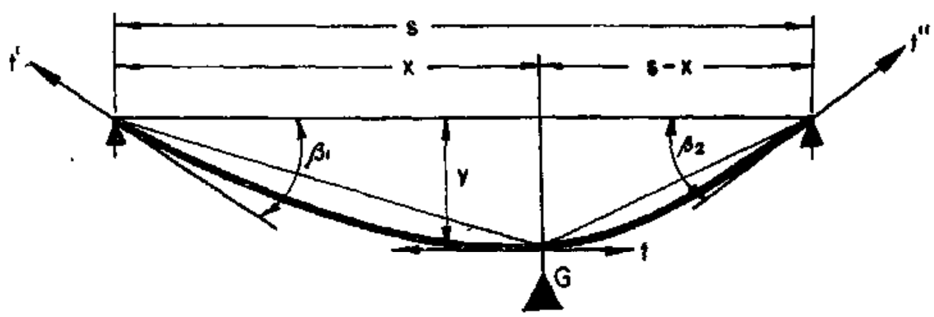
$$T_{Hoisting} = \frac{s^2 \cdot w}{8 \cdot y_H} \cdot \sec\alpha = \frac{100^2 \cdot 2.46}{8 \cdot 1.06} \cdot 1.0009 = 2904\text{ Kg} \qquad \left(\sec\alpha = \frac{1}{\cos\alpha}\right)$$

e) Tension when the cable car hangs 5 m in front of one support
Knowing the tension t at the center of the span, the deflection at other points may be determined from:

$$y = \frac{x(ws + 2G)^2 (s - x)}{2t(ws^2 + 4G)\sqrt{x(s-x)}} = \frac{95(2.46 \cdot 100 + 1200) \cdot 5}{2 \cdot 6025(2.46 \cdot 100^2 + 2400)\sqrt{95 \cdot 5}} = 1.074\text{ m}$$

However it must be understood this formula will only give approximate results, as it is based on constant cable length, neglecting the elastic properties of the cable.

After determining the deflection for any position of the load, the corresponding approximate tension at xy can be found.



$$t'' = \frac{x(s - x)(ws + 2G)}{2\,s\,y} = \frac{95 \cdot 5\,(2.46 \cdot 100 + 2 \cdot 600)}{2 \cdot 100 \cdot 1.074} = 3198\text{ Kg}$$

$$\tan\beta_2 = \frac{G + w.s}{2.\,t} = \frac{600 + 2.46 \cdot 100}{2 \cdot 3198} = 0.1323 \qquad \beta_2 = 7.54^\circ$$

f) Required force to pull the cable car (when hanging 5 m toward the support) factor of friction between 'cable and roller bearing of the car' = 0.03

Required pulley force = $\Sigma V\ (\sin\beta_2 + \mu \cdot \cos\beta_2)$

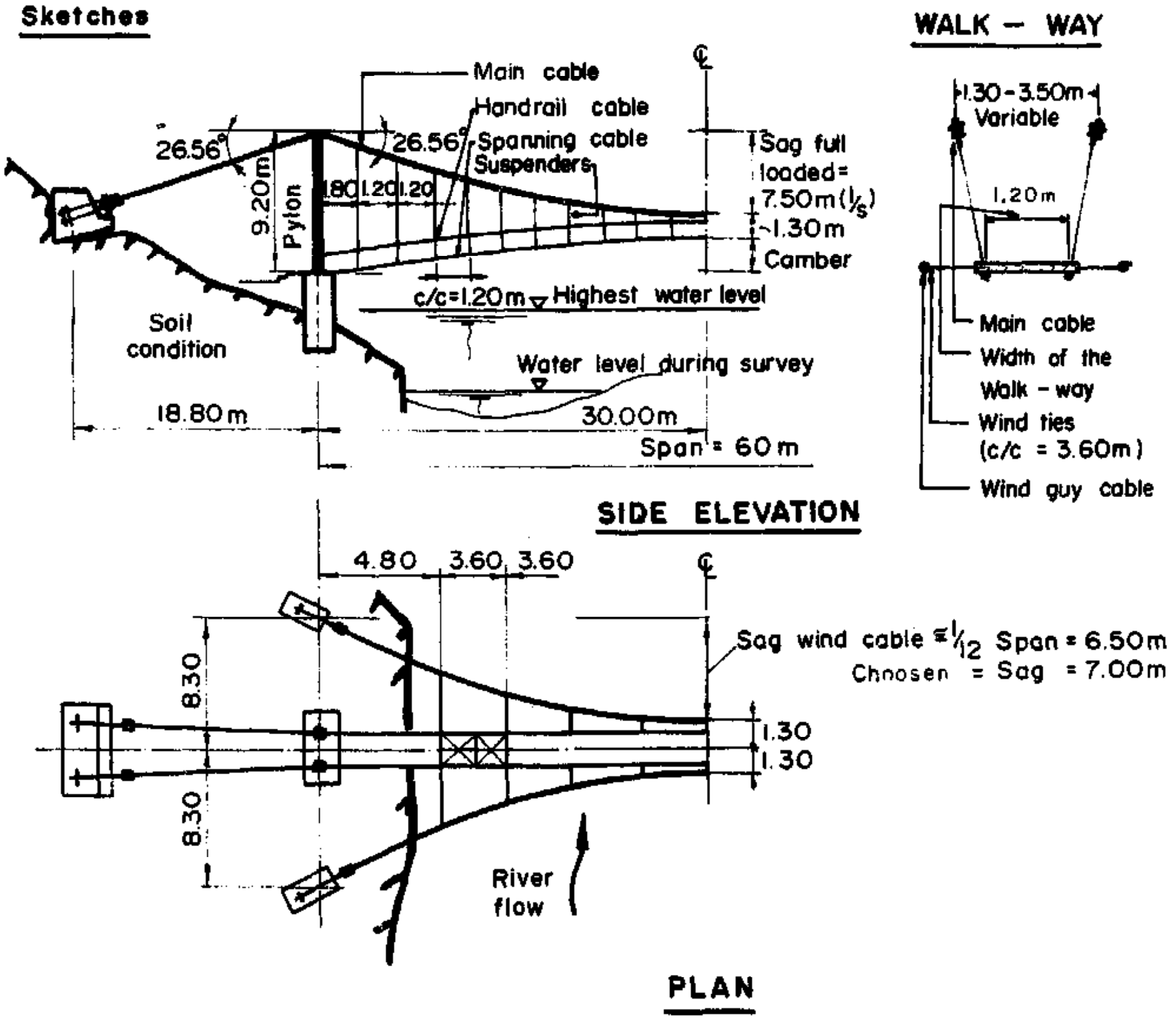
$R = 600\text{ Kg}\ (\sin 7.54^\circ + 0.03 \cdot \cos 7.54^\circ)$

$= 96.58\text{ Kg}$

Say 100 Kg

EXAMPLE FOR A STATICAL CALCULATION OF AN UNSTIFFENED SUSPENSION BRIDGE OF 60 M SPAN

Sketches



System

Span $L = 60.00$ m

Walk-way width $= 1.20$ m

$$\text{Sag } f = \frac{\text{Span}}{8} = \frac{60}{8} = 7.50 \text{ m}$$

$$f_H = \frac{\text{Width of pylon} - \text{Width of walk-way}}{2} = \frac{3.50 - 1.20}{2} = 1.15 \text{ m} > \frac{\text{Span}}{100}$$

Length of main cable (between pylons) L_c

$$L_c = L \cdot \rho$$

Where $\rho = 1 + \frac{8}{3}\left(\frac{Sag}{Span}\right)^2 - \frac{32}{5}\left(\frac{Sag}{Span}\right)^4$

$$\rho = 1 + \frac{8}{3}\left(\frac{7.5}{60}\right)^2 - \frac{32}{5}\left(\frac{7.5}{60}\right)^4$$

$$\rho = 1 + 0.04166 - 0.0015625 = 1.04010416$$

$$L_c = L \cdot \rho = 60m \cdot 1.04010416 = 62.406m$$

(middle span only) for full load case.

Loading Cases.

(a) Dead load of the bridge = 120 kg/m'

(b) Uniformly distributed live load = 400 kg/m² [480kg/m']

Wind: Wind load = 150kg/m²
(i.e. for exposed area = 100kg/m')

Construction materials

Cable 6 × 19 (12/6/1) with W. S. C. (Wire Strand Core)

Tensile Strength of wire 160 kg/mm².

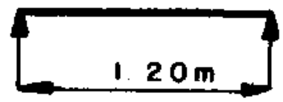
Ø mm	Breaking load tons	Area mm²
6.3	2.30	14.38
8.0	3.40	21.25
20.0	21.20	132.50
32.0	54.40	340.00
38.0	77.00	481.00

Open thimbles (IS 2315—1963)

Bulldog grips (IS 2361—1970)

Walk – way with Wooden deck

System:



6 Plan ks 5/19 cm
(dead load = 49 kg/m')

Loading Case 1.

Uniformly distributed load = 480 kg/m'

Dead load = 49 kg/m'

Total load W = 529 kg/m

Bearing reaction = 0,6·0,529 = 0.3174 t

Bending moment $= \frac{W \cdot S^2}{8} = \frac{0.529 \cdot 1.2^2}{8} = 0.09522$ mt

Modulus of section $= \frac{6(19 \cdot 5^2)}{6} = 475\ cm^3$

Sectional area = 6(19·5) = $570\ cm^2$

$\sigma_{Bending} = \frac{9522}{475} = 20{,}05\ kg/cm^2 \ll \sigma_{Permissible}$

$\tau_{Vorh} = \frac{S \cdot 3}{F \cdot 2} = \frac{317{,}4 \cdot 3}{570 \cdot 2} = 0.835\ kg/m^2 \ll \tau_{Permissible}$

Loading Case 2.

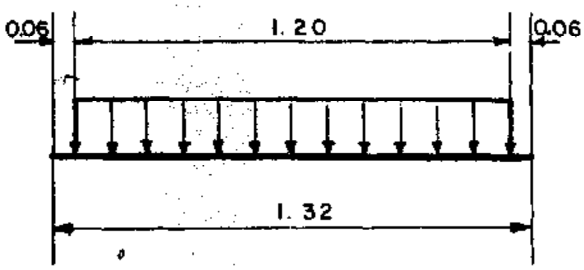
Single load of 100 kg on one Plan k

dead load of one Plan k = 8.075 kg/m'

$M_{max.} = \frac{0.0081 \cdot 1.2^2}{8} + \frac{0.100 \cdot 1.2}{4} = 0.031458$ mt.

$\sigma_{max.} = \frac{3145.8}{475} = 6.62\ kg/cm^2 \ll \sigma_{Permissible}$

Cross beam



Load = 529 kg • 1.2 = 634.8 kg

Weight of the Cross beam

2L 65/65/5 = 2·4.9 kg/m = 9.8 kg/m

Loading Case 1.

$$M_{max.} = (1.2 \cdot 0.6348 \cdot 0.5 \cdot 0.66) - (0.6 \cdot 0.6348 \cdot 0.3) + \frac{(0.0098 \cdot 1.32^2)}{8}$$

$$M_{max.} = 0.2514 - 0.1143 + 0.0029 = 0.1392 \text{ mt}$$

Moduli of Section (1 L) $Z_{xx} = Z_{yy} = 5.2 \text{ cm}^3$; $A = 6.25 \text{ cm}^2$

$$\sigma_{max.} = \frac{13920}{2 \cdot 5.2} = 1338 \text{ kg/cm}^2 < 1650 \text{ kg/cm}^2$$

$$\tau \cong \frac{0.6 \cdot 634.8 + 9.8 \cdot 0.66}{(6.5 - 0.5) \cdot 0.5} = \frac{380.88 + 6.488}{(6.5 - 0.5) \cdot 0.5} = 129.116 \text{ kg/cm}^2$$

Loading Case 2.

Single load of 100 kg + dead load.

$$M_{max.} = (1.2 \cdot 0.049 \cdot 0.5 \cdot 0.66) - (0.6 \cdot 0.049 \cdot 0.3) + \frac{0.0098 \cdot 1.32^2}{8} + \frac{0.100 \cdot 1.2}{4}$$

$$M_{max.} = 0.019404 - 0.00882 + 0.00213 + 0.03 = 0.042714 \text{ mt}$$

$$\sigma_{max.} = \frac{4271.4}{2 \cdot 5.2} = 410.71 \text{ kg/cm}^2$$

$$\tau \cong \frac{0.5 \cdot 100 + 0.66 \cdot 9.8}{(6.5 - 0.5) \cdot 0.5} = 18.82 \text{ kg/cm}^2$$

Comparision Stress $\sigma_c = \sqrt{411^2 + 3 \cdot 19^2} = 412 \text{ kg/cm}^2 <<< 1400 \text{ kg/cm}^2$

Suspenders

Weight to be carried by the Suspenders:

- Weight of Wind Cables
- Weight of Wind ties
- Weight of Walk — Way
- Vertical reaction due to Prestressed Spanning Cable
- live load

Total load ≅ 600 kg/m'

I. Load on One Suspender $= \frac{600 \cdot 1.2}{2} = 360 \text{ kg}$

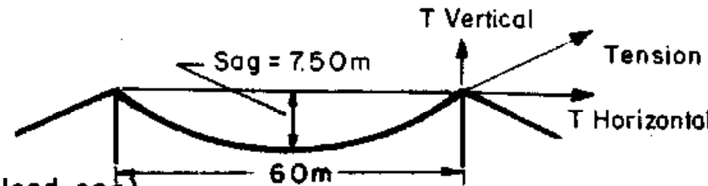
Suspender rods of Ø 13 mm (1.327 cm^2) are used.

$$\sigma_{tension} = \frac{360}{1.327} = 271.3 \text{ kg/cm}^2 << 1400 \text{ kg/cm}^2$$

During errection work a load of about 1000kg might be suspended on one Suspender

$$\sigma_{errection} = \frac{1000}{1.327} = 753.6 \text{ kg/cm}^2 < 1400 \text{ kg/cm}^2$$

Main Cable



Span = 60m

Sag $= \frac{\text{Span}}{8}$ = 7.50(full load sag)

We choose 2 Cables of Ø 1½"(38mm) 6×19 (12/6/1) with W.S.C. having a breaking load of 77 tons.

Loading Cases

Hoisting	= 2·4.06 kg/m'	= 8.12 kg/m'
Dead load		= 120 kg/m'
Full load	W_f	= 600 kg/m'

Max. Cable Tension

$$T = \sqrt{T_H^2 + T_V^2}$$

$$T_H = \frac{W_f \cdot \text{Span}^2}{8 \cdot \text{Sag}} = \frac{0.600 \cdot 60^2}{8 \cdot 7.5} = 36 \text{ tons}$$

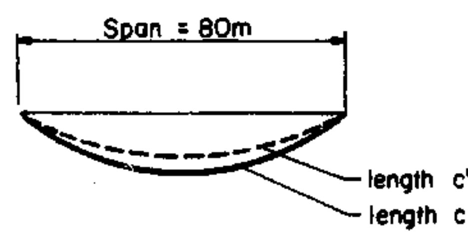
$$T_V = \frac{W_f \cdot \text{Span}}{2} = \frac{0.6 \cdot 60}{2} = 18 \text{ tons}$$

$$T = \sqrt{36^2 + 18^2} = \sqrt{1296 + 324} \cong 40.25 \text{ tons}$$

Safety factor of the two main Cables:

$$S.F. = \frac{\text{No. of Cables} \times \text{breaking load}}{\text{max. tension}} = \frac{2 \cdot 77}{40.25} = 3.83 > 3.0$$

Temperature



$\Delta \text{ length}_c = L_c \cdot \alpha_f \cdot \Delta_t$

$L_c = 62.406$ m

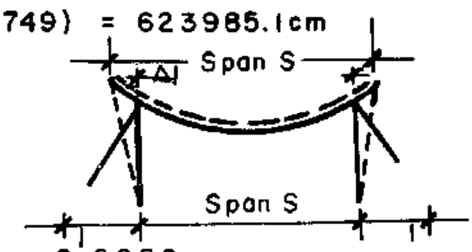
$\alpha_f = 0.000012$

$\Delta_t = -10°C$

$\Delta L_c = 6240.6 \cdot 0.000012 \cdot (-10°) = -0.749$ cm

$L_{c'} = L_c + \Delta L_c = 6240.6 + (-0.749) = 623985.1$ cm

Increasing of the span



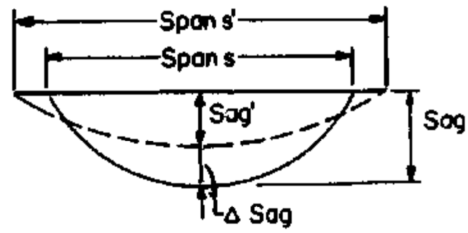
Span S' = Span + 2 Δ Span

Δ Span = $l \cdot \alpha t \cdot \Delta t$

Δ l = 1880·0.000012·10 = 0.2256 cm

Span S' = 6000 + 2·0.2256 = 6000.4512 cm

Decreasing of the Sag



$$\varrho' = \frac{L_c'}{s'} = \frac{6239.851}{6000.4512} = 1.039897$$

$$X = \left(\frac{Sag'}{s'}\right)^2$$

$$1 + \frac{8}{3}\cdot X - \frac{32}{5}X^2 = 1.039897$$

$$6.4X^2 - 2.666\cdot X + 0.039897 = 0$$

$$X = \frac{2.666\cdot \pm \sqrt{2.666^2 - 4\cdot 6.4\cdot 0.039897}}{2\cdot 6.4} \text{ cm}$$

X_1 = 0.4010173 cm (absurd)

X_2 = 0.015545 cm (possible)

But

$$X_2 = \left(\frac{Sag'}{s'}\right)^2$$

$$Sag' = s'\cdot\sqrt{X_2} = 6000.4512\sqrt{0.015545} = 748.133792 \text{ cm}$$

$$\Delta\, Sag = Sag - Sag' = 750 - 748.133792 \cong 1.87 \text{cm}$$

Increasing of the force T_H

$$\Delta T_H = T_H\left(\frac{Sag}{Sag'} - 1\right) = 36\left(\frac{750}{748.134} - 1\right) = 0.09 \text{t}/10°\text{C}$$

If we assume $\Delta t = 30°C$

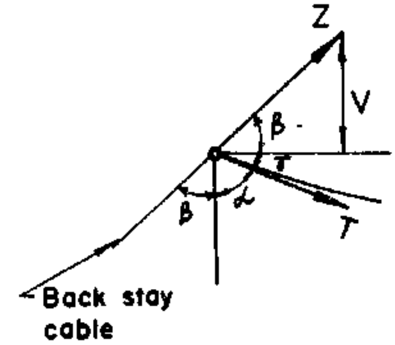
$$T_H = 36 + 3\cdot 0.09 = 36.27 \text{ tons}$$

$$T_V = 18 \text{ tons}$$

$$\text{Max. tension} = \sqrt{36.27^2 + 18^2} = 40.491 \text{ tons}$$

$$\text{Factor of Safety} = \frac{2.77}{40.491} = 3.80 > 3.0$$

Vertical reaction on the Pylon (V)



$T = 40.25$ tons

$C = \sqrt{(2 \cdot Sag)^2 + \left(\frac{Span}{2}\right)^2}$

$C = \sqrt{(2 \cdot 7.5)^2 + \left(\frac{60}{2}\right)^2}$

$C = 33{,}541$

$\cos\alpha = \frac{2 \cdot Sag}{C} = \frac{2 \cdot 7.5}{33.541} = 0.4472$

$Z = T \cdot \frac{\sin\alpha}{\sin\beta}$

$V = T \cdot \cos\alpha + Z \cdot \cos\beta$

When $\beta < \alpha$, the force Z is higher than the force T

In our case $\alpha = \beta$

$Z = T = 40{,}25$ tons

$V = 2 \cdot T \cdot \cos\alpha = 2 \cdot 40{,}25 \cdot 0{,}4472 = 35{,}9996 \cong 36$ tons

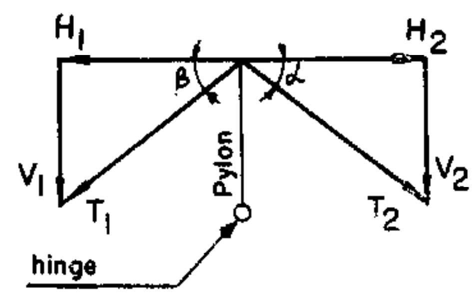
Due to the hinge bearing the horizontal forces H_1 and H_2 must be equal.

$H_1 = H_2$

$\tan\alpha = \frac{V}{H}$

$T_2 = \sqrt{V_2^2 + H_2^2} = \frac{H_2}{\cos\alpha}$

$T_1 = \frac{H_2}{\cos\beta} = \frac{T_2 \cdot \cos\alpha}{\cos\beta}$



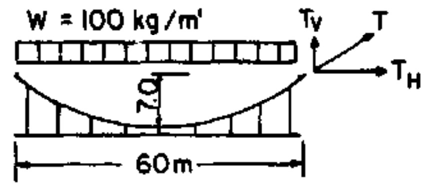
$V_2 = T_2 \cdot \sin\alpha$

$V_1 = T_1 \cdot \sin\beta$

$V_1 = \frac{T_2 \cdot \cos\alpha \cdot \sin\beta}{\cos\beta}$

$V_1 = T_2 \cdot \cos\alpha \cdot \tan\beta$

Wind guy Cable



Sag Wind guy Cable = 6.50m

Centre to centre Wind tie Cable = 3.60m

$$T_H = \frac{W.S^2}{8 \cdot Sag} = \frac{0.1 \cdot 60^2}{8 \cdot 7.0} = 6.429 \text{ tons}$$

$$T_V = \frac{W.S}{2} = \frac{0.1 \cdot 60}{2} = 3.00 \text{ tons}$$

$$T = \sqrt{T_H^2 + T_V^2} = \sqrt{6.429^2 + 3^2} = 6.66 \text{ tons}$$

For Cable Ø 20mm (Breaking load = 21.20 tons),

$$\text{factor of Safety} = \frac{21.20}{6.66} = 3.18 > 3.0$$

For Wind ties Ø 1/4"(Breaking load = 2.3 tons,

load on one Wind tie = 3.60·0.1 = 0.36 tons)

$$\text{factor of Safety} = \frac{2.3}{0.36} = 6.39 \gg 3.0$$

As the Wind ties are carring also the Wind guy Cable they are subjected to greater forces.

$$\tan\alpha = \frac{50}{600} = 0.083 \; ; \quad \alpha = 4.76°$$

$$\sin\alpha = 0.083 \; ; \quad \cos\alpha = 0.997 = 0.997$$

Tension in the inclined Wind ties

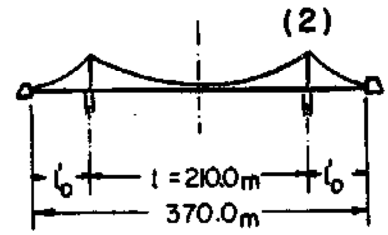
$$T_t = \frac{360}{\cos\alpha} + \frac{10}{\sin\alpha} = \frac{360}{0.997} + \frac{10}{0.083} = 361 + 120 = 481 \text{kg}$$

$$\text{Factor of Safety} = \frac{2300}{481} = 4.78 > 3.0$$

The above Calculation are given just in the simplified form. For the Sags, which are also to be found out, for hoisting and dead load cases, refer to technical literatures. The different Sags for the Suspended and Suspension Bridges according to the HMG's Standard Designs are given in the Pages 2.303 and 2.403.

STRUCTURAL ANALYSIS FOR A THREE SPAN BRIDGE

(a) Basic data



$l_o' = 80m$ $\qquad l_o = 210m$

total length

$l = 2 \cdot 80.0 + 210.0 = 370 \; [m]$

$g = \; = 0.150 \; \left[\frac{t}{m}\right]$

$p = 0.470 \cdot 0.8 = 0.380 \; \left[\frac{t}{m}\right]$ (reduction due to wide span)

$q = g + p = 0.530 \; \left[\frac{t}{m}\right]$

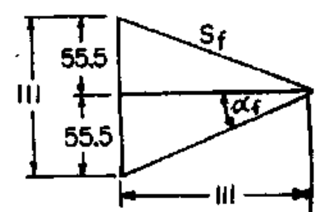
$E = \; = 10.500 \; \left[\frac{kg}{mm^2}\right]$

$a = 481\,mm^2 = 1 \; \varnothing \; 1\frac{1}{2}''$

$F_B = 77t \qquad \eta_{min} = 3$

$w = 5.5 \; \frac{kg}{m}$

(b) Main Cable Force S_f

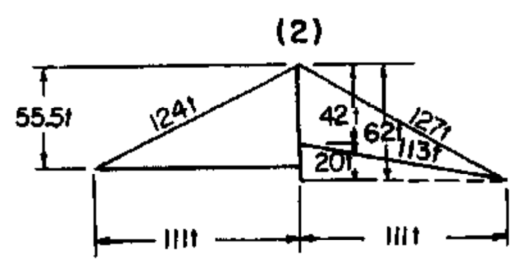


Full load sag for 210m Standard span according to H.M.G. Standard Design: 26.25 m

Total weight of the 210 m span structure: $0.530 \cdot 210 = 111\,t$

Factor of safety for the 210m span: $\frac{6 \cdot 77}{124} = 3.73 > 3.0 = \eta_{required}$

(c) Main Cable Force max. S_f



Side span: 80.0m

Total weight of the side span structure:

$0.530 \cdot 80.0 = 42\,t$

max. $S_f = 127\,t$

Factor of safety for the 80m span:

$\frac{6 \cdot 77.0}{127} = 3.63 > 3.0 = \eta_{required}$

EXAMPLE OF STRUCTURAL CALCULATION FOR SUSPENDED BRIDGE

1. Basic data

Span	= 42m
Hoisting load	= 0.011 t/m'
Dead load	= 0.075t/m'
Full load	= 0.500t/m'
Modulus of elasticity	= 10 500kg/mm^2
Cable cross section A	= 962 mm^2 (2 Cables ø 1¼")
Breaking load B_L	= 2×77 = 154 tons
Factor of safety η_{min}	= 3.0

2. Allowable main Cable force

$$S_f = \frac{N \times B_L}{\eta_{min}} = \frac{2 \times 77}{3} = 51.3 \text{ tons}$$

3. Full load sag

$$\sin \alpha_f = \frac{\text{full load} \times \text{span}}{2 \cdot S_f} = \frac{0.500 \cdot 42}{2 \cdot 51.3} = 0.20467$$

$$\alpha_f = 11.81^\circ \Rightarrow \tan \alpha_f = 0.2091$$

$$h_f = \frac{\text{Span} \times \tan \alpha_f}{4} = \frac{42 \cdot 0.2091}{4} = 2.196\text{m}$$

Say, full load sag h_f = 2.20 m

4. Dead load sag

$$\sigma_f = \frac{S_f}{A} = \frac{51300}{962} = 53.326 \text{ kg/mm}^2$$

$$\sigma_{dead} = \frac{\text{dead load}}{\text{full load}} \cdot \sigma_f = \frac{0.075}{0.500} \cdot 53.326 = 8 \text{ kg/mm}^2$$

Chosen σ_d = 10.8 kg/mm^2

$\text{Sag}_{dead} < \text{Sag}_{full\ load}$

$$\Delta\sigma = \sigma_f - \sigma_d = 53.326 - 10.8 = 42.526 \text{ kg/mm}^2$$

$$\Delta l = \frac{l_0 \cdot \Delta\sigma}{E} = \frac{42.31 \cdot 42.526}{10500} = 0.1793\text{m}$$

$$l_0 \cong S\left[\left\{1 + \left(\frac{\text{Sag}}{\text{Span}}\right)^2 \frac{8}{3}\right\}\right] = 42.307\text{m} \cong 42.31\text{m}$$

$$\Delta \text{Sag} = \frac{3}{16} \cdot \frac{\text{Span}}{\text{Sag}} \cdot \Delta l = \frac{3}{16} \cdot \frac{42}{2.20} \cdot 0.1713 = 0.6132\text{ m}$$

dead load sag = 2.20 − 0.6132 = 1.586 ≅ 1.59

5. Check of chosen σ_d = 10.8 kg/mm²

$$\tan \alpha_d = \frac{4 \cdot 1.59}{42} = 0.1514$$

$$\alpha_d = 8.6108° \Rightarrow \sin\alpha = 0.14972$$

$$S_d = \frac{0.075 \cdot 42}{2 \cdot 0.14972} = 10.5196 \text{ tons}$$

$$\sigma_d = \frac{10520}{962} = 10.90 \text{ kg/mm}^2 \cong 10.8 \text{ kg/mm}^2$$

6. Hoisting sag

$$\sin\alpha_d = 0.14972 = \sin\alpha_{hoisting}$$

$$S_H = \frac{\text{Hoisting load} \cdot \text{Span}}{2 \cdot \sin\alpha} = \frac{0.011 \cdot 42}{2 \cdot 0.14972} = 1.5429$$

$$\sigma_H = \frac{S_H}{A} = \frac{1543}{962} = 1.6 \text{ kg/mm}^2$$

$$\Delta\sigma = 10.8 - 1.6 = 9.2 \text{ kg/mm}^2$$

$$l_d = 42.188 \text{ m}$$

$$\Delta l = \frac{42.188 \cdot 9.2}{10500} = 0.037$$

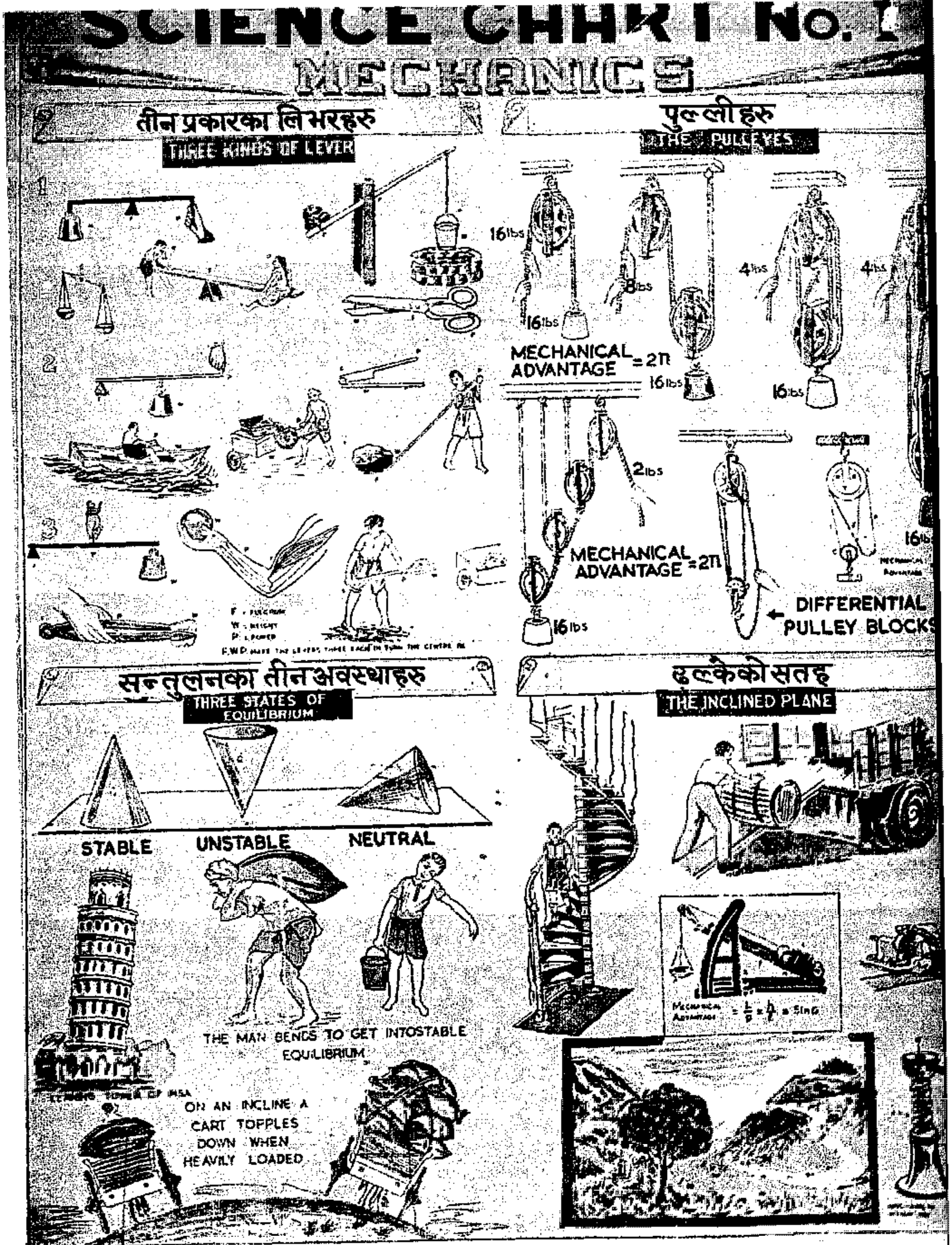
$$\Delta \text{Sag} = \frac{3}{16} \cdot \frac{\text{Span}}{\text{Sag}_d} \cdot \Delta l = \frac{3}{16} \cdot \frac{42}{1.59} \cdot 0.037 = 0.183 \text{ m}$$

$$\text{Sag}_H = \text{Sag}_d - \Delta \text{Sag} = 1.59 - 0.183 = 1.407$$

Say, Sag_H = 1.41 m.

All values depend very much on the modulus of elasticity which may differ by about ± 20%

In the above calculation the cable lengths beyond the saddles are not taken into account.



3. STRUCTURAL ANALYSES

SOILS AND SOIL INVESTIGATIONS

All buildings are founded on ground. It is, therefore, very necessary to study the structure and compisition of the ground before going over the considerations of foundation. Soil mechanics is a branch of Engineering which studies the structure of the soil and its behaviour under loading and changing weather conditions. Material which are found in excavation are classified into two types : one is the soil, and the other, rock. Soils are formed by the disintegration and decomposition of rocks. It is an aggregate of mineral particles in loose condition, which can be easely separated by mechanical means. Rock, on the other hand, is a natural aggregate of minerals which are compounds of chemical elements consolidated under enormous pressure. The here given informations are very briefly. Some more information of how to investigate the soil conditions are given later in one of the chapter written by Leo Condrau, Civil Engineer with SATA.

Rocks are classified under three categories:
- Igenous Rocks
- Sedimentary Rocks
- Metamorphic Rocks

Generally, rocks provide a very good foundation unless they are porous, or have fissures, or hollows etc.

Soils are four types according to the size of the grains or particels as shown below:

Gravel	Coarse	60 mm to 20 mm
	Medium	20 mm to 6 mm
	Fine	6 mm to 2 mm
Sand	Coarse	2 mm to 0·6 mm
	Medium	0·6 mm to 0·2 mm
	Fine	0·2 mm to 0·06 mm
Silt	Coarse	0·06 mm to 0·02 mm
	Medium	0·02 mm to 0·006 mm
	Fine	0·006 mm to 0·002 mm
Clay		0·002 mm
Colloidal clay		all sizes below 0·002 mm
Sizes above 60 mm are :		
Pebbles		60 mm to 200 mm
Boulders		larger than 200 mm

Source : A treatise on building construction by: Deshpande and Vartak, 1968

The foundation for bridges designed by HMG Roads Department (Suspension Bridge Division) are proposed in such a way to be easy and needing a simple execution work. However, it is important to check the foundation's condition at site proper, and, if necessary redesign the foundations.

Characteristics of Soils :

Gravel : Can be easily identified by the large size of its grains. It is not affected by frost, nor does it swell with addition of moisture nor shrinks with withdrawal of moisture. It has got no cohesion, but possesses good internal friction. Gravel has a high bearing capacity and thus forms a good foundation material.

Sand : like gravel, is coarse-grained. It is also not affected by frost. It lacks cohesion, but possesses high internal friction. Up to a certain percentage of moisture it swells or bulks. Sand forms a very good foundation material when it is pure and prevented from spreading under load. Generally sand found in building foundations is never pure but always mixed with clay and silt. Sand is very permable. Quicksand is not a soil type, but condition, which is caused by water occupying the pores in sand layer and thus reducing its power of resistance to loading.

Silt : Silts and clays, when dry, are identical in appearance but can be easily identified by their behaviour with water. Silt is not affected by moisture as far as plasticity is concerned, clay becomes sticky and plastic. Particles of silt cannot be seen wth naked eye. It has no cohesion nor internal friction and is difficult to compact. Silt, when dry in form of a clod, can easily be pulverized between fingers. It sticks to fingers but can be readily dusted off.

Clay : is the finest type of soil. It is highly plastic and, thus, has a very low resistance to deformation. It possesses good cohesion, but no internal friction. It is compressible when just moist, but incompressible when wet. It is virtually impervious and difficult to drain by ordinary means. Dry clods of clay can be offering considerable high resistance to crushing.

BEARING CAPACITY OF SOILS

Exepting hard murum and rock, all soils are liable to sink. Every soil has got its own certain bearing capacity which denoted as so many tonnes per sq. metre (t/m2). If the load put upon it exeeds this limit, the soil yields by failure of shear indicated by its sinking. The maximum intensity of load that just causes sinking is called the ultimate bearing capacity of the soil. This capacity divided by a factor of safety of 2 or 3 gives the safe bearing capacity of that particular soil. The table below gives the safe bearing capacities of some soils as a rough guide. In the case of important buildings actual tests should be taken.

SAFE BEARING CAPACITIES OF DIFFERENT SOILS

	Description of Soil	Safe Bearing Capacity in Tonnes/m²	
1.	Soft, wet, pasty or muddy clay, and marshy clay	2	to 3·5
2.	Alluvial deposits of moderate depths in river-beds	2	to 3·75
3.	Diluvial clay in beds of rivers	3·75	to 11.00
4.	Black cotton soil	5	to 10
5.	Alluvial earth, loams, sandy loams (clay and 40 to 70 per cent of sand) and clay loams (clay and about 30 per cent of sand)	7·5	to 16
6.	Moist clay	11	to 18
7.	Compact clay, nearly dry	22	to 27
8.	Solid clay mixed with very fine sand	44	
9.	Dry, compact clay of considerable thickness	33	to 55
10.	Loose sand in shifting river-beds, the safe load increasing with depth	16	to 27
11.	Silted sand of uniform and firm character in a river-bed secure from scour and at depths below 8 m	38	to 44
12.	Compact sand	22	to 33
13.	Compact sand, prevented from spreading	55	to 82
14.	Sandy gravel, or " kunkur "	22	to 33
15.	Do. but compact, dry and prevented from spreading	44	to 65
16.	Very firm, compact sand at a depth not less than 6·5 m and compact sandy gravel	65	to 75
17.	Firm shale, protected from weather and clean gravel	65	to 85
18.	Red earth	33	
19.	" Muram "	44	
20.	Compact gravel	75	to 95
21.	Soft rock	45	
22.	Residual deposits of shattered and broken bed rock and hard shale, cemented material	90	
23.	Laminated rocks (e. g. sandstone and limestone) in sound condition	165	
24.	Rocks—hard without lamination and defects e. g. granite, trap and diorite	330	

Noteworth : e.g. 22 tonnes/m2 is equal to 2,2 kg/cm2

Source : A treatise on building construction by : Deshpande and Vartak, 1968

EXCAVATION FOR FOUNDATIONS

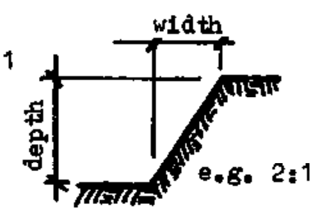
The trenches for foundation of walls or piers should be excavated to exact width, length and depth, as shown on the drawings etc. The widths shown on the drawings are those at the bottom. If the soil is firm and the depth is not exessive, the sides of the excavation may remain vertical. This may be happen wthout support for a few days till concreting is done and masonary is raised to the ground level. But when the excavation is deep or the sides are not of firm soil, the sides must either be suitably sloped, or if left vertical, they must be supported by some arrangement of boarding, called timbering or shoring. The latter is necessary when the excavation adjoins a property line. Usually, when depth of excavation exceeds 2 m, shoring the sides is more economical. At the bridge sites in hill areas shoring might be the costlier way, because timber is expensive and the labour costs are low. The resident engineeres should work out a proper comparison to choise the system which is cheaper. But also that depends upon the quality of the material to be excavated as well as on the slope of the escarpment where the foundation etc. have to be placed. If it is running sand, marsh, or morass, shoring will have to be resorted to almost from the surface of the ground. At the usuall bridge sites there are soil conditions which are quite stabil, but, however, the resident engineer has to take care to the execution of the excavation work.
When the soil is of a clayey nature, which though firm, is likely to develop vertical cracks in the sides by exposure to the sun and wind, and slip, simple poling boards of size 20 cm x 4 cm are placed vertically in pairs, one on each side of the trench, and strutted apart by stout pieces of bullies about 10 cm in diameter called struts. But when the soil is looser, the poling boards must be placed closer together perpendicularly with walings 25 cm x 8 cm held horizontally against them on the inner side and strutted as before at intervals of about one meter.
On bridge sites with theyr foundations we are dealing with excavation work done without timbering or shoring. For some foundation types a trench foundation is to be done because the passive resistance has been taken into account. This kind of foundation is very economical, but, the surface of the soil around the foundations must be protected against erosion etc. The resident engineers should take the general arrangement and detail drawings into consideration by execution of the work.

INCLINATION OF SLOPE :

in a good stabil material depth : width = 3 : 1 or 4 : 1

in a medium stabil material .... = 2 : 1

in a rolling material .... = 1 : 1



TRENCH TIMBERING (Earth pressure per kg/m2, assuming horizontal ground level)

The chart can only be used for the calculation of the trench timbering. The earth pressure of retaining walls are different to such pressures acting on timbering.

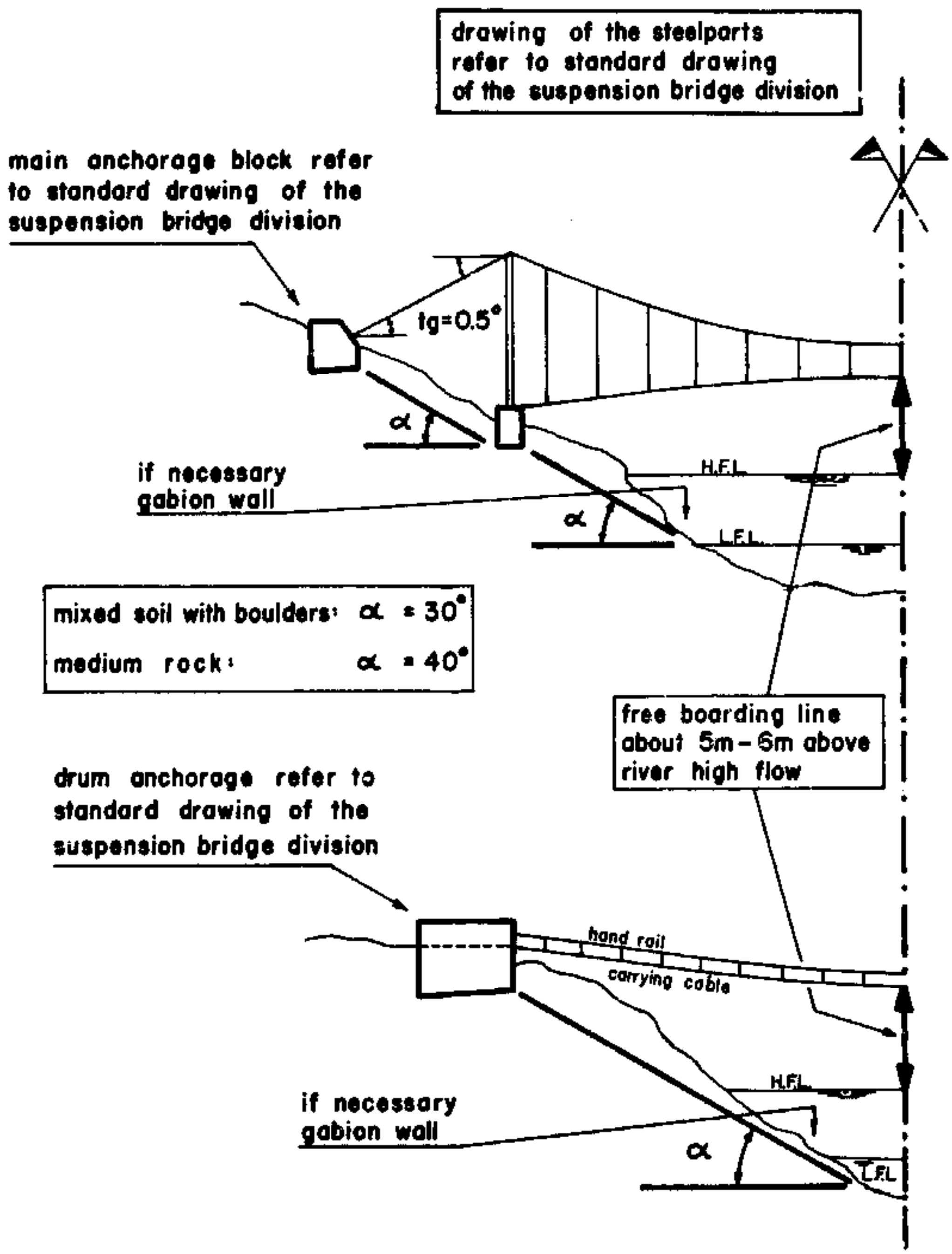
	Type of soil		
	Stabil moraine soil moisture	Sand, gravel soil moisture	Sandy loams wet
Weight per cubicmetre of the soil (t/m^3)	2·2 t/m^3	2·0 t/m^3	2·0 t/m^3
Angle of repose (of the natural slope)	42·5°	32·6°	25·0°
Coefficient of earth pressure	0·192	0·301	0·406
Excavation depth	Max. earth pressure per sq metre (kg/m^2)		
2·0	500	720	980
2·5	625	900	1225
3·0	750	1080	1470
3·5	875	1260	1715
4·0	1000	1440	1960

Sources : A treatise on building construction by : Deshpande and Vartak, 1968
Taschenbuch fuer Baufuehrer und Poliere: Buechel, Eng. ETH/SIA, 1965

PLACING OF FOUNDATION

Before construction of foundations on sloping ground, the stability of the slope itself must be investigated, footings should not be constructed on slopes which are unstable. The stability of a stable slope may be endangered by the addition of footings. Slopes failures which might arise should be proved with the well known different methods. To get more deeply into the matter of technologies the reference to the special books schould be made-e.g. Wayne C. Teng: Foundation Design, 1974
H. Gaylord & N. Gaylord: Structural Engineering Handbook, New York, 1968

Placing of the fundation



$\phi_u=0$ analysis

Fig. 23·5 shows a slope AB, the stability of which is to be determined. The method consists in assuming a number of trial slip circles, and finding the factor of safety of each. The circle corresponding to the minimum factor of safety is the *critical slip* circle. Let AD be a trial slip circle, with r as the radius and O as the centre of rotation. Let W be the weight of the soil of the wedge $ABDA$ of unit thickness, acting through its centroid. The driving moment M_D will be equal to $W\bar{x}$, where $\bar{x}$ is the distance of line of action of W from the vertical line passing through the centre of rotation. If c_u is the unit cohesion, and $\widehat{L}$=length of the slip arc $AD=\frac{2\pi r\delta}{360}$, the shear resistance developed along the slip surface will be equal to $c_u\widehat{L}$, which acts at a radial distance r from the centre of rotation O. Hence the resisting moment M_R will be equal to $r.c_u\widehat{L}$.

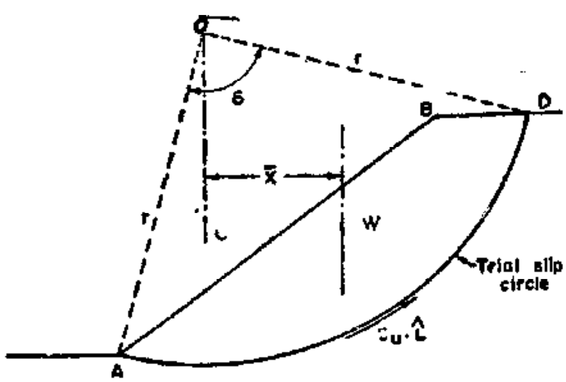


FIG. 23·5
$\phi_u=0$ analysis

The factor of safety F is then given by

$$F=\frac{M_R}{M_D}=\frac{c_u\,\widehat{L}r}{W\bar{x}}$$

Alternatively, Let c_m=mobilised shear resistance of soil ($\phi=0$), necessary for equilibrium

Then $$W\bar{x}=c_m\widehat{L}r$$

or $$c_m=\frac{W\bar{x}}{\widehat{L}r}$$

Hence $$F=\frac{c_u}{c_m}=\frac{c_u\,\widehat{L}.r}{W\bar{x}}$$

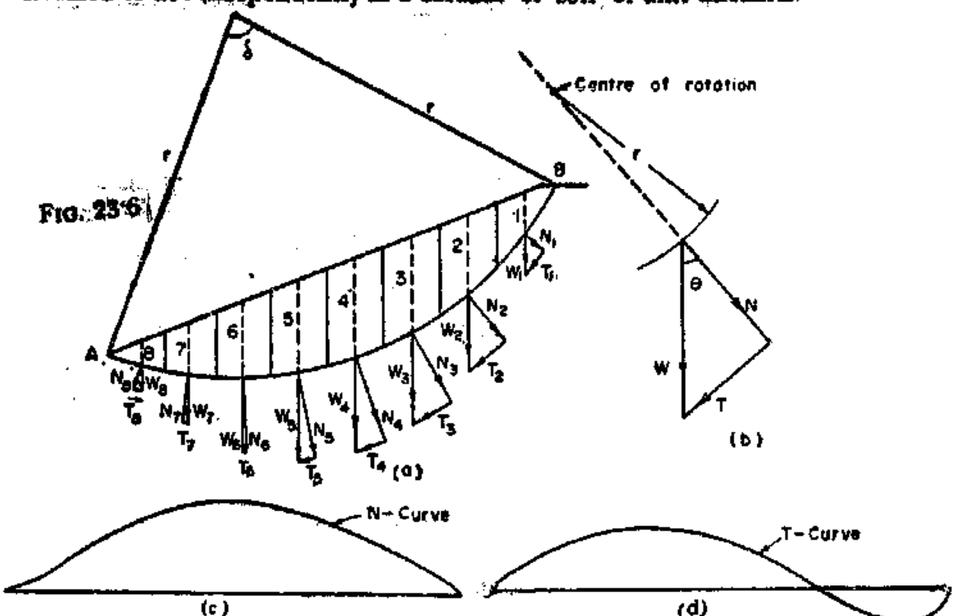
The distance $\bar{x}$ of the centroid of the wedge, from centre of rotation O, can be determined by dividing the wedge into a number of vertical slices and dividing the algebraic sum of moment of weight of each slice by the weight of the wedge.

Source: Soil mechanics and foundation by B.C. Punmia, 1973

c–φ analysis

In order to test the stability of the slope of a $c-\phi$ soil, trial slip circle is drawn, and the material above the assumed slip surface is divided into a convenient number of vertical strips or slices. The forces between the slices are neglected, and each slice is assumed to act independently as a column of soil of unit thickness

FIG. 23·6



and of width b. The weight W of each slice is assumed to act at its centre. If this weight of each slice is resolved into normal (N) and tangential (T) components, the normal components will pass through the centre of rotation (O), and hence do not cause any driving moment on the slice. However, the tangential component T causes a driving moment $M_D = T \times r$, where r is the radius of the slip circle. The tangential components of the few slices at the base may cause resisting moment ; in that case T is considered negative.

If c is the unit cohesion and ΔL is the curved length of each slice, then the resisting force, from Coulomb's equation is equal to $(c\Delta L + N \tan\phi)$.

For the entire slip surface AB, we have

Driving moment $M_D = r\Sigma T$

Resisting moment $M_R = r[c\Sigma\Delta L + \tan\phi\Sigma N]$

where ΣT = algebraic sum of all tangential components

ΣN = sum of all normal components

$$\Sigma\Delta L = \widehat{L} = \frac{2\pi r\delta}{360°} = \text{length } AB \text{ of slip circle.}$$

Hence factor of safety against sliding is

$$F = \frac{M_R}{M_D} = \frac{c\widehat{L} + \tan\phi\,\Sigma N}{\Sigma T}$$

A number of trial slip circles are chosen and factor of each is computed. The circle giving the minimum factor of safety is the *critical* slip circle.

In order to find ΣN and ΣT, N-curves and T-curves are drawn (Fig. 23·6 *c, d*) by making the ordinates of these diagrams equal to N and T values for different strips and joining them by smooth curves. The area of these diagrams can be measured with the help of planimeter and ΣN and ΣT can then be computed.

Source: Soil mechanics and foundations by B.C. Punmia, 1973

Backfill of a retaining wall is the portion of the soil retained by the wall which has been artificially placed behind the wall after the wall (or any foundation) is completed and matured. The backfill material should be carefully selected. In add., it should be compacted to prevent large ground subsidence due to consolidation under its own weight. The material should be placed in thin layers not thicker than 25 to 35 cm each. Each layer should be compacted before the next one is placed. It should not be allowed to dump the material in sloping layers toward the wall, thus forming segregated layers of potential sliding surfaces.
It is always a good practice to place an impervious soil in the upper layer of the backfill for the purpose of cutting down the amount of infiltration from the rain water, thus decreasing the influence of the erosion too. Where the passive earth resistance (e.g. deadman, main anchor blocks) has been taken into account, a trench foundation -i.e. excavation with vertival slopes- should be build or the backfill material must be placed carefully and the layers must be compacted very well.

Drainage and backfilling

The backfill must be done in all types of subground buildings. The backfill protects the surface ground against erosion, sliding etc.

(a)

Pervious backfill

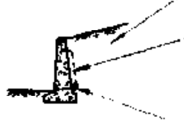
Weep holes 15 cm diameter or larger at 1.5 to 3 m horizontal spacing

(b)

Pervious backfill

Filter material

open-joint clay pipe or perforated metal pipe should be provided with rod-out system

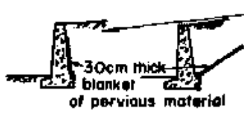


(c)

Semipervious backfill

Vertical strips of filter material about 0.09 m^2 at midway between weep holes; used in conjunction with continuous horizontal strip of filter material

Filter material in pockets at weep holes, or in continuous strip



(d)

Fine-grained backfill

Longitudinal drain pipes (as shown) or weep holes can be used as desired

(e)

Expansive clay backfill

Common types of retaining wall drainage:

a) weep holes; b) longitudinal drain pipe;
c) weep holes with filter strips; d) blanket drain;
e) double blanket drain.

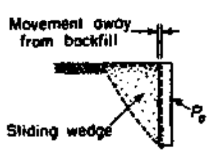
Boulder and rubble backing used as filter material

RETAINING WALLS AND FOUNDATION STRUCTURES FOR SUSPENDED AND SUSPENSION BRIDGES

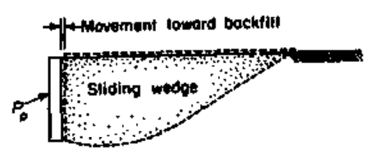
A retaining wall is a wall constructed for the purpose of supporting a vertical or nearly vertical earth bank which, in turn, may support vertical loads. It may also be used to retain water or other materials such as coal, ore, etc. It differs from other types of retaining structures because it does not require external bracing for stability. For this reason, retaining walls have been widely used in a variety of purposes. When a retaining wall is used to support the end of a bridge as well as retaining the earth backfill, it is called an abutment. In the cases of suspended and suspended bridges we are dealing with a combination of foundation blocks & retaining walls. At the bridges there are normally not true retaining walls, be - cause on the same structures often tensile forces are to be anchored.
The calculation and design work, however, is shown on the following examples. Discussing the various theories in detail is outside the scope of this volume, and it is proposed to give here only the results obtained by important theories and summarize the assumpticn made in each.

EARTH PRESSURE

Substructures and foundations, such as retaining walls and basement, are subjected to lateral pressure where the ground level on one side differs from the ground level on the other side.
If the retaining structure is permitted to move away from the soil allowing a lateral expansion of the soil, the earth pressure decreases with the increasing expansion. Further expansion will cause a shear failure of the soil which a sliding wedge tends to move forward and downwards. At this state of failure the earth pressure is at the minimum value; additional deformation does not reduce the earth pressure any further. This minimum pressure is known as <u>a c t i v e</u> earth pressure.
On the other hand if the retaining structure is forced to move towards the soil causing a lateral construction of the soil, the force required to start the movement is greater than the earth pressure against a rigid and unyielding wall. A larger force is required to move a greater distance until a state of failure is reached where sliding is formed. This wedge of soil moves upwards with respect to its original position. At this state of failure the earth pressure is at a maximum value known as <u>p a s s i v e</u> earth pressure ore passive resistance.



a c t i v e earth pressure



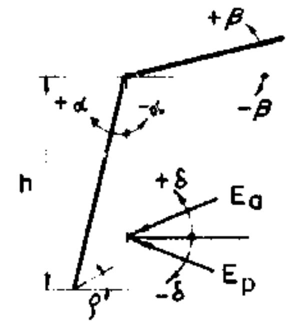
p a s s i v e earth pressure

Angle of repose (internal angle), weights and coefficients of friction of different soils

Description	Angle of repose	Coefficient of friction	Weight in kg/m³
Very wet earth, wet clay.	15°	0·24	1440
Wet sand, gravel with sand.	25°	0·41	1600
Dry earth, dry clay, dry sand.	30°	0·52	1700
Clean sand, loose.	30°	0·50	1800
Clean sand, medium.	34°	0·50	1800
Clean sand, dense.	38°	0·55	1950
Rock	—	0·60—0·70	2000—2200

Active earth pressure on a retaining wall

E_a = active earth pressure
E_p = passive earth pressure
K_a = coefficient of active earth pressure
K_p = coefficient of passive earth pressure
γ = unit weight of soil (t/m^3)
β = angle of ground surface
α = angle of the back of the wall
δ = angle of the wall friction
ϱ = angle of internal friction



h = height of the wall

$$K_a = \frac{\cos^2(\varrho+\alpha)}{\cos^2\alpha\cdot\cos(\alpha-\delta)\left[1+\sqrt{\frac{\sin(\varrho+\delta)\cdot\sin(\varrho-\beta)}{\cos(\alpha-\delta)\cdot\cos(\alpha+\beta)}}\right]^2}$$

$$K_p = \frac{\cos^2(\varrho-\alpha)}{\cos^2\alpha\cdot\cos(\alpha-\delta)\left[1-\sqrt{\frac{\sin(\varrho-\delta)\cdot\sin(\varrho+\beta)}{\cos(\alpha-\delta)\cdot\cos(\alpha+\beta)}}\right]^2}$$

$E_a = \frac{1}{2}\cdot\gamma\cdot h^2\cdot K_a\ [t/m]$ $\qquad$ $E_p = \frac{1}{2}\cdot\gamma\cdot h^2\cdot k_p\ [t/m]$

$e_a = \gamma\cdot h\cdot K_a\ [t/m^2]$ $\qquad$ $e_p = \gamma\cdot h\cdot K_p\ [t/m^2]$

Horizontal earth pressure:

$E_{ah} = E_a\ \cos(\alpha-\delta)$ $\qquad$ $E_{ap} = E_p\ \cos(\alpha-\delta)$

$E_{ah} = \frac{1}{2}\cdot\gamma\cdot h^2\cdot K_{ah}\ t/m$

EARTH PRESSURE COEFFICIENT

(The angle of wall friction is assumed to be 20°)

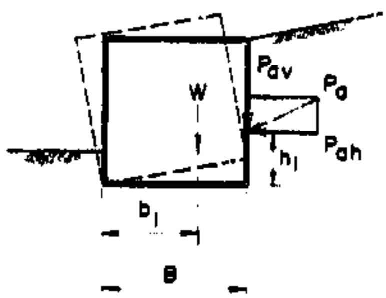
angle of internal friction ρ				20°		25°		27°		30°		33°	
angle of ground surface β				8°	15°	10°	20°	12°	25°	14°	28°	15°	30°
angle of the back of the wall α	back batten (width in depth)	Earth pressure coefficients K_a											
0°	Vertical		K_a	0.494	0.603	0.419	0.547	0.400	0.614	0.364	0.574	0.323	0.497
0°	Vertical		K_{ah}	0.463	0.565	0.412	0.538	0.395	0.606	0.362	0.571	0.323	0.497
+9.46°	1:6		K_a	0.418	0.507	0.341	0.442	0.319	0.487	0.283	0.444	0.245	0.373
+9.46°	1:6		K_{ah}	0.392	0.475	0.335	0.434	0.315	0.481	0.281	0.442	0.245	0.373
+11.31°	1:5		K_a	0.404	0.490	0.327	0.423	0.305	0.466	0.269	0.421	0.231	0.352
+11.31°	1:5		K_{ah}	0.379	0.459	0.321	0.416	0.301	0.460	0.267	0.419	0.231	0.352
+14.03°	1:4		K_a	0.385	0.467	0.307	0.398	0.285	0.435	0.249	0.390	0.211	0.322
+14.03°	1:4		K_{ah}	0.361	0.437	0.302	0.392	0.281	0.430	0.248	0.388	0.211	0.322
+18.43°	1:3		K_a	0.355	0.430	0.276	0.357	0.254	0.388	0.217	0.342	0.181	0.276
+18.43°	1:3		K_{ah}	0.333	0.403	0.271	0.351	0.251	0.383	0.216	0.340	0.181	0.276

Structure stability of anchor blocks, walls etc.

Stability against overturning

Factor of safety against overturning = 1.5 (for granular backfill)
= 2.0 (for cohesive backfill)

$$F.S. = \frac{\text{Sum of stabilizing moment}}{\text{Sum of overturning moment}} = 1.5 \text{ to } 2.0 \text{ (minimum)}$$



$$F.S = \frac{\text{stabilizing moment}}{\text{overturning moment}}$$

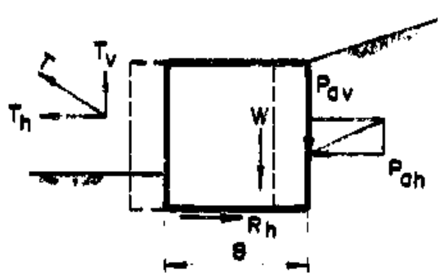
$$= \frac{Wb_1}{P_{ah}h_1 - P_{av}B} = \text{at least } 1.5\ (2.0)$$

where W = weight of wall + (weight of soil above the base uplift due to Tension)

= horizontal and vertical components of lateral pressure P_a respectively (and Tensile forces)

Stability against sliding

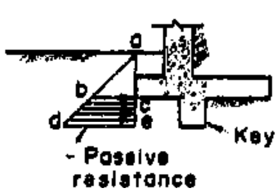
Factor of safety against sliding = 1.50 (normal cases)
= 2.00 (anchor walls etc)



$$F.S. = \frac{\text{Horizontal resistance}}{\text{Horizontal force}}$$

$$= \frac{R_h}{P_{ah} + T_h} \text{ at least } 1.5\ (2.0)$$

where R_h = (Total weight − uplift forces) x μ
μ = coefficient of friction

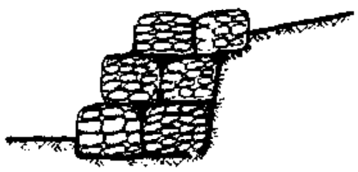


Stability against bearing capacity and soil failure

Refer to literature about soil mechanics

Types of walls.

Gabion walls.



A barrier made of wire mesh, forming cells which are filled with stones or rubble. No tensile stress in any portion of the building unit. The design is similar to gravity walls.

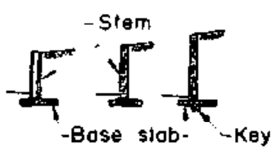
Gravity walls.

Plain concrete or rubble (also drystone and breast walls), no tensile stress in any portion of wall.
Rugged construction is conservative but not in all cases economical for higher walls.

Semigravity walls.

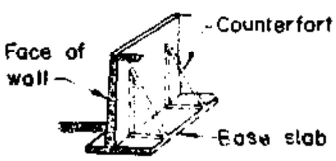
A small amount of reinforcing steel is used for reducing the mass of concrete.

Cantilever walls.



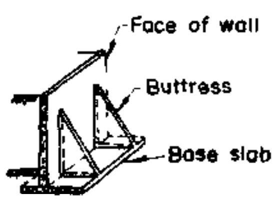
In the form of an inverted T, each projecting portion acts as a cantilever. Generally made of reinforced concrete. For small walls, reinforced concrete blocks may be used.
This type is economical for walls of small to moderate height. (about 6 – 8 m.)

Counterfort walls.



Both base slab and face of wall span horizontally between vertical brackets known as counterforts. This type is suitable for high retaining walls, greater than about 6 m.

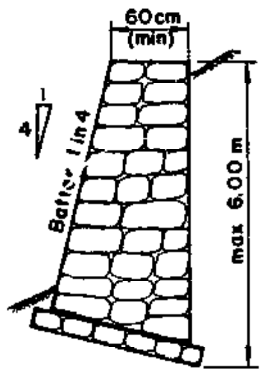
Buttressed walls.



Similar to counterfort wall except that the backfill is on the opposite side of vertical brackets (known as buttresses).
Not commonly used because of the exposed buttresses.

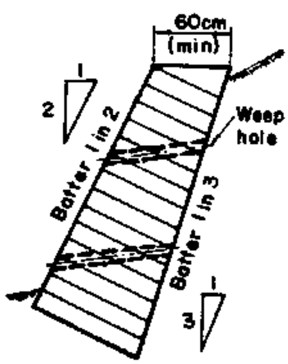
DRYSTONE RETAINING WALLS

Utmost care is required in the selection of stones of the proper shape and size and in the bonding of the whole work, as the stability of these walls entirely depends on these two factors, there being no mortar to cover the defects of workmanship and those aris - ing from an improper coise of materials. For these reasons, it is the best plan to collect at site all the required ma- terials, and to put the earth filling at the back after few meters of the wall are constructed and approved. The correct section of the wall depends on the quality of workmanship, the typ of material to be supported, and the height. How - ever, roughly speaking, the top width of the retaining wall should be kept at a minimum of 60 cm and the face batter 1 in 4, or 1 in 3, the latter being used for walls higher than 3 m. As a rule, no drystone retaining wall should be con - structed of a height greater than 6 m. In case, where the height of the embankment is greater than this, the top 6 m may be made up of drystone masonary, but the portion below this must be constructed in lime or cement mortar. The beds of the courses must be laid perpendicular to the face batter, and all other pre- cautions as to the proper bonding of the work detailed under rubble masonary must be taken. Weep-holes must be provided to protect the drystone masonary wall against more pressure resulting from the water behind the wall.



BREAST WALLS

The main function of a breast wall is to protect the slopes of cutting in natural ground from the action of water and weather, and incidentally they have to support some pressure of earth behind. The section of a breast wall is very much dependent on the soil to be protected and the slope of the cutting. In some cases, the section adopted has a top width of 60 cm and a face batter of 1 in 2 and back batter of 1 in 3. Most soils can stand a steep slope im- mediately after they are cut, but a little exposure to weather makes the soil crumble and fall. It is, therefore, necessary that breast walls be constructed as soon after cutting is made as is possible. Water should not be allowed to get access to the back of the wall, and any interstices which exist should be filled either with puddle or small gravel. As in the case of retaining walls, the beds of the courses must be laid pro- per perpendicular to the face batter and the work must be correct bonded. Also on the breast wall the weep-holes must be often provided and it is importent that theyr slope is going downwards. It is this possiple to protect the breast wall against water. The top of a breast wall should be compacted by using a little quantity of cement.



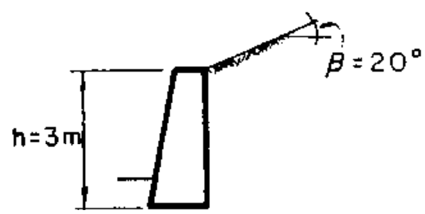
PITCHING

Pitching is a stone lining to protect earth surface from the scouring action of water, therefore, the resident engineer should take care to the coming rainy season. When the slope of the cutting is fairly flat, it is sufficient to line the face with a uniform thickness of drystone work. The thickness varies according to the requirements, the minimum being 30 cm and the maximum about 50 cm. Drystone pitching is often pointed with lime or cement mortar. In constructing pitching, stones should be properly fitted in so as to leave no large gaps between adjacent stones. Pitching is many times used on slopes of channels and dams,

Source : A treatise on building construction by : Deshpande and Vartak, 1968

Calculation Examples for retaining walls.

Example 1. Calculate the maximum thrust intensity and total pressure on a retaining wall of 3m. height with the following assumptions:



angle of repose	= 25°
angle of wall friction	= 20°
angle of the back of the wall	= 0°
weight of the soil	= 1600 kg/m³

Total pressure per m length.

$$E_a = \frac{1}{2}\gamma \cdot h^2 \cdot k_a = \frac{1}{2} \cdot 1.6 \cdot 3^2 \cdot 0.547 = 3.938\ t/m.$$

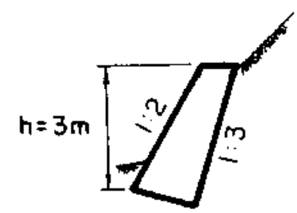
$$E_{ah} = \frac{1}{2}\gamma \cdot h^2 \cdot k_{ah} = \frac{1}{2} \cdot 1.6 \cdot 3^2 \cdot 0.538 = 3.874\ t/m.$$

acting at $\frac{h}{3} = \frac{3}{3} = 1.00$ m. from bottom.

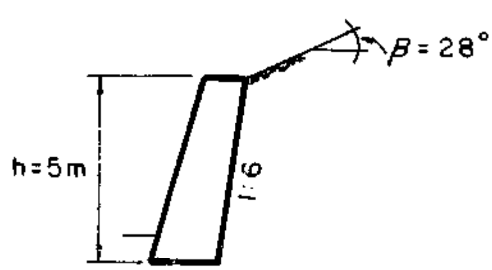
Example 2. Calculate the maximum thrust intensity and total pressure on a breast wall instead of above retaining wall.

$$E_a = \frac{1}{2}\gamma \cdot h^2 \cdot k_a = \frac{1}{2} \cdot 1.6 \cdot 3^2 \cdot 0.342 = 2.462\ t/m.$$

$$E_{ah} = \frac{1}{2}\gamma \cdot h^2 \cdot k_{ah} = \frac{1}{2} \cdot 1.6 \cdot 3^2 \cdot 0.340 = 2.448\ t/m.$$



Example 3. Calculate the maximum thrust intensity and total pressure on a retaining wall of 5m. height with the following assumptions:



angle of repose	= 30°
angle of wall friction	= 20°
angle of the back of the wall	= 9.46°
weight of the soil	= 2000 kg/m³

Total pressure per m length.

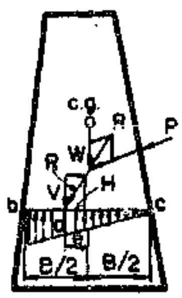
$$E_a = \frac{1}{2}\gamma \cdot h^2 \cdot k_a = \frac{1}{2} \cdot 2.0 \cdot 5^2 \cdot 0.444 = 11.1\ t/m.$$

$$E_{ah} = \frac{1}{2}\gamma \cdot h^2 \cdot k_{ah} = \frac{1}{2} \cdot 2.0 \cdot 5^2 \cdot 0.442 = 11.05\ t/m.$$

acting at $\frac{h}{3} = \frac{5}{3} = 1.67$ m. from bottom.

Design of gravity wall.

A. Gravity walls. Gravity walls are made of plain masonry, rubble stone, bricks or concrete. The wall should be proportioned such that there is no tensile stress at any point of the wall under any condition of loading.



P = total lateral pressure acting on back of wall above pt. c
W = weight of wall above section bc
R = resultant of W and P

Proportion of wall must satisfy the following:

(1) Maximum vertical pressure at point b:

$$p = \frac{V}{B}\left(1 + 6\frac{e}{B}\right) \leq \text{allowable compression}$$

(2) Minimum vertical pressure at point c:

$$p = \frac{V}{B}\left(1 - 6\frac{e}{B}\right) \geq 0$$

(3) Horizontal shear along plane bc:

$$v = \frac{H}{B} \quad \text{allowable shear}$$

Stresses in gravity wall.

A gravity wall may be analysed by the principle of simple statics. Any horizontal section of the wall is subjected to two forces: a lateral force due to earth pressure and surcharge, and a vertical force equal to the weight of the wall above. The magnitude, direction and point of application of the resultant *R* of these two forces can be readily determined, Fig. above. Let the resultant force intercept the horizontal section at the point a, and let e be the distance from point a to the middle of the horizontal section, then this section is subjected to a vertical pressure q and a horizontal shear v

$$\text{(Pressure)} \qquad q = \frac{V}{B}\left(1 \pm 6\frac{e}{B}\right)$$

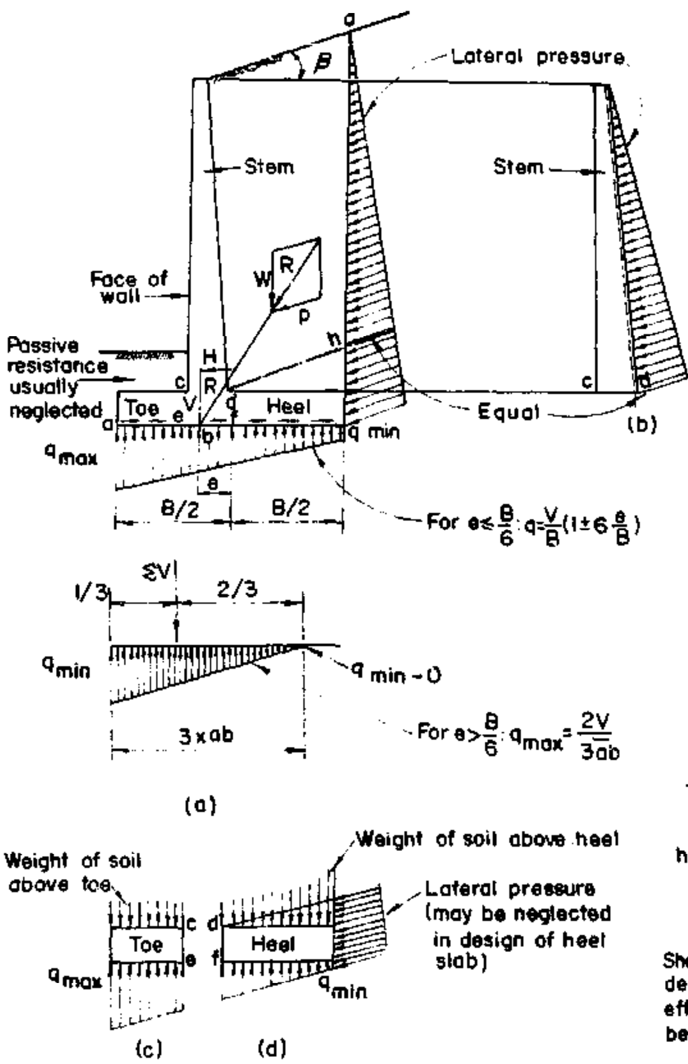
$$\text{(Shear)} \qquad v = \frac{H}{B}$$

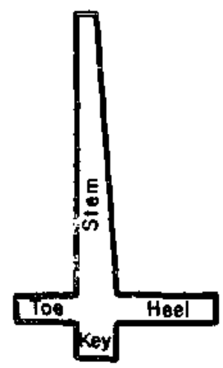
Where V, H = vertical and horizontal component of the resultant force R,

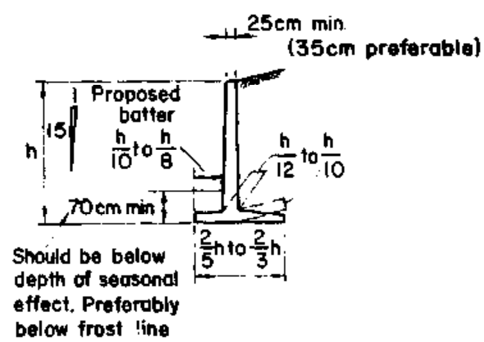
B = width of the horizontal section under investigation.

Semigravity wall & Cantilever wall.

These type of walls consist of three structural elements; the stem, the toe, and the heel, each acting as individual cantilevers. Sometimes there is provided a key which may help to get a greater factor of safety against sliding by using the passive earth pressure. The width of the base of a cantilever wall is usually 0.4 to 0.65 times the height of the wall.







Forces acting on cantilever and counterfort walls

Common propertions of cantilever retaining walls

INTRODUCTION

For the block calculation the following loads, or the most unfavourable combination of loads, have to be taken into account :

a) maximum cable or wire force
b) dead weight of the block
c) load of refilled earth
d) active earth pressure
e) passive earth resistance (pressure)
f) friction force

In order to achieve the most suitable and economical anchorage solution the following conditions must be guaranteed :

- thorough soil investigations at the actual site, perhaps also shearing and bearing tests, revising of the plans according to the last determined results, possible application of a more appropriate solution.
- careful investigations of possible soil failures specially in cases of steep slopes with danger of sliding.
- qualified personnel for a careful supervision and execution.

Anchorage Type No. 1 (Gravity Blocks)

To improve the economy of the massive anchor block the use of block fills is recommended and shown in the standardized drawing of HMG Standard Design. It should be mentioned here, that at each bridge site under construction the solution of the so called "cell-type" foundation is proposed.

Anchorage Type No. 2 (Gravity/Earth Block)

In case the shape of the embankment is suitable and the fixation point of the main cable or wires is required to be above ground level these anchorage types are more economical than the types No. 1. The following forces are acting on this typ :

- cable wire force
- active earth pressure
- passive earth pressure
- block dead weight
- weight of refill earth
- friction force

Four cases of possible soil failures and eart slides have to be considered :

- horizontal sliding. The calculation results in a minimum bank width in front.
- Sliding upward on a plane.
- Sliding upward on an arc.
- (Classical) passive sliding triangle loading to the (minimum) earth resistance.

In cases of endangered slopes their safety against earth failure has to be analysed carefully (e.g. Swedish circle method).

Anchorage Type No. 3 (Gravity/Rock block)

In the calculation of these two block types, namely Type 3a and 3b, the actual rock resistance is only regarded as an addition to safety, since only medium rock quality is assumed. If the technical report of the survey team includes the results of a guite well medium rock, however, the rock anchor rods may be taken into account (either acting by shearing or real anchorage bars), but, the safety factor without taking the rods into account should be at least about 0.9 to 1.0. Many variations of the block design are possible according to the embankment situation.
The calculation of the block of Typ No. 3c takes the rock resistance into account. This leads to a reduced concrete volume. The assumed value of the permissible pressure in front of the block spur should not be greater than 8 kg/cm2. For calculating the Type No. 3d a good rock is required. The excavation work must be made proper according to the detail drawings and the front face should be as vertical as possible. The rock surface has to be sufficiently rough and to be provided with the required number of steel anchor bars. The usual steel concrete analysis has to be applied.

Anchorage Type No. 4 (Rock anchor)

In every case of good or medium rock, found at an anchorage site, the applicability of rock anchors should be investigated. A considerable cost reduction can be made possible by these anchor types. The types of tunnel anchorage needs excellent rock conditions. The rock excavations should be limited to relatively small volumes of 20 to 30 m3. If a large tunnel should be excavated the required volume of a foundation (Types 1,2, or 3) might be the cheaper way of anchor a tensile force. These kind of foundations needs a skill labour too and a very good supervision and controll.

STRUCTURAL ANALYSIS

Gravity blocks typ no. 1

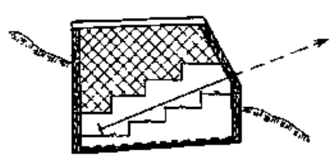
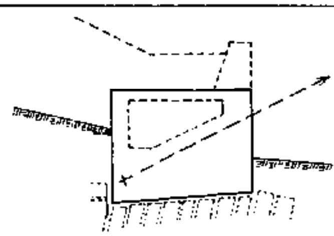
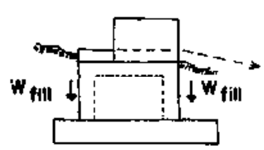
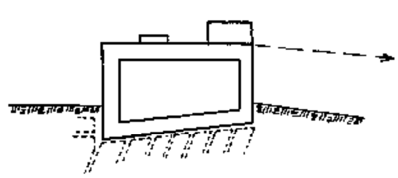
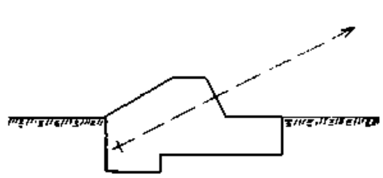
No. : 3.602

Date : 10th Jan. 77

Sig :

GRAVITY BLOCKS

Type No. I: Utilising normal friction only (partly weight of backfilling) (without passive earth pressure)

TYPE NO	Shape of anchorage blocks	coefficient of friction	General description, presupposed soil conditions, comparison calculation methods, permissible soil pressure	used at bridge type
Ia		0.45 (Soil) 0.70 (Rock)	HMG standard design. The shape applied may vary. Due to infill of sand, gravel and rubble concrete can be saved. R.R. Masonary 1:6 Plumb concrete 1:3:6 + 40% Boulder (rubble)	Suspension
Ib		0.45 (Soil) 0.70 (Rock)	HMG standard design and modified standard design. This type is used on soil and on rock. The shape applied may vary. R.R. Masonary 1:6 Plumb concrete 1:3:6 + 40% rubble	Suspension
Ic		0.45 (Soil) 0.70 (Rock)	Used on soil and on rock. Concrete savings due to infill of sand, gravel and boulders. Economical type of Foundation. Certain slope shape and earth protection in front of the anchorage required. R.R. Masonary 1:6 and mainly Plumb concrete 1:3:6 + 40% Boulder.	Suspended
Id		0.45 (Soil) 0.70 (Rock)	Used on soil and on rock. Concrete saving due to infill of sand, gravel and boulders R.R. Masonary 1:6 and mainly Plumb concrete 1:3:6 + 40% Boulder.	Suspended
Ie		0.45 (Soil)	Poor soil conditions with an estimated maximum permissible soil pressure of about 0.5 – 1.0 $\frac{kg}{cm^2}$ Calculation according to Ia and Ib. No soil resistance considered.	Suspension

Sources: German Consultants (Dr. Ing. Walter KG. DIWI)
Design Section of HMG Suspension Bridge Division

STRUCTURAL ANALYSIS

Gravity blocks typ no. 2

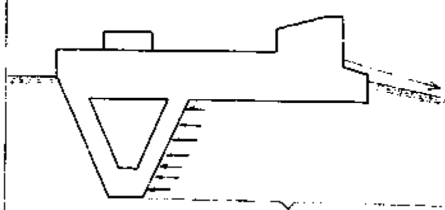
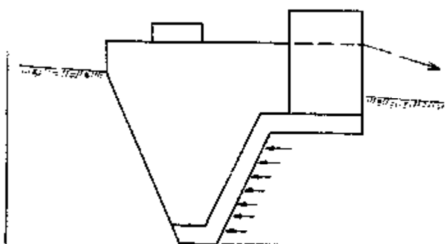
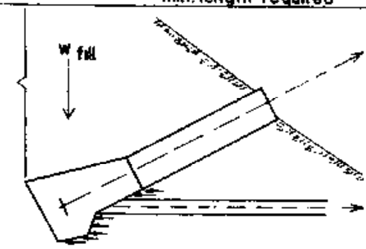
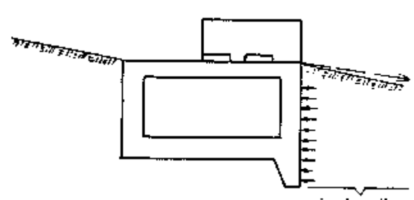
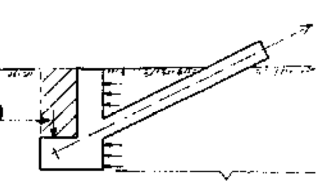
No. :3.603

Date :10th Jan. 77

Sig. : [signature]

GRAVITY BLOCKS

Type NO. 2: Utilising passive soil resistance plus normal friction (using passive earth pressure)

TYPE NO	Shape of anchorage blocks	coefficient of friction	General description, presupposed soil conditions, comparison, calculation methods, permissible soil pressure	used at bridge type
2a		tan(0.9 φ)	Application requires special shape of embankment. Considerable savings of concrete. Several cases of sliding or soil failure have to be taken into consideration. Assumed value of maximum soil pressure. 3.0 $\frac{kg}{cm^2}$ Saftey factors>2.0	Suspended
2b		tan(0.9 φ)	Middle-wall modification of type 2a Application if a higher saddle level for the main cables is required. Other conditions and values according to 2a.	Suspended
2c		tan(0.9 φ)	Very little concrete consumption, but requiring big excavation and refill. Certain minimum length l and height h necessary (a): Suspension Bridge. (b): Suspended Bridge. Slope to be protected against erosion.	Suspension Suspended
2d		0.45	Shape according to 1d in principle. Certain amount of soil resistance additionally taken into consideration. Certain slope shape and slope protection necessary.	Suspended
2e		tan(0.9 φ)	Very economical wall type anchorage. More difficult application in case of horizontal acting force. Certain slope shape and earth protection in front of the anchorage required.	Suspension Suspended

Sources: German Consultants (Dr. Ing. Walter KG DIWI)
Design Section of HMG Suspension Bridge Division

HMG Nepal Roads Department Suspension Bridge Division

STRUCTURAL ANALYSIS

Gravity rock blocks type no. 3

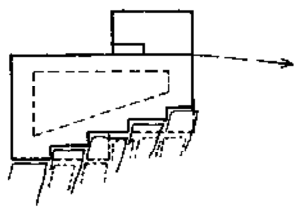
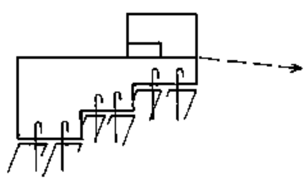
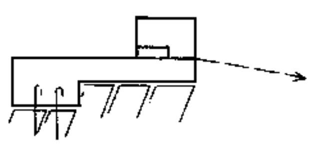
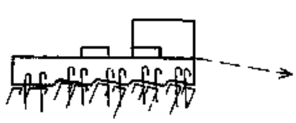
No. :3.604

Date :10th Jan. 77

Sig :

GRAVITY ROCK BLOCKS

Type No. 3: Utilising rock resistance.

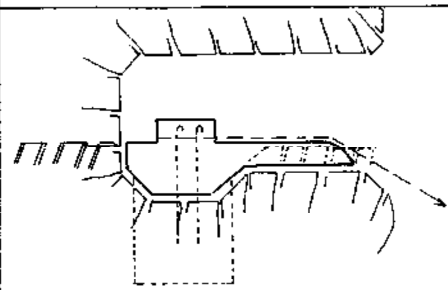
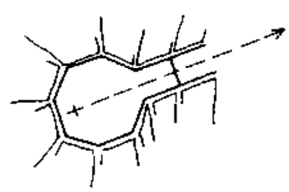
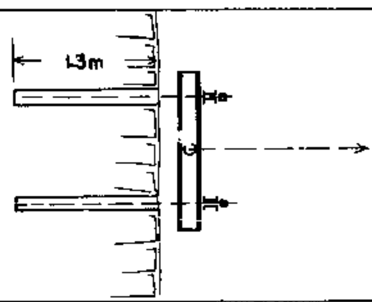
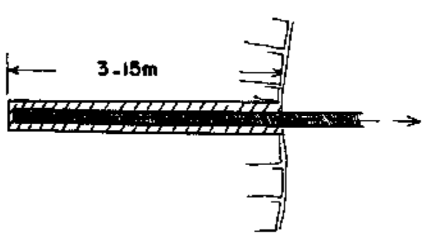
TYPE NO	Shape of anchorage blocks	coefficient of friction	General description, presupposed soil conditions, comparison, calculation methods, permissible soil pressure	used at bridge type
3a		0.7	Some variations of the shape possible. Horizontal widening of the rear section of the anchor; filling; and various numbers of steps. Calculation simplified by considering friction only. Reduced safety factor possible. Medium rock with layers not inclined towards the river. R.R. Masonary 1:6 and mainly Plumb concrete 1:3:6 + 40% rubble.	Suspended
3b		0.7	Differing from 3a by the application of anchor bars. Further reduction of concrete volume. Rock conditions according to 3a. Mainly Plumb concrete 1:3:6 + 40% boulders	Suspended
3c		0.7	Reduced concrete volume, one step only, anchor bars possible. Reduced safety factor, rock resistance taken into account. Good rock conditions. Mainly Mass concrete 1:3:6	Suspended
3d		0.7	Minimum concrete volume using a larger number of anchor bars. Good rock conditions. Mainly Mass concrete 1:3:6	Suspended

Sources: German Consultants (Dr. Ing. Walter KG. DIWI)
Design Section of HMG Suspension Bridge Division

STRUCTURAL ANALYSIS Rock anchors typ no. 4	No. : 3.605 Date : 10th Jan. 77 Sig : [signature]

ROCK ANCHORS

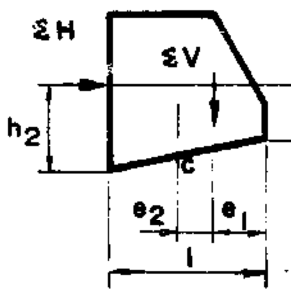
Type No. 4: Utilising rock resistance in an excavated hole and utilising drilled rock holes

TYPE NO	Shape of anchorage blocks	Coefficient of friction rock bearing bond stress	General description, presupposed soil conditions, comparison, calculation methods, permissible soil pressure	used at bridge type
4a		$\mu = 0.9 \tan \varphi$ max. rock bearing = 10–15 Kg/cm²	Very small requirement of concrete. Many variations of the excavation shape possible, also a non-tunnel solution. Excellent rock required. Mainly Mass concrete 1:3:6	Suspension Suspended
4b		$\mu = 0.9 \tan \varphi$ max. rock bearing = 10–15 Kg/m² Bond stress 1–4 Kg/cm² (Steel concrete)	Bulbed-shaped anchor. Rock conditions according to 4a. Also applicable at suspended bridge type in case of suitable slope shape. Mainly Mass concrete 1:3:6	Suspension Suspended
4c		Bond stress 1–4 Kg/cm² (Steel-mortar-rock)	No concrete required. Holes drilled with percussion-rotation equipment. Length of holes limited. Anchors fitted with system described in Chapter 9.5 Excellent rock required.	Suspension Suspended
4d		Bond stress 1–4 Kg/cm² (Steel wire-mortar-rock)	No concrete required. Holes drilled with core drilling equipment, rotation only. Length of holes extended. Anchors fitted with cement injection (hand operated injection pump). At least medium rock required	Suspension Suspended

Sources: German Consultants (Dr. Ing. Walter KG. DIWI)
Design Section of HMG Suspension Bridge Division

Simplified design of a gravity anchor block

used on standard bridges etc.



block with b

ΣH = horizontal component of the anchorage forces and sometimes also of the earth pressure

ΣV = Total vertical reactions

Safety against sliding $= \dfrac{0.45 \cdot \Sigma V}{\Sigma H} \geqq 1.5$

Block weight required $= \Sigma V \geqq 3.33 \cdot \Sigma H$

Safety against overturning $= \dfrac{\Sigma V \cdot e_1}{\Sigma H \cdot h_1} \geqq 1.50$

Maximum eccentricity $= e_1 \geqslant \dfrac{l}{6}$

Maximum soil pressure $= \dfrac{4}{3} \; \dfrac{\Sigma V}{b\,(l - 2\,e_2)} \leqq 3.0 \text{ Kg/cm}^2$ Safe bearing capacity

if $e_2 \leqq \dfrac{l}{6}$

Maximum soil pressure $= \dfrac{\Sigma V}{b \cdot l}\left(1 \pm \dfrac{6 e_2}{l}\right) \leqq$ Safe bearing capacity

if $e_2 > \dfrac{l}{6}$

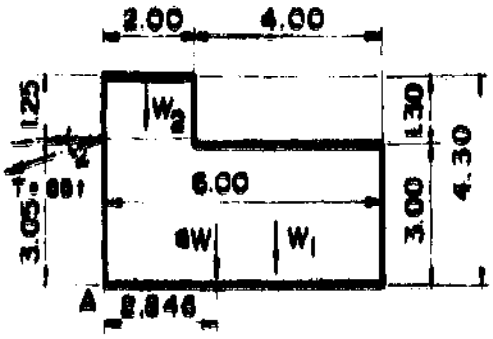
Eccentricity $e_2 = \dfrac{\Delta M_c}{\Sigma V}$

STRUCTURAL ANALYSIS

Calculation example for a main anchor block for a suspended bridge(without taking any earth pressure into account)

No	: 3.702
Date	: 19th Jan. 77
Sig	: [signature]

Calculation example for a main anchor block of a suspended bridge. (without any earth pressure)



Cell type foundation = 2 t/m³

Width = 4.50 m

Gangway = 1.90 m

α ......= 12.5°

T...... = 65 t

T_V ...... = 65 Sin α = 14.07 t

T_r ...... = 65 Cos α = 63.46 t

Soil quality = $\tan\mu$ = 0.50

Permissible pressure = 2.5 Kg/cm²

$W_1 = 6.0\cdot3.0\cdot4.5\cdot2.0 = 162.00$ t

$W_2 = 2.0\cdot1.3\cdot(4.5-1.90)\cdot2 = 13.52$ t

$T_V = 65\cdot0.2164 = 14.07$ t

$\Sigma V = 189.59$ t

$\Sigma W = 175.52$ t

Eccentricity of total weight

$$e = \frac{W_1\cdot3.0 + W_2\cdot1.0}{\Sigma W} \qquad e = \frac{162.00\cdot3.00 + 13.52\cdot1.00}{175.52} = \underline{2.846\ m}$$

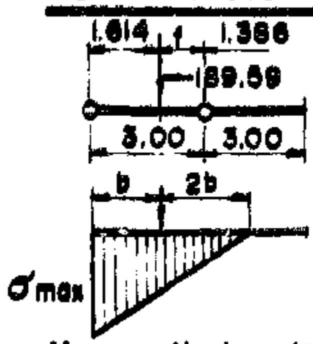
Stability against overturning

$$S = \frac{\Sigma M_r}{\Sigma M_l} = \frac{\Sigma W\cdot2.846}{T\cdot3.05\cdot\cos\alpha} = \frac{499.53}{197.81} = 2.52 > 1.5$$

Stability against sliding

$$S = \frac{\Sigma V\cdot\mu}{\Sigma H} = \frac{189.59\cdot0.5}{63.46} = 1.494 \approx 1.50$$

Max. soil bearing



$$M_A = -W_1\cdot0 + W_2\cdot2.0 + T_H\cdot3.05 + T_V\cdot3.00$$

$$M_A = +13.52\cdot2.0 + 63.46\cdot3.05 + 14.07\cdot3.00 = 262.80\ \text{mt}$$

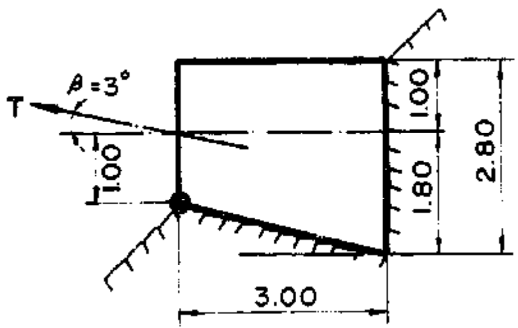
$$f = \frac{M_A}{\Sigma V} = \frac{262.80}{189.59} = 1.386\ \text{m} > \frac{6}{6} = 1$$

$$b = 3.00 - f = 1.614\ \text{m}$$

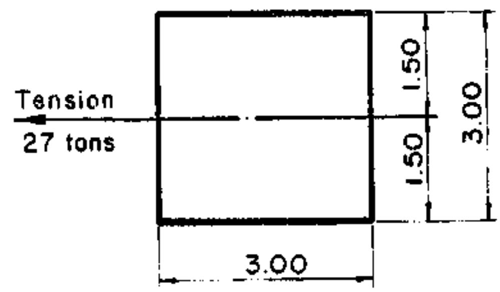
$$\text{Max. soil bearing} = \sigma_{max} = \frac{2\cdot\Sigma V}{3b\cdot\text{width of the foundation}}$$

$$\sigma_{max} = \frac{2\cdot189590}{3\cdot161.4\cdot450} = 1.74\ \text{Kg/cm}^2 < 2.5$$

CALCULATION EXAMPLE FOR A WIND GUY ANCHOR BLOCK.



Side Elevation



Plan

Foundation width = 3.00 m
Rock quality : weathered
Tension = 27.0 tons
$tg\,\alpha = 80 : 300 = 0.267 \quad \alpha = 14.93°$

Coefficient of friction = 0.60
Permissible rock pressure = 6 Kg/cm^2
$T_V = T \cdot \sin\beta = 1.4$ tons (uplifting)
$T_H = T \cdot \cos\beta = 27.0$ tons

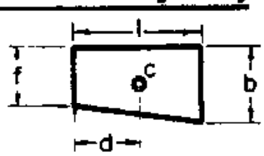
Volume of the block

$$V = \left[\frac{(2.80-0.80)+2.80}{2} \cdot 3.0\right] \cdot 3.0 = 21.60\,m^3$$

Weight of the block

$$W = 21.6 \cdot 2.3 = 49.68\ t$$

Centre of gravity



$$d = \frac{l}{3} \cdot \frac{b+2f}{b+f} = \frac{3.0}{3} \cdot \frac{2.8+4.0}{2.8+2.0} \cong 1.42\,m$$

Stability against overturning

$$S.F = \frac{\Sigma\ M_{st}}{\Sigma\ O} = \frac{49.68 \cdot 1.42}{27.0 \cdot 1.0} = \frac{70.5456}{27.0} = 2.613 > 1.50$$

Stability against sliding

Due to the inclined span the following formula can be used
α = angle of the inclined bottom $\quad \mu$ = factor of friction

$$S.F = \frac{(\Sigma W - T_V)\cdot(\cos\alpha \cdot \mu + \sin\alpha)}{\Sigma H \cdot \cos} = \frac{(49.68-1.4)\cdot(0.966\cdot 0.6+0.258)}{27.0 \cdot 0.966} = 1.55 > 1.50$$

Max. rock bearing at A (simplified calculation)

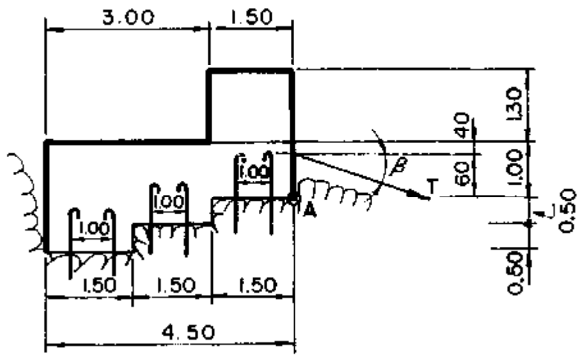
$$b = \frac{\text{Moment stabilizing} - \text{Moment overturning}}{\Sigma V} = \frac{(70.5456-27.0)}{(49.68 \cdot 1.4)} = 0.902\,m$$

$$e = 1.42 - 0.902 = 0.518 > l/6 = 0.50$$

$$\sigma_{max} = \frac{2 \cdot \Sigma V}{3 \cdot b \cdot \text{width of the foundation}} = \frac{2 \cdot 48.28}{3 \cdot 0.902 \cdot 3.0} = 11.894\ t/m^2 = 1.19$$

$$\sigma_{max} = 1.19\ Kg/cm^2 \ll 6.0\ Kg/cm^2$$

CALCULATION EXAMPLE FOR A GRAVITY/ROCK BLOCK FOR A SUSPENDED BRIDGE.



Gangway .... = 1.90m

Foundation width......... = 3.50m

Rock quality............ = medium

β = Angle of cable force = 12.5°

T = 60t

T_V = T· Sin β = 12.99t

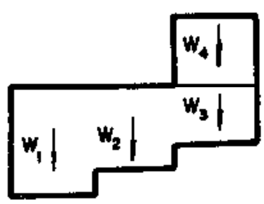
T_H = T· Cos β = 58.58t

Permissible rock pressure = 6kg/m²

Total 6·4 = 24 rod Ø 1"

Coefficient of friction = 0.65

Weights



W_1 = 1.5· 2.0·3.5·2.2 = 23.100t

W_2 = 1.5· 1.5·3.5·2.2 = 17.325t

W_3 = 1.5· 1.0·3.5·2.2 = 11.550t

W_4 = 1.5· 1.3·(3.5−1.9)·2.2 = 6.864t

W_T = 58.839t

Volume = 26.745m³

Eccentricity of the total weight

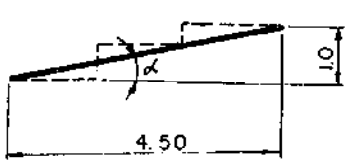
$$e = \frac{23.10 \cdot 3.75 + 17.325 \cdot 2.25 + 11.550 \cdot 0.75 + 6.864 \cdot 0.75}{58.839}$$

$$e = \frac{86.625 + 38.98125 + 8.6625 + 5.148}{58.839} = 2{,}37\text{m.}$$

Safety against overturning (with reference to A) without considering the steel bar anchors.

$$S.F. = \frac{\Sigma V \cdot e}{T \cdot \cos\alpha \cdot 0.60} = \frac{58.839 \cdot 2.37}{60 \cdot 0.9763 \cdot 0.60} = 3{,}97 > 1.5$$

Safety against sliding without considering the steps and the anchor bars.



$$\tan\alpha = \frac{1.0}{4.5} = 0.222; \quad \alpha = 12.53°$$

$$S.F. \cong \frac{\min.\ \Sigma v\ (\cos\alpha \cdot \mu + \sin\alpha)}{\max.\ \Sigma H \cdot \cos\alpha}$$

$$S.F. \cong \frac{(58.839 + 12.99)(0.976 \cdot 0.65 + 0.217)}{58.58 \cdot 0.976} = 1.07$$

As this value has been found out by a simplified calculation, it can be regarded to be sufficient.

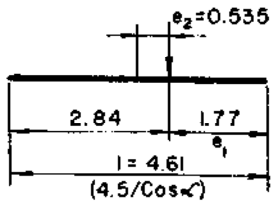
STRUCTURAL ANALYSIS

Calculation example for a gravity/rock block for a suspended bridge (continuation)

No.	3.705
Date	24th Jan. 77
Sig.	[signature]

Eccentricity of the resultant force

$$e = \frac{\Delta M}{\Sigma V} \quad \frac{(58.839 \cdot 2.37) - (60 \cdot 0.9763 \cdot 0.6)}{58.839} = 1.77\,m$$



Max. pressure on rock

$$\frac{l}{6} = 0.768\,m < 0.535$$

$$\sigma_{max.} = \frac{4}{3} \cdot \frac{\Sigma V}{b(l - 2 \cdot e_2)} = 6.33\,t/m^2 = 0.63\,kg/cm^2 << 8.0$$

Note worth: The safety against overturning is greater than 1.5 (3.92) just by weight. The stability against sliding of 1.07 is a fictive value. The actual one is higher than required, as the foundation is provided with anchor bars and excavated steps.

Anchor length of the bars required

$$l_A = \frac{Tension}{G \cdot bond\ stress}$$

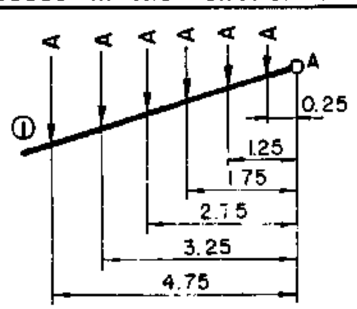
We assume a bond stress of $2.0\,kg/cm^2$

$$l_A = \frac{912.5\,kg}{2.5 \cdot \pi \cdot 2.0} = 58.1\,cm$$

Due to unknown rock formation, the anchor length is chosen with 1.00 m.

In case the anchor bars are considered to take the load, the stresses are:

Stresses in the anchor bars:



$$A = 4 \cdot A\,\varnothing_{25} = 19.63\,cm^2$$

$$M_A = T \cdot Cos\beta \cdot 0.6$$

$$M_A = 35.148\,mt$$

$$Tension_1 = \frac{\Sigma M_A \cdot 4.25}{(4.25^2 + 3.25^2 + 2.75^2 + 1.75^2 + 1.25^2 + 0.25^2)} = 3.65\,t$$

$$\sigma_T \text{ in one rod} = \frac{3.65\,t}{19.63\,cm^2} = 0.186\,t/m^2 << \sigma_{permissible.}$$

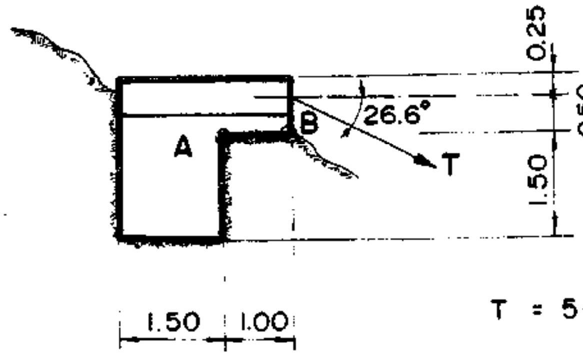
Shearing in the anchor bars

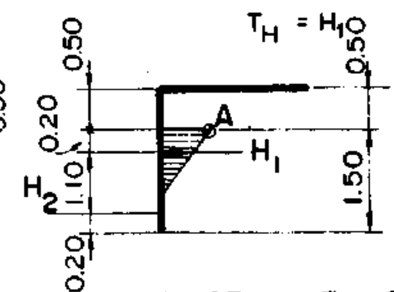
$$\tau = \frac{\Sigma H}{\Sigma F} = \frac{58.58}{117.78} = 0.497\,t/m^2 < \tau_{permissible}$$

Comparison stress in the anchor bars

$$\sigma_c = \sqrt{\sigma^2 + 3 \cdot \tau^2} = \sqrt{0.186^2 + 3 \cdot 0.497^2} = 0.881\,t/m^2 < \sigma_{permissible.}$$

CALCULATION EXAMPLE FOR ROCK ANCHORAGE

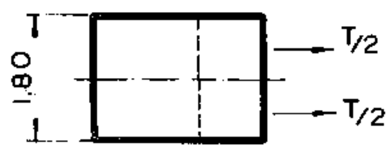




T = 56 ton T_H = 50.07 ton T_V = 25.07 ton

Concrete Volume:

Slab = 0.75 · 2.50 · 1.8 = 3.375 m^3
Post = 1.50 · 1.80 · 1.5 = 4.050 m^3
Total = 7.425 m^3



Concrete weight = 16.34 ton
Rock condition is excellent
Permissible bearing = 15 Kg/m^2

max. rock bearing at A

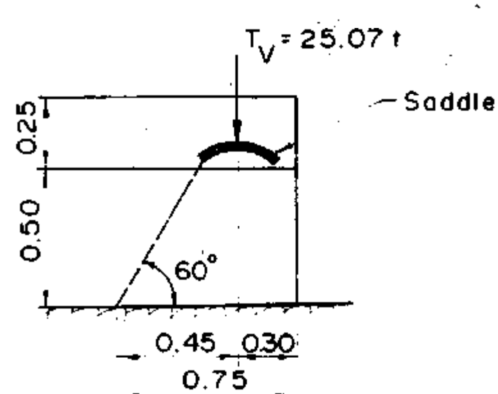
$$H \cdot (2.0 - 0.2) = H_1 \cdot (1.50 - 0.2 - 0.2)$$

$$H \cdot 1.80 = H_1 \cdot 1.10$$

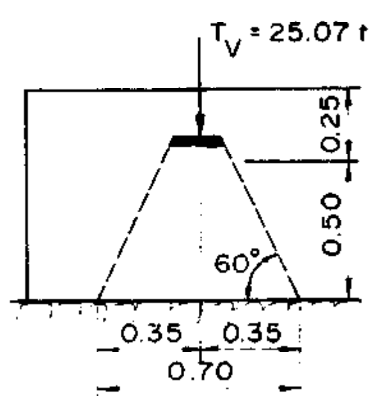
$$H_1 = \frac{1.80}{1.10} \cdot 50.07 = 81.933 \text{ t}$$

$$\sigma_{max} = \frac{2 \cdot 81.933}{(3 \cdot 0.20) \cdot 1.8} = 151.17 \text{ t/m}^2 \cong 15.0 \text{ Kg/cm}^2$$

max. soil bearing at B



Side elevation



Front elevation

$$\sigma \cong \frac{25070}{75 \cdot 70} = 4.775 \text{ Kg/m}^2 << \sigma \text{ permissible}$$

Shearing in the concrete post

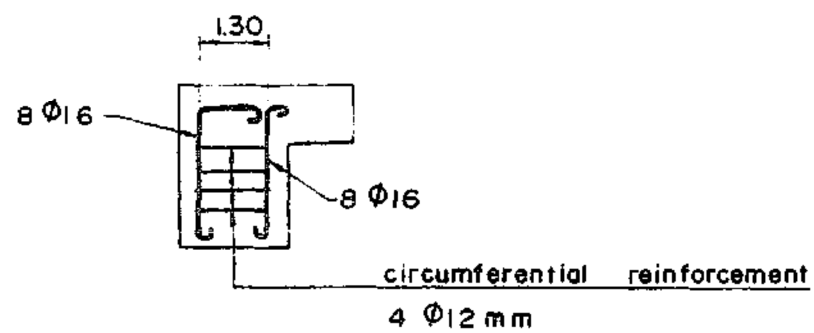
$$\tau \cong \frac{50070}{0.9 \cdot 140 \cdot 180} = 2.21 \text{ Kg/cm}^2 < \tau_{permissible}$$

Reinforcement in the post

$$M = 0.50 \cdot 50.07 = 25.035 \text{ mt}$$

required reinforcement steel $= \dfrac{M}{0.9 \cdot h \cdot 1.4} = \dfrac{25.035}{0.9 \cdot 1.4 \cdot 1.4} = 14.19 \text{cm}^2$

say $8\,\phi 16 \cong 16 \text{cm}^2 > 14.19 \text{cm}^2$



Reinforcement in the slab

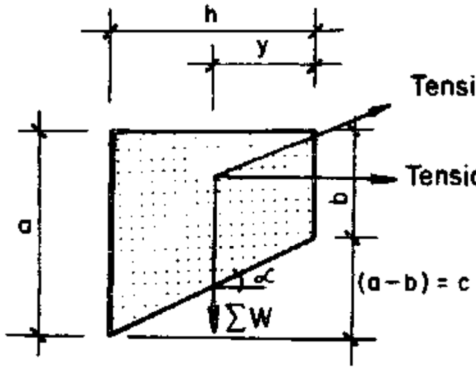
$Z = 50.07$ tons

required reinforcement steel $= \dfrac{50.07}{1.4} = 35.76 \text{cm}^2$

say $= 2 \times 9 = 18\,\phi 16 = 36 \text{cm}^2 > 35.76 \text{ cm}^2$

STRUCTURAL ANALYSIS Factor of friction for inclined foundation bottom	No.: 3.708 Date: 22nd Feb. 77 Sig.:

FACTOR OF FRICTION FOR INCLINED FOUNDATION BOTTOM



$$y = \frac{h}{3} \cdot \frac{a+2b}{a+b}$$

$$\tan\alpha = \frac{(a-b)}{h} = \frac{c}{h} \qquad \tan\rho = \mu = \text{factor of friction}$$

$$T_H = T_\alpha \cdot \cos\alpha \qquad T_\alpha = \frac{T_H}{\cos\alpha}$$

Resistant force due to weight (ΣW)

$$R.F_{\text{parallel to bottom}} = R.F_\alpha = \Sigma W (\sin\alpha + \mu \cdot \cos\alpha)$$

$$\mathbf{R.F._{Horizontal} = R.F_H = \Sigma W \cdot \tan(\alpha + \rho)}$$

$$\mathbf{R.F._H = \Sigma W \cdot \mu'} \quad \text{(when inclined bottom face)}$$

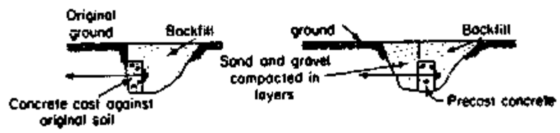
Table for factor of friction μ' (when inclined bottom)

α	μ Horizontal bottom						
	0.40	0.45	0.50	0.55	0.60	0.65	0.70
0°	0.40	0.45	0.50	0.55	0.60	0.65	0.70
4°	0.48	0.54	0.59	0.64	0.70	0.75	0.81
8°	0.57	0.63	0.69	0.75	0.81	0.87	0.93
12°	0.67	0.73	0.79	0.86	–	–	–
α	μ' (inclined bottom)						

Factor of safety against sliding: $\mathbf{F.S = \frac{\Sigma W \cdot \mu'}{T_H} \geq 1.5 \text{ to } 2.0}$

PASSIVE EARTH PRESSURE ON AN ANCHOR WALL

This kind of foundation is suitable when it can be installed below the level of the original ground. Short deadman near ground surface is shown below. This dead-



man with a length L is subjected to keep an anchor pull T (e.g. Tension of the main-cables of a suspension bridge). The system of the main anchor blocks for suspended bridges allows the use of the passive earth pressure which leads to a very economical solution. Take care that a certain slop shape and slope protection must be exist. The following passive and active earth pressure coefficient are usefull :

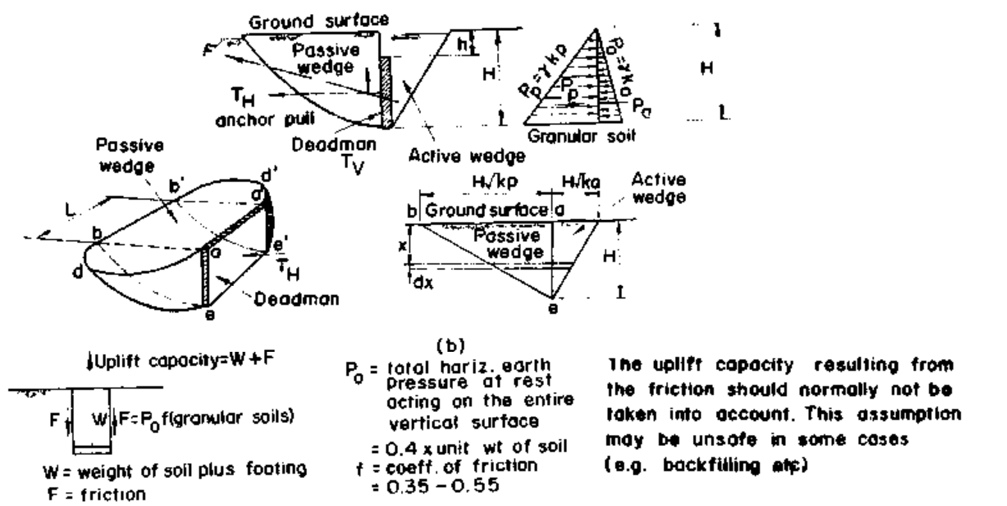
Description	soil in place				backfill	
angle of internal friction φ	26°	30°	34°	38°	26°	30°
coefficient of active earth pressure K_a	0.35	0.30	0.25	0.20	0.50	0.35
coefficient of passive earth pressure K_p	3.00	5.00	7.00	9.00	—	—

For the above figures the soil surface is assumed as horizontal -i.e. $\beta = 0°$

The total ultimate capacity of a short deadman in granular soil near ground surface is :

$$T_{ult} \leq L(E_p - E_a) + \tfrac{1}{3} K_0 \gamma (\sqrt{K_p} + \sqrt{K_a}) H^3 \tan \varphi$$

where L = length of the deadman, m
H = height of deadman
φ = angle of internal friction
E_p, E_a = total passive and active earth pressure, t per m
K_0 = coefficient of earth pressure at rest. It may be taken as 0.4 for design of deadman,
γ = unit weight of soil, t/m³ K_p, K_a = coefficients of passive and active earth pressure,



The factors of safety should be taken at least with 1.5 for the ultimate capacity as well as for the safety against sliding, therefore a safety factor of 1.5 x 1.5 = 2.25 will be developed.

Reference : Wayne C. Teng : Foundation design, Teng Associates, USA, 1974

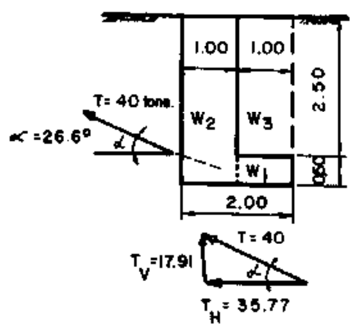
Anchor wall.

(Deadman used as main cable anchorage by using the passive earth pressure)

This system allows saving of concrete and costs. Certain slope, shape and slope protection are necessary. The factors of safety should be taken as follows:

Factor of safety against overturning = 1.5 (for granular backfill).
= 2.0 (for cohesive backfill).
Factor of safety against sliding = 2.0
Slipping: Frictional resistance = Total weight x co-efficient of friction.

Formulas refer to Chapter: Passive earth pressure on an anchorage wall.



H = 3.00 m.
L = 3.00 m. (Width)
φ = 30°
Weight of soil = 1.7 t/m³
Weight of concrete = 2.3 t/m³
Factor of sliding = 0.9 tan φ = 0.52

$T_V = T \cdot \sin\alpha = 17.91t.$
$T_H = T \cdot \cos\alpha = 35.77t.$

Coefficient of earth pressure: $k_a = 0.35$; $k_p = 5.00$

Total weight = $W_1 + W_2 + W_3 = W_T$

$W_T = (1.0 \cdot 0.50 \cdot 3.00 \cdot 2.3) + (1.0 \cdot 3.0 \cdot 3.0 \cdot 2.3) + (1.0 \cdot 2.5 \cdot 3.0) = 36.90\ t$

Factor of safety against uplift = $\frac{36.90}{17.91} = 2.06 > 2.0$

Weight acting on the bottom = W_R

$W_R = W_T - W_{uplift} = 36.90 - 17.91 = 18.99.$

Frictional resistance F. R. = $W \cdot \mu = 18.99 \cdot 0.52 = 9.87\ t$

Resistance force due to earth pressure:

$T_{ult.} = L\ (E_p - E_a) + \frac{1}{3} \cdot k_o \gamma (\sqrt{k_p} + \sqrt{k_a})\ H^3 \tan\varphi$

$E_a = \frac{1}{2} \cdot k_a \cdot \gamma \cdot H^2 = \frac{1}{2} \cdot 0.35 \cdot 1.7 \cdot 3^2 = 2.68\ t/m'$

$E_p = \frac{1}{2}\ k_p \cdot \gamma \cdot H^2 = \frac{1}{2} \cdot 5.00 \cdot 1.7 \cdot 3^2 = 38.25\ t/m'$

$T_{ult.} = 3.0\,(38.25 - 2.68) + \frac{1}{3} \cdot 0.4 \cdot 1.7\ (\sqrt{5} + \sqrt{0.35})\ 3^2 \cdot \tan 30°$

$T_{ult.} \leq 112.478\ t$

minimum length of ground surface in front of the foundation = $1.5 \cdot H\sqrt{k_p} = 1.5 \cdot 3 \cdot \sqrt{5} = 1.5 \cdot 6.71 = 10.07$ m.
(1.5 = safety factor)

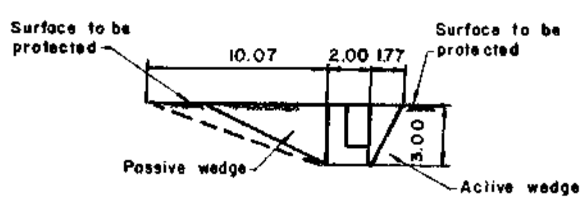
length of ground surface in back of the foundation = $H\sqrt{k_a} = 3.0\ \sqrt{0.35} = 1.77$ m

Total horizontal resistance = H. R.

H. R. = $T_{ult.} + F.R. = \frac{112.478}{1.5} + 9.87 = 84.765$

Factor of safety against sliding = $\frac{HR}{T_H}$

F. S. = $\frac{84.765}{35.77} = 2.37 > 2.0$



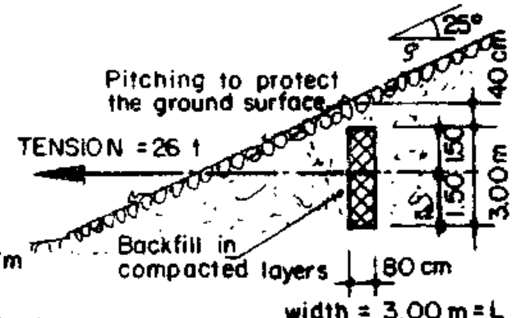
STRUCTURAL ANALYSIS	No. : 3.803
Calculation example for a deadman used as wind guy anchorage	Date : 15th March 77
	Sig. : for Pfaffen

CAPACITY OF THE DEADMAN

$\varphi = 25°$ $K_p = 3,78$ (p. 3.804)

$\gamma = 1700$ kg/m3 $K_a = 0,441$ (p. 3.804)

$K_o = 0,40$



$$T_{ult} \leq L(E_p - E_a) + \frac{1}{3} \cdot K_o \cdot \gamma \cdot (\sqrt{K_p} - \sqrt{K_a}) \cdot H^3 \cdot \tan\varphi$$

$$E_a = \frac{K_a \cdot \gamma \cdot 0,4\,m + K_a \cdot \gamma \cdot 3,40\,m}{2} \cdot 3.0\,m = 4,273\ t/m \quad (12,819\,t)$$

$$E_p = \frac{K_p \cdot \gamma \cdot 0,4\,m + K_p \cdot \gamma \cdot 3,40\,m}{2} \cdot 3.00\,m = 36,6282\ t/m \quad (109,8846\,t)$$

$$T_{ult} \leq 3.0(36,6282 - 4,273) + \frac{1}{3} \cdot 0,4 \cdot 1,7 \cdot (\sqrt{3,78} - \sqrt{0,441}) \cdot \frac{0,4 + 3,4}{2} \cdot 3,0 \cdot 0,5774$$

$$T_{ult} \leq 97,0656 + 0,2266... \cdot (1,2801439) \cdot 1,9 \cdot 3,0 \cdot 0,5774 = 97,0656 + 1,123516 = 98,189116\ t$$

say : $T_{ult} \leq 98$ tons

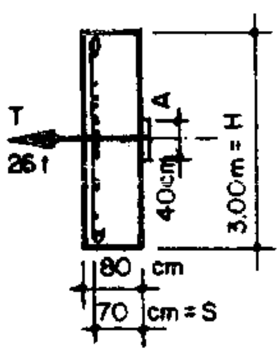
DEADMAN RESISTANCE taken into account $= \dfrac{98 \text{ tons}}{\text{factor of safety} = 1,5} = 65,33$ tons

Factor against sliding $= \dfrac{\text{red. deadman's capacity}}{\text{tension guy}} = \dfrac{65,33}{26} = 2,51 > 2$ O.K.

Theoretical stability = safety factor · safety factor = $1,5 \cdot 2,51 = 3,765$ = t.s.f.

Due to the unsafe soil information, execution and backfilling it is recommended to get rather high safety figures.

DIMENSIONING OF THE REINFORCED CONCRETE SHIELD (deadman)



max. Moment $= \dfrac{T(H - A)}{8} = \dfrac{26(3,0 - 0,40)}{8} = 8,45$ mt

max. Shearing $= \dfrac{T(H - A)}{2 \cdot H \cdot 0,9 \cdot S \cdot H} = \dfrac{26(3,0 - 0,4)}{2 \cdot 3 \cdot 0,9 \cdot 0,7 \cdot 3} = 5,9612\ t/m2$

max. Shearing = 0,60 kg/cm2 O.K.

Because of the modulus of foundation and the difference of the soil bearing on the bottom and top face, however, the dimensioning of reinforcement should be done by taking the max. moment twice into consideration.

Reinforcement required $= \dfrac{\text{Moment}}{0.9 \cdot S \cdot \sigma_{R\,all.}} = \dfrac{2 \cdot 8,45}{0,9 \cdot 0,7 \cdot 1,4} = 19,161\ cm^2$

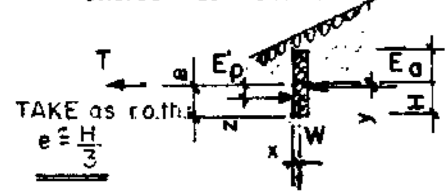
say : 14 ø 14 mm ≙ 21,56 cm2 > 19,161 cm2 ≙ 100%

The reinforcement should be placed crosswise – i.e. total 28 ø 14 mm

REINFORCEMENT				
	percentage	area req.	pieces	eff. area
8 graduations	6 %	1,15 cm2	1 ø 14	1,54 cm2
	8 %	1,53 cm2	1 ø 14	1,54 cm2
	13 %	2,49 cm2	2 ø 14	3,08 cm2
	23 %	4,40 cm2	3 ø 14	4,62 cm2
	23 %		3 ø 14	
	13 %		2 ø 14	
	8 %		1 ø 14	
	6 %		1 ø 14	

Total = 100% = 14 ø 14 = 21,56 cm2

To get no overturning moment with reference to point A, the tensile force might be anchored as follows:

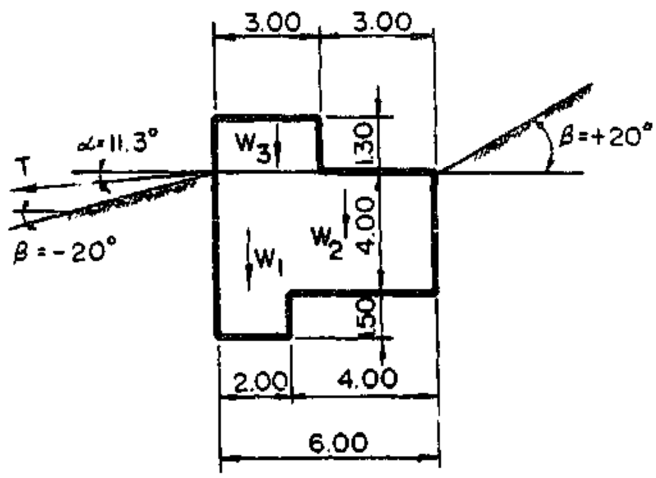


note worth : While taking $E_p = T_{ult}$ the results will be absurd $\therefore E_p' \cong \dfrac{E_p}{t.s.f.}$

$$(E_p' \cdot z) - (E_a \cdot y) - W \cdot x = 0$$

neglecting the weight of the soil above the deadman

EXAMPLE FOR CALCULATION OF A MAIN ANCHOR BLOCK FOR A SUSPENDED BRIDGE TAKING THE PASSIVE EARTH RESISTANCE INTO ACCOUNT



Cell-type foundation .... = 2 t/m³

Width .... = 5.00 m.

Gangway .... = 1.90 m.

T .... = 130 tons.

T_V = T· Sin α .... = 25.47 t.

T_H = T· Cos α .... = 127.48 t.

Trench excavation needed

- Soil quality = ϱ = 30°   Soil = 1.9 t/m³
- Coefficient of friction = 0.9 tan ϱ = 0.52
- Permissible pressure = 3 kg/cm²
- Weight of the foundation

W_1 = 2.0·5.5·5.0·2.0 = 110.00 t.
W_2 = 4.0·4.0·5.0·2.0 = 160.00 t.
W_3 = 3.0·1.3(5.0−1.9)·2.0 = 31.98 t
W_T = 301.98 t

Eccentricity of the foundation

$$e = \frac{W_1 \cdot 1.0 + W_2 \cdot 3.0 + W_3 \cdot 1.5}{301.98} = \frac{110.00 + 480.00 + 47.97}{301.98} = 2.11\,m.$$

Calculation of the acting forces etc.

Passive and active earth pressure coefficient (ground surface = β = 20°)

Description	Soil in place (β = 20°)					
angle internal friction ϱ	25°	27.5°	30°	32.5°	35°	37.5°
coefficient of active earth pressure K_a	0.572	0.500	0.441	0.389	0.344	0.303
coefficient of passive earth pressure K_p	2.78	3.22	3.78	4.44	5.36	6.55

Passive earth pressure $= \frac{1}{2} \cdot \gamma \cdot k_p \cdot H^2 = 0.5 \cdot 1.9 \cdot 3.78 \cdot 5.5^2 = 108.63$ t.

Total passive earth pressure $= 5.0 \cdot 108.63 = 543.15$ t.

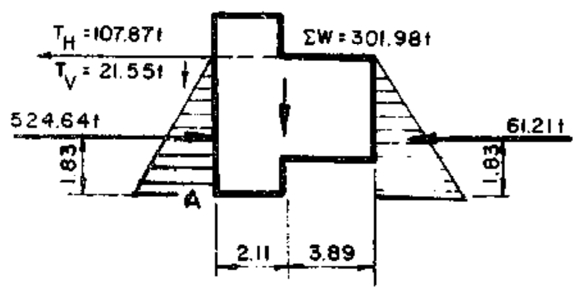
$E_{PH} = 543.15 \cdot \cos(45 - \varphi) = 524.64$ t.

Active earth pressure $= \frac{1}{2} \cdot \gamma \cdot k_a \cdot H^2 = 0.5 \cdot 1.9 \cdot 0.441 \cdot 5.5 = 12.67$ t.

Total active earth pressure $= 5.0 \cdot 12.67 = 63.37$ tons.

$E_{aH} = 63.37 \cdot \cos(45 - \varphi) = 61.21$ t

Stability against overturning



$\Sigma V = \Sigma W + T_v = 301.98 + 25.47 = 327.45$

Moment about A

$M_{overturning} = 127.48 \cdot 5.5 + 61.21 \cdot 1.83$
$= 813.15$ mt.

$M_{stabilizing} = \frac{524.64}{1.5} \cdot 1.83 + 301.99 \cdot 2.11$
$= 1277.24$ mt.

Safety against overturning $= \frac{1277.24}{813.15}$
$= 1.57 > 1.5$

– Stability against sliding

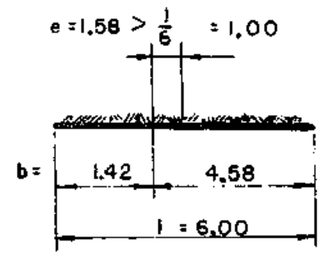
$\Sigma H_{sliding} = 127.48 + 61.21 = 188.69$

(safety factor = 1.5)

$\Sigma H_{stabilizing} = \frac{1}{1.5} \cdot E_{PH} + \Sigma V \cdot \mu = \frac{1}{1.5} \cdot 524.64 + 327.45 \cdot 0.52 = 520.03$

Safety against sliding $= \frac{520.03}{159.08} = 3.27 > 1.50.$

Max. soil bearing



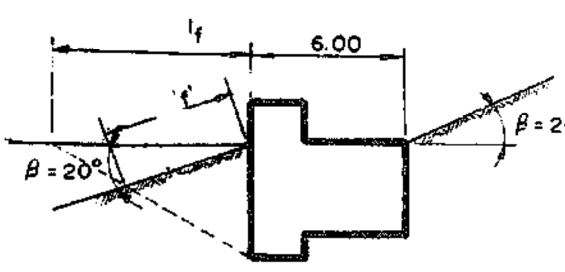
$b = \frac{\text{Moment stabilizing} - \text{Moment overturning}}{\Sigma V}$

$b = \frac{1277.24 - 813.15}{327.45} = 1.42$ m.

max. soil bearing $= \sigma_{max.} = \frac{2 \cdot \Sigma V}{3 \cdot b \cdot \text{Width of the foundation}}$

$\sigma_{max.} = \frac{2 \cdot 327450}{3 \cdot 142 \cdot 500} = 3.07$ kg/cm² ≅ 3 kg/cm²

Ground – Surface to be protected.



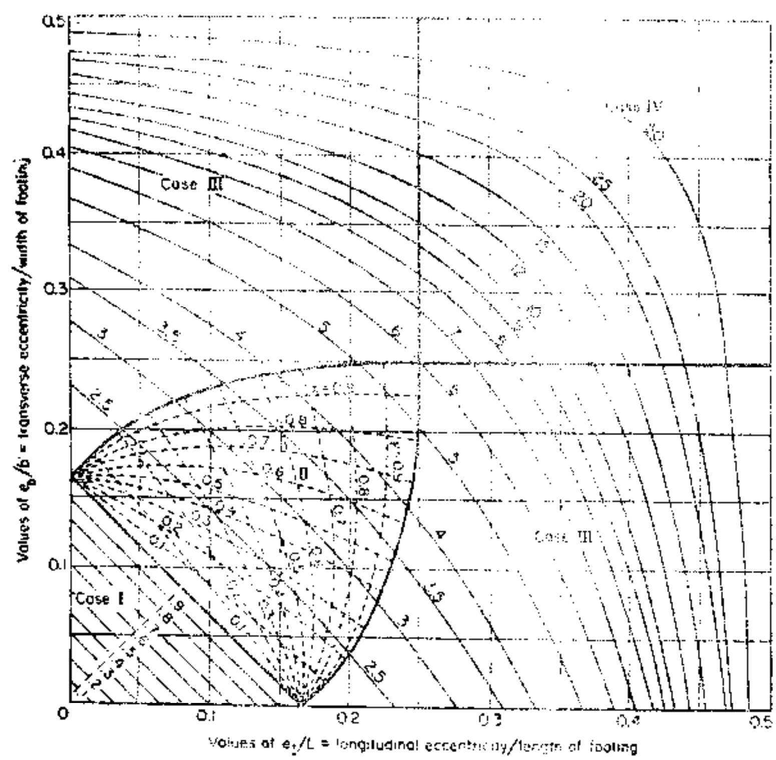
(safety factor)

$l_f = 1.5 \cdot H \cdot \sqrt{k_p} = 1.5 \cdot 5.5 \cdot \sqrt{3.78} = 16.03$ m

$l_f' = l_f \cdot \cos\beta = 15.22$ m.

DOUBLE ECCENTRIC LOADING

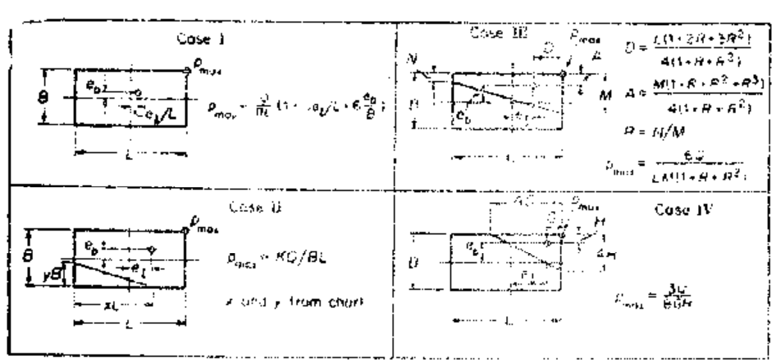
The chart below is very usefull by calculating the max. soil bearing (max. contact pressure). It is out of the scope of this manual to explain the theory, but reference to the books about soil mechanics may be made by the reader himself. There are two well known ways to calculate the max. soil bearing, either with the chart below or with the next page of "coefficients for calculating the max. soil bearing of bi-axial and eccentric compressed foundations".



Solid curves give values of K

Maximum pressure $p_{max} = K \times Q/BL$

Q = concentrated load on footing



Rectangular footing, double eccentric

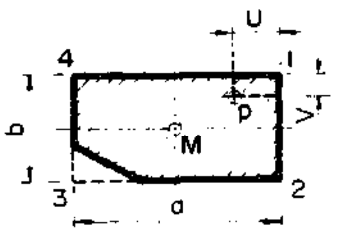
Source : Wayne C. Teng : Foundation design, Teng Associates, USA, 1974

STRUCTURAL ANALYSIS

Coefficients for calculating the max. soil bearing of bi-axial and eccentric compressed foundations

No	: 3.902
Date	: 13th Jan. 77
Sig	: [signature]

COEFFICIENTS FOR CALCULATING THE MAX. SOIL BEARING OF BI-AXIAL AND ECCENTRIC COMPRESSED FOUNDATION



$$\max \sigma = z \cdot \frac{\Sigma V\ (P)}{2u \cdot 2v} \leqq \text{permissible pressure}$$

Example:

a = 2.00 m, u = 0.50 m, ΣV = 26 tons

b = 3.00 m, v = 1.00 m, permissible pressure = 2 Kg/cm^2

$$\frac{u}{a} = \frac{0.50}{2.00} = 0.25\ ; \quad \frac{v}{b} = \frac{1.00}{3.00} = 0.33\ ; \quad z = 1.48$$

$$\text{max. soil bearing} = 1.48 \cdot \frac{26000}{2 \cdot 50 \cdot 2 \cdot 100} = 1,924 < 2.0 \text{Kg/cm}^2$$

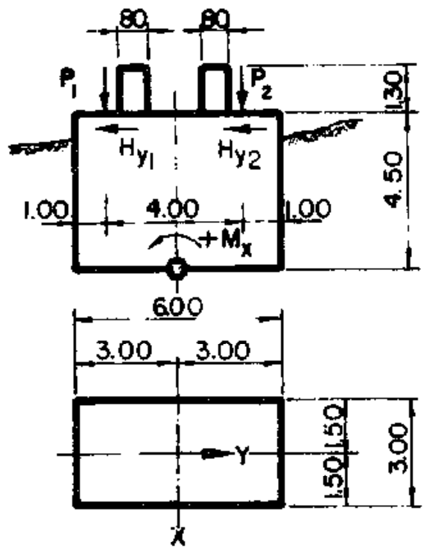
Z - Factors

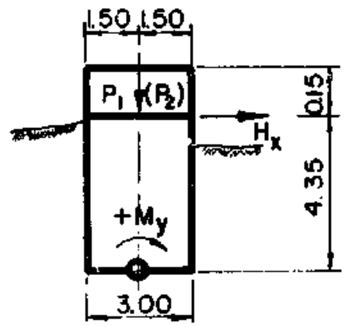
V/b	U/a 0.00	to 0.16	0.18	0.20	0.22	0.24	0.26	0.28	0.30	0.32	0.34	0.36	0.38	0.40	0.42	0.44	0.46	0.48	0.50	V/b
0.00	*Point I*	*1.50*	*1.50*	*1.50*	*1.50*	*1.50*	*1.50*	*1.50*	*1.50*	*1.49*	*1.48*	*1.46*	*1.45*	*1.43*	*1.42*	*1.40*	*1.38*	*1.36*	*1.33*	0.00
to 0.16	*1.50*	*1.50*	*1.50*	*1.50*	*1.50*	*1.50*	*1.50*	*1.50*	*1.50*	*1.49*	*1.48*	*1.46*	*1.45*	*1.43*	*1.42*	*1.40*	*1.38*	*1.36*	*1.33*	to 0.16
0.18	*1.50*	*1.50*	*1.50*	*1.50*	*1.50*	*1.50*	*1.50*	*1.50*	*1.50*	*1.49*	*1.48*	*1.46*	*1.45*	1.43	1.42	1.40	1.38	1.36	1.33	0.18
0.20	*1.50*	*1.50*	*1.50*	*1.50*	*1.50*	*1.50*	*1.50*	*1.50*	*1.50*	*1.49*	1.48	1.46	1.45	1.43	1.42	1.40	1.38	1.36	1.33	0.20
0.22	*1.50*	*1.50*	*1.50*	*1.50*	*1.50*	*1.50*	*1.50*	*1.50*	1.50	1.48	1.48	1.46	1.45	1.43	1.42	1.40	1.38	1.36	1.33	0.22
0.24	*1.50*	*1.50*	*1.50*	*1.50*	*1.50*	*1.50*	*1.50*	1.50	1.50	1.48	1.48	1.46	1.45	1.43	1.42	1.40	1.38	1.36	1.33	0.24
0.26	*1.50*	*1.50*	*1.50*	*1.50*	*1.50*	*1.50*	1.50	1.50	1.50	1.48	1.48	1.46	1.45	1.43	1.42	1.40	1.38	1.36	1.33	0.26
0.28	*1.50*	*1.50*	*1.50*	*1.50*	*1.50*	1.50	1.50	1.50	1.50	1.48	1.48	1.46	1.45	1.43	1.42	1.40	1.38	1.36	1.33	0.28
0.30	*1.50*	*1.50*	*1.50*	*1.50*	1.50	1.50	1.50	1.50	1.49	1.48	1.47	1.46	1.45	1.43	1.42	1.40	1.38	1.36	1.33	0.30
0.32	*1.49*	*1.49*	*1.49*	*1.49*	1.48	1.48	1.48	1.48	1.48	1.48	1.47	1.46	1.45	1.43	1.42	1.40	1.38	1.36	1.33	0.32
0.34	*1.48*	*1.48*	*1.48*	1.48	1.48	1.48	1.48	1.48	1.48	1.47	1.47	1.45	1.45	1.43	1.42	1.40	1.38	1.36	1.33	0.34
0.36	*1.46*	*1.46*	*1.46*	1.46	1.46	1.46	1.46	1.46	1.46	1.46	1.45	1.45	1.44	1.43	1.42	1.40	1.38	1.35	1.33	0.36
0.38	*1.45*	*1.45*	*1.45*	1.45	1.45	1.45	1.45	1.45	1.45	1.45	1.44	1.44	1.43	1.42	1.41	1.39	1.37	1.34	1.31	0.38
0.40	*1.43*	*1.43*	1.43	1.43	1.43	1.43	1.43	1.43	1.43	1.43	1.43	1.43	1.42	1.41	1.40	1.38	1.35	1.32	1.28	0.40
0.42	*1.42*	*1.42*	1.42	1.42	1.42	1.42	1.42	1.42	1.42	1.42	1.42	1.42	1.41	1.40	1.38	1.36	1.33	1.29	1.24	0.42
0.44	*1.40*	*1.40*	1.40	1.40	1.40	1.40	1.40	1.40	1.40	1.40	1.40	1.40	1.39	1.38	1.36	1.33	1.30	1.25	1.20	0.44
0.46	*1.38*	*1.38*	1.38	1.38	1.38	1.38	1.38	1.38	1.38	1.38	1.38	1.38	1.37	1.35	1.33	1.30	1.25	1.20	1.20	0.46
0.48	*1.36*	*1.36*	1.36	1.36	1.36	1.36	1.36	1.36	1.36	1.36	1.36	1.35	1.34	1.32	1.29	1.25	1.20	1.20	1.25	0.48
0.50	*1.33*	*1.33*	1.33	1.33	1.33	1.33	1.33	1.33	1.33	1.33	1.33	1.33	1.31	1.28	1.24	1.20	1.20	1.25	1.30	0.50

For the zone beneath the upper zick-zack line the centre of the foundation lies in the compressed part of the section, for the zone on the right lower corner the point of application lies in the middle third of the foundation section.

Source : Stahl im Hochbau, Verlag Stahleisen M.B.H., Duesseldorf, West Germany (12.Afl)

CALCULATION EXAMPLE FOR A PYLON FOUNDATION





Loading cases	P_1	P_2	H_{y_1}	H_{y_2}	H_x
Case 1	46	-10	3.1	3.3	15
Case 2	50	43	0.1	0.5	3.7

Case 1: Full wind and some load.
Case 2: Full load and some wind.

Soil conditions

Max. soil bearing σ max. = 3.5 kg/cm^2
Coefficient of friction μ = 0.44
Weight of soil γ = 1.90 t/m^3
Coeff. of active earth pressure k_a = 0.35
Angle of repose . . . . = 26°

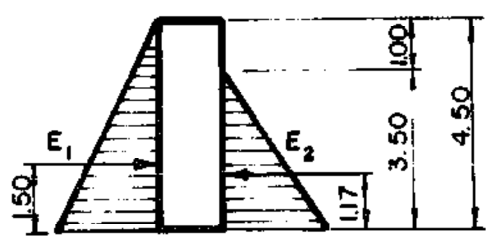
Weight of the foundation.

$W_1 = 6.0 \cdot 4.50 \cdot 3.0 \cdot 2.2 = 178.20\,t$

$W_2 = 2(1.3 \cdot 3.0 \cdot 0.8 \cdot 2.2) = 13.73\,t$

Total = 191.95 t
Volume = 87.25 m^3

Earth pressure.



$$E = \frac{1}{2} \cdot \gamma \cdot K \cdot H^2$$

$$E_1 = \frac{1}{2} \cdot 1.9 \cdot 0.35 \cdot 4.5^2 = 6.73\,t/m^1$$

$$E_2 = \frac{1}{2} \cdot 1.9 \cdot 0.35 \cdot 3.5^2 = 4.07\,t/m^1$$

$E_{1\,Total} = 6.73 \cdot 6.00 = 40.38\,t$

$E_{2\,Total} = 4.07 \cdot 6.00 = 24.42\,t$

Loading case 1 (full wind, some load)

$H_x = E_1 + H_x - E_2 = 40.38 + 15.00 - 24.42 = 30.96t$

$H_y = -H_{y_1} - H_{y_2} = -3.1 - 3.3 = -6.4t$

$M_x = (H_{y_1} + H_{y_2}) \cdot 4.5 + P_1 \cdot 2.0 - P_2 \cdot 2.0 = (3.1+3.3) \cdot 4.5 + 46.0 \cdot 2.0 - (-10) \cdot 2.0 = 140.80mt$

$M_y = E_1 \cdot 1.50 - E_2 \cdot 1.17 + H_x \cdot 4.35 = 40.38 \cdot 1.5 - 24.42 \cdot 1.17 + 15.0 \cdot 4.35 = 97.25 mt$

Eccentricities

$e_x = \frac{\Sigma My}{\Sigma V} = \frac{97.25}{191.95+46-10} = 0.43m \qquad e_y = \frac{\Sigma My}{\Sigma V} = \frac{140.80}{191.95+46-10} = 0.62m$

Max. soil bearing

Refer to Chapter: Coefficient for calculating the max. soil bearing of bi-axial and eccentric compressed foundations. (3.902)

$U = 3.0 - 0.62 = 2.38m \qquad U/a = 2.38/6.0 = 0.40$

$V = 1.5 - 0.43 = 1.07m \qquad V/b = 1.07/3.0 = 0.36$

$Z = 1.43$ max. soil bearing $\sigma max. = Z \cdot \frac{\Sigma V(P)}{2U \cdot 2V}$

$\sigma max. = 1.43 \cdot \frac{227950}{2 \cdot 238 \cdot 2 \cdot 107} = 1.43 \cdot 2.24 = 3.20 kg/cm^2 < 3.5 Kg/cm^2$

Loading case 2 (full load, some wind)

$H_x = E_1 + H_x - E_2 = 40.38 + 3.7 - 24.42 = 19.66t$

$H_y = -H_{y_1} - H_{y_2} = -0.1 - 0.5 = -0.6t$

$M_x = (H_{y_1} + H_{y_2}) \cdot 4.5 + P_1 \cdot 2.0 - P_2 \cdot 2.0 = (0.1+0.5) \cdot 4.5 + 50.0 \cdot 2.0 - 43 \cdot 2.0 = 16.7mt$

$M_y = E_1 \cdot 1.50 - E_2 \cdot 1.17 + H_x \cdot 4.35 = 40.38 \cdot 1.5 - 24.42 \cdot 1.17 + 3.7 \cdot 4.35 = 48.09mt$

Eccentricities

$e_x = \frac{48.09}{191.95+50+43} = 0.17m \qquad e_y = \frac{16.70}{191.95+50+43} = 0.06m$

Max. soil bearing

$U = 3.0 - 0.06 = 2.94m \qquad U/a = 2.34/6.0 = 0.39$

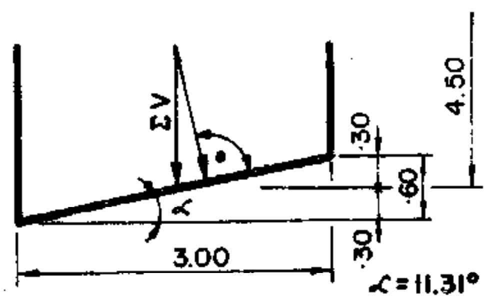
$V = 1.5 - 0.17 = 1.33m \qquad V/b = 1.33/3.0 = 0.44$

$Z = 1.385$

Max. soil bearing $\sigma max. = 1.385 \cdot \frac{284950}{2 \cdot 294 \cdot 2 \cdot 133} = 1.385 \cdot 1.822 = 2.52 kg/cm^2 < 3.5 kg/cm^2$

Safety against sliding

$$S.F. = \frac{\text{min. } \Sigma V \cdot \text{coefficient of friction}}{\text{max. } \Sigma H} = \frac{227 \cdot 0.44}{30.96} = 3.23 > 1.5$$ if horizontal



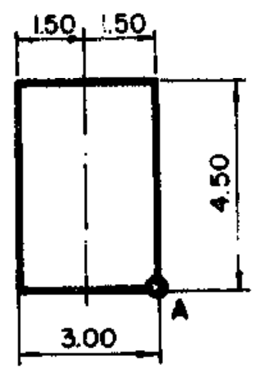
Example safety factor for a inclined bottom

$$S.F = \frac{\text{min. } \Sigma V (\cos\alpha \cdot \tan 26° + \sin 11.31)}{\text{max. } H \cdot \cos}$$

$$S.F. = \frac{227 (\cos 11.31 \cdot \tan 26° + \sin 11.31)}{30.96 \cdot \cos 11.31}$$

$$= 5.04 > 1.5$$ if inclined

Safeties against overturning



$$S.F. = \frac{\text{max. overturning moment}}{\text{min. stabilizing moment}}$$

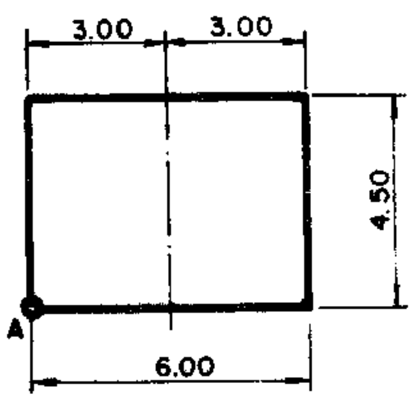
$$M_o = 15.0 \cdot 4.35 + 40.38 \cdot 1.50$$

$$M_o = 125.82 \text{ mt}$$

$$M_{st} = 191.95 \cdot 1.5 + 24.42 \cdot 1.17 + 36 \cdot 1.5$$

$$M_{st} = 371.67 \text{mt}$$

$$S.F. = \frac{371.67}{125.82} = 2.95 > 1.5$$

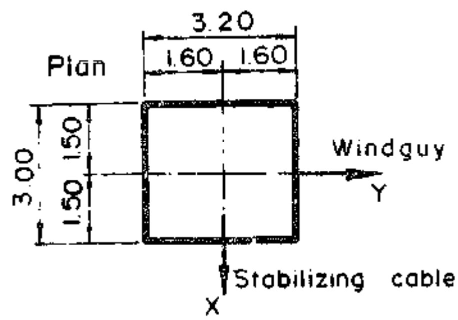


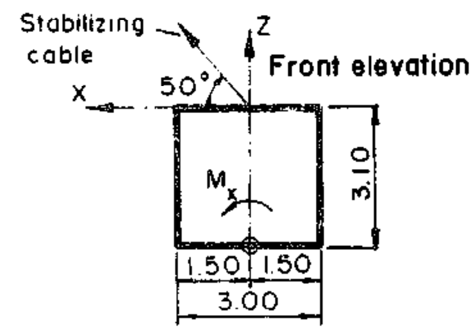
$$M_o = 6.4 \cdot 4.5 + 10 \cdot 5.0 = 78.80 \text{mt}$$

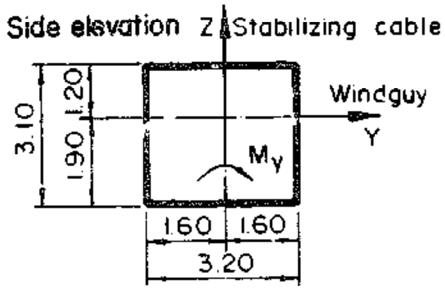
$$M_{st} = 3.0 \cdot 191.95 + 46 \cdot 1.00 = 521.85 \text{mt}$$

$$S.F. = \frac{521.85}{78.80} = 6.62 >> 1.5$$

CALCULATION EXAMPLE FOR AN ANCHOR BLOCK USED AS WINDGUY AND SIDE STAY CABLE ANCHORAGE







Forces:

Description	Case 1	Case 2
Windguy H_y	18 tons	3.0 tons
Stabilizing H_x	1.9 tons	2.3 tons
cable V_z	3.3 tons	2.7 tons

Case 1 : Full wind, some load
Case 2 : Full load, some wind

Soil condition = factor of friction = 0.45
max. soil bearing = 2.0 Kg/cm^2

The ground surface around the foundation is horizontal, therefore the active earth pressure resulting from the backfilling is assumed as equal i.e. we are calculating without taking any earth pressure into account.

Weight of the foundation

$W_T = 3.2 \cdot 3.1 \cdot 3.0 \cdot 2.2 = 65.472$ tons ; Volume = 29.76 m^3

Loading Case I (Full wind, some load)

H_x = 1.9 tons ; H_y = 18 tons ; $M_x = H_x \cdot 3.10 = 1.9 \cdot 3.10 = 5.89$ mt

$M_y = H_y \cdot 1.90 = 18.0 \cdot 1.9 = 34.20$ mt

Eccentricities

$\Sigma V = W_T - V_z = 65.472 - 3.3 = 62.172$ tons $\quad e_x = \frac{\Sigma M_y}{\Sigma V} = \frac{34.20}{62.172} = 0.550$ m

$e_y = \frac{\Sigma M_x}{\Sigma V} = \frac{5.89}{62.172} = 0.095$ m

max. soil bearing

Refer to page 3.902: Coefficients for calculating the max. soil bearing of bi-axial and eccentric compressed foundations.

$u = 1.60 - 0.095 = 1.505$. $\quad u/a = 1.505 / 3.20 = 0.47$

$v = 1.50 - 0.550 = 0.950$ $\quad v/b = 0.950 / 3.00 = 0.32$

$z = 1.37$ $\quad$ max. soil bearing = $\sigma_{max} = z \cdot \frac{\Sigma V (P)}{2u \cdot 2v}$

$$\sigma_{max.} = 1.37 \cdot \frac{62172}{2 \cdot 1505 \cdot 2 \cdot 95} = 1.49 \text{ Kg/cm}^2 < 2.0 \text{ Kg/cm}^2$$

Loading Case 2 (Full load, some wind)

$H_x = 2.3$ tons; $H_y = 3.0$ tons; $M_x = H_x \cdot 3.1 = 2.3 \cdot 3.1 = 7.13$ mt

$M_y = H_y \cdot 1.9 = 3.0 \cdot 1.9 = 5.70$ mt

Eccentricities

$\Sigma V = W_T - V_Z = 65.472 - 2.7 = 62.772$ tons, $e_x = \frac{\Sigma M_y}{\Sigma V} = \frac{5.70}{62.772} = 0.091$ m

$e_y = \frac{\Sigma M_x}{\Sigma V} = \frac{7.13}{62.772} = 0.114$ m

max. soil bearing

$u = 1.60 - 0.091 = 1.509$ $\quad u/a = 1.509/3.2 = 0.47$

$v = 1.50 - 0.114 = 1.386$ $\quad v/b = 1.386/3.0 = 0.46$

$z = 1.2125$ $\quad$ max. soil bearing $\sigma_{max} = z \cdot \frac{\Sigma V(P)}{2u \cdot 2v}$

$\sigma_{max} = 1.2125 \cdot \frac{62772}{2 \cdot 150.9 \cdot 2 \cdot 138.6} = 0.91 \text{ Kg/cm}^2 < 2.0$

Safety against sliding

Horizontal forces $F_H = \sqrt{H_x^2 + H_y^2}$ $\quad$ Vertical weight = Dead load $- V_Z = W_T$

Case 1 (Full wind, some load)

$F_H = \sqrt{1.9^2 + 18.0^2} = 18.1$ tons $\quad W_T = 65.472 - 3.3 = 62.172$ tons

Safety against sliding $= \frac{W_T \cdot \text{factor of friction}}{F_H}$

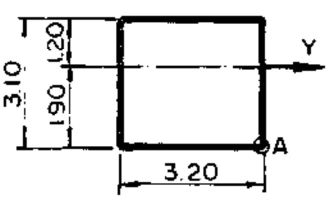
Safety factor $= \frac{62.172 \cdot 0.45}{18.1} = 1.55 > 1.5$

Case 2 (Full load, some wind)

$F_H = \sqrt{2.3^2 + 3.0^2} = 3.78$ tons $\quad W_T = 65.472 - 2.7 = 62.772$ tons

Safety factor $= \frac{62.772 \cdot 0.45}{3.78} = 7.47 >> 1.5$

Safety against overturning

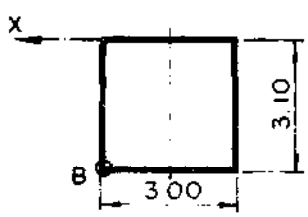


$S.F = \frac{\text{max. overturning moment}}{\text{min. stabilizing moment}}$

$M_o = H_y \cdot 1.9 + V_z \cdot 1.6 = 18.0 \cdot 1.9 + 3.3 \cdot 1.6 = 39.48$ mt

$M_{st} = W \cdot 1.6 = 65.472 \cdot 1.6 = 104.75$ mt

$S.F = \frac{104.75}{39.48} = 2.73 > 1.5$



$S.F = \frac{\text{max. overturning moment}}{\text{min. stabilizing moment}}$

$M_o = H_x \cdot 3.1 + V_z \cdot 1.5 = 2.3 \cdot 1.9 + 2.7 \cdot 1.5 = 11.18$ mt

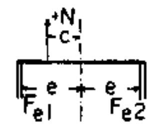
$M_{st} = W \cdot 1.5 = 65.472 \cdot 1.5 = 98.208$ mt

$S.F = \frac{98.208}{11.18} = 8.78 >> 1.5$

DIMENSIONING IN REINFORCED CONCRETE CONSTRUCTION TAKING THE AXIAL FORCE INTO ACCOUNT

$M_e = M - N \cdot e$, Tensile force $= N$ (positive), Compression force $= N$ (negative)

In the rectangular section $e = h - \frac{d}{2}$

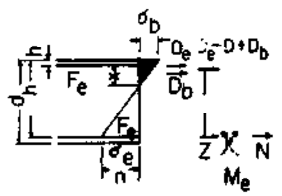


In case N acts as tensile force (+) still withen the reinforcement, i.e. $c < e$

$F_{e1} = \frac{N}{\sigma_e} \cdot \frac{e+c}{2e}$ $F_{e2} = \frac{N}{\sigma_e} \cdot \frac{e-c}{2e}$ for the tensile force action directly at the centre

$F_{e1} = F_{e2} = \frac{N}{2\ e}$

Rectangular section for uniaxial bending (with or without taking the axial force into account)



(the neutral fibre coincides with the main axis of the section)

Designation:

$m = \frac{\sigma e}{\sigma_b}$; $n = \frac{E_a}{E_b} = 15$; $x = k_x \cdot h$; $k_x = \frac{n}{n+m}$

$z = k \cdot h$; $h' = \beta \cdot h$; $\mu = \frac{F_e}{b \cdot h}$; $\mu' = \frac{F_e'}{b \cdot h}$

For the calculation of various problems concerning the dimensioning in Building construction, where the defermation is mainly the binding, the permissible stress for the steel has been fixed as σe. In order to reduce the volume of calculation on can use the corresponding table for every permissible stress of steel.

Section without any compression reinforcement

$h = k_h \sqrt{\frac{M_e}{b}}$ 4   h in cm, M in mt, b in m

In case the k_h – value obtained from the above formula $\geq$ that of k_h^* given in the table I for the given σ_b, there is no need of ....

$F_e = \frac{M_e}{h} \cdot K_e + \frac{N}{e}$, ... [2]

For mainly bending cases $F_e = \frac{M}{h} K_e$ .... [2a]

F_e in cm^2; M_e in mt; h in m; N in t

σe in t/cm^2; M in mt.

The K_e – values / which corresponds to the next smallor recosumend value of K_h will be taken from the table I.

Section with compression reinforcement

In case the K_h – value obtained from the formula 1 is smaller then that of K_h given in the table 1, there is need of compression reinforcement.

Tension reinforcement and the equation 2 and 2a, 1 K – value like in table 2, starting with σ_b and K_h

Compression reinforcement

$F_e' = \frac{M_e}{h} K_e'$ (for $\beta < 0.08$), $F_e' = \frac{M_e}{h} \cdot K_e' \cdot \rho'$ for $\beta \geq 0.08$)

Dimensions as in the equation, K_e' as K_e from the table 2, ρ' for $\beta = \frac{h'}{h}$ from the table 3

TABLE 1

σ_b Kg / cm^2	Recommended values K_h and K_h' coefficients K_e and K_e'								
	σ_e = 1.200 t/cm^2			for σ_e = 1.400 t/cm^2			for σ_e = 2.200 t/cm^2		
	K_h and K_h'	K_e	K_z	K_h and K_h'	K_e	K_z	K_h and K_h'	K_e	K_z
20	23.1	0.89	0.93	–	–	–	–	–	–
30	16.4	0.92	0.91	17.3	0.78	0.92	20.4	0.48	0.94
35	14.5	0.93	0.90	–	–	–	–	–	–
40	13.0	0.94	0.89	13.6	0.79	0.90	15.9	0.49	0.93
45	11.8	0.95	0.88	–	–	–	–	–	–
50	10.9	0.96	0.87	11.4	0.81	0.88	13.1	0.50	0.92
60	–	–	–	9.9	0.82	0.87	11.3	0.50	0.90
70			–	[illegible]	0.83	0.86	10.0	0.51	0.89
80		–	–	8.0	0.84	0.85	9.0	0.52	0.88

TABLE 2

$\beta = \frac{h'}{h}$	Coefficients ρ'														
	for σ_e = 1.200 t/m^2					for σ_e = 1.400 t/m^2					for σ_e = 2.200 t/m^2				
	σ_b					σ_b					σ_b				
	40	50	-	-	-	-	50	60	70	80	-	50	60	70	80
0.08	1.05	1.04	-	-	-	-	1.05	1.04	1.04	1.04	-	1.07	1.06	1.05	1.05
0.09	1.11	1.09	-	-	-	-	1.10	1.09	1.08	1.08	-	1.15	1.12	1.10	1.10
0.10	1.17	1.14	-	-	-	-	1.16	1.14	1.13	1.12	-	1.23	1.20	1.17	1.15
0.11	1.23	1.20	-	-	-	-	1.22	1.19	1.18	[illegible]	-	1.34	1.28	1.24	1.22
0.12	1.30	1.26	-	-			1.29	1.25	1.23	1.21	-	1.45	1.37	1.32	1.26
0.14	1.47	1.39	-	-			1.44	1.38	1.34	1.32	-	1.74	1.59	1.49	1.44
0.16	1.68	1.53	-				1.64	1.54	1.46	1.42	-	2.17	1.87	1.72	1.62
0.20	2.30	1.89					[illegible]	[illegible]	[illegible]	[illegible]	-	3.95	2.84	2.30	2.15

S A T A , Swiss Association for Technical Assistance

STRUCTURAL ANALYSIS

Dimensioning in reinforced construction taking the axial compression force into account (2nd continuation)

No. : 3.910

Date : 2oth Febr.77

Sig : [signature]

TABLE 3

Coefficients K_e and K'_e

σ_e for σ_e = 1.200 t/m²

40

K_h	K'_e (in %)	K_e (in %)
13.0	-	94
12.9	03	
12.8	07	
12.7	10	94
12.6	13	
12.5	17	
12.4	20	
12.3	24	
12.2	27	93
12.1	30	
12.0	33	
11.9	37	
11.8	40	
11.7	43	93
11.6	46	
11.5	49	
11.4	52	94
11.3	55	

K_h	K'_e (in %)	K_e (in %)
11.2	58	
11.1	61	93
11.0	64	
10.9	67	
10.8	70	
10.7	73	92
10.6	76	
10.5	79	
10.4	82	
10.3	84	
10.2	87	92
10.1	89	
10.0	92	

50

K_h	K'_e (in %)	K_e (in %)
11.0	-	96
10.9	01	
10.8	04	
10.7	07	95
10.6	10	
10.5	13	
10.4	16	
10.3	19	
10.2	22	95
10.1	25	
10.0	28	
9.9	31	
9.8	34	
9.7	37	94
9.6	40	
9.5	43	
9.4	46	94
9.3	48	

K_h	K'_e (in %)	K_e (in %)
9.2	51	
9.1	54	94
9.0	56	
8.9	59	
8.8	62	
8.7	64	93
8.6	67	
8.5	69	
8.4	72	
8.3	74	
8.2	77	93
8.1	79	
8.0	81	
7.9	84	
7.8	86	
7.7	88	93
7.6	90	
8.5	93	

σ_e for σ_e = 1.400 t/m²

50

K_h	K'_e (in %)	K_e (in %)
11.5	-	81
11.4	-	
11.3	03	
11.2	06	81
11.1	09	
11.0	12	
10.9	15	
10.8	18	
10.7	21	80
10.6	24	
10.5	27	
10.4	30	
10.3	33	
10.2	36	80
10.1	38	
10.0	41	
9.9	44	
9.8	47	
9.7	49	80
9.6	52	
9.5	55	
9.4	57	
9.3	60	
9.2	62	79
9.1	65	
9.0	67	
8.9	70	
8.8	72	
8.7	75	79
8.6	77	
8.5	80	

60

K_h	K'_e (in %)	K_e (in %)
10.0	-	82
9.9	-	
9.8	03	
9.7	06	82
9.6	09	
9.5	12	
9.4	14	
9.3	17	
9.2	20	81
9.1	23	
9.0	25	
8.9	28	
8.8	31	
8.7	33	81
8.6	36	
8.5	38	
8.4	41	
8.3	43	
8.2	46	80
8.1	48	
8.0	50	
7.9	53	
7.8	55	
7.7	57	8U
7.6	60	
7.5	62	
7.4	64	
7.3	66	
7.2	69	80
7.1	71	
7.0	73	
6.9	75	
6.8	77	
6.7	79	79
6.6	81	
6.5	83	

70

K_h	K'_e (in %)	K_e (in %)
9.0	-	83
8.9	-	
8.8	01	
8.7	03	83
8.6	06	
8.5	08	
8.4	11	
8.3	14	
8.2	17	82
8.1	20	
8.0	22	
7.9	24	
7.8	27	
7.7	29	82
7.6	32	
7.5	34	
7.4	36	
7.3	39	
7.2	41	81
7.1	43	
7.0	45	
6.9	48	
6.8	50	
6.7	52	81
8.6	54	
6.5	56	
6.4	58	
6.3	60	
6.2	62	80
6.1	64	
6.0	66	
5.9	68	
5.8	70	
5.7	71	80
5.6	73	
5.5	75	
5.4	77	
5.3	78	
5.2	80	79
5.1	81	
5.0	83	

σ_e for σ_e = 2.200 t/m²

50

K_h	K'_e (in %)	K_e (in %)
13.0	03	50
12.9	06	
12.8	09	
12.7	12	50
12.6	15	
12.5	18	
12.4	21	
12.3	24	
12.2	27	50
12.1	29	
12.0	32	
11.9	35	
11.8	38	
11.7	40	50
11.6	43	
11.5	46	

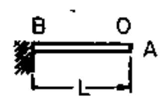
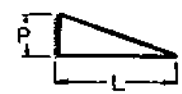
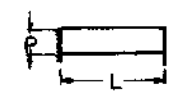
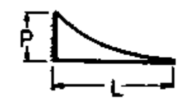
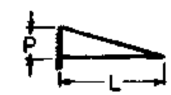
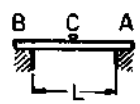
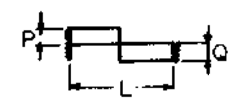
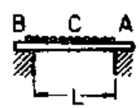
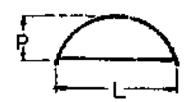
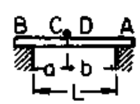
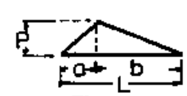
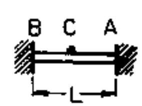
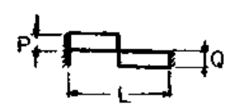
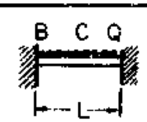
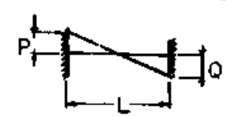
60

K_h	K'_e (in %)	K_e (in %)
11.5	-	50
11.4	-	
11.3	-	
11.2	02	50
11.1	05	
11.0	08	
10.9	10	
10.8	13	
10.7	16	50
10.6	18	
10.5	21	
10.4	24	
10.3	26	
10.2	29	50
10.1	31	
10.0	34	
9.9	36	
9.8	39	
9.7	41	50
9.6	43	
9.5	46	

70

K_h	K'_e (in %)	K_e (in %)
10.0	-	51
9.9	01	
9.8	04	
9.7	07	51
9.6	09	
9.5	12	
9.4	14	
9.3	17	
9.2	19	51
9.1	21	
9.0	24	
8.9	26	
8.8	29	
8.7	31	50
8.6	33	
8.5	34	
8.4	38	
8.3	40	
8.2	42	50
8.1	44	
8.0	46	

N. B. , For σ_b > 100, compression reinforcement is not permissible, because in that case σ_e will > σ_e permissible.

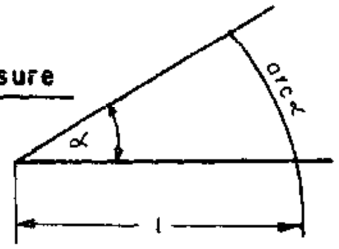
Method of Loading	Location of Maximum Bending	Location of Maximum Deflection	Bending Moment Maximum	Bending Moment Diagram	Shearing Forces Maximum	Shearing Forces Diagram	Maximum Deflection and Slope
	B	A	P = WL		P = W		$\frac{WL^3}{3EI}$; $\frac{WL^2}{2EI}$
	B	A	$P = \frac{WL}{2}$		P = W		$\frac{WL^3}{8EI}$; $\frac{WL^2}{6EI}$
	C	C	$P = \frac{WL}{4}$		$P = \frac{W}{2}$ $Q = \frac{W}{2}$		$\frac{WL^3}{48EI}$; $\frac{WL^2}{16EI}$
	C	C	$P = \frac{WL}{8}$		$P = \frac{W}{2}$ $Q = \frac{W}{2}$		$\frac{5WL^3}{384EI}$; $\frac{WL^2}{24EI}$
	C	D not max at C	$P = \frac{Wab}{L}$		$P = \frac{Wb}{L}$ $Q = \frac{Wa}{L}$		$\frac{Wa^2b^2}{3EIL} = \delta C$*
	at AB&C	C	$P = \frac{WL}{4}$ $Q = \frac{WL}{8}$		$P = \frac{W}{2}$ $Q = \frac{W}{2}$		$\frac{WL^3}{192EI}$
	A or B C	C	$P = \frac{WL}{8}$ $Q = \frac{WL}{12}$		$P = \frac{W}{2}$ $Q = \frac{W}{2}$		$\frac{WL^3}{384EI}$

*At D, distant $\sqrt{a(2L-a)\div 3}$ from B, $\delta = W(L-a)(2aL-a^2)^{3/2} \div 9\sqrt{3}EIL$

TRIGONOMETRY

Basic notations

Angular & circular measure



$$\hat{\alpha} = \text{arc}\ \alpha = \frac{\pi \cdot \alpha^\circ}{180^\circ}$$

$$\text{arc}\ \alpha \approx 0.017453 \cdot \alpha^\circ$$

$$\alpha^\circ \approx 57.2967 \cdot \text{arc}\ \alpha$$

Angular measure	0°	30°	45°	60°	90°	180°	270°	360°
Circular measure	0	$\frac{\pi}{6}$	$\frac{\pi}{4}$	$\frac{\pi}{3}$	$\frac{\pi}{2}$	π	$\frac{3\pi}{2}$	2π
arc ∝	0	0.52	0.78	1.05	1.57	3.14	4.71	6.28

The length of the arc of a circle which makes an angle ∝ with the centre of the circle with radius r is:

$$b = r \cdot \text{arc}\ \alpha$$

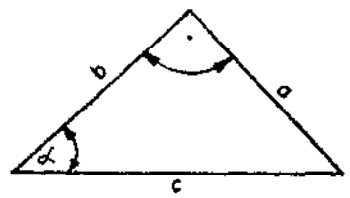
The right-angled triangle

$$\sin\alpha = \frac{\text{Perpendicular}}{\text{Hypoteneus}} = \frac{a}{c}$$

$$\cos\alpha = \frac{\text{Base}}{\text{Hypoteneus}} = \frac{b}{c}$$

$$\tan\alpha = \frac{\text{Perpendicular}}{\text{Base}} = \frac{a}{b}$$

$$\cot\alpha = \frac{\text{Base}}{\text{Perpendicular}} = \frac{b}{a}$$



Functional values of the important angles

Angle	0°	30°	45°	60°	75°	90°	180°	270°	360°
Sine	0	0.500	0.707	0.866	0.966	1	0	−1	0
Cosine	1	0.866	0.707	0.500	0.259	0	−1	0	1
tangent	0	0.577	1.000	1.732	3.732	∞	0	∞	0
Cotangent	∞	1.732	1.000	0.577	0.268	0	∞	0	∞

STRUCTURAL ANALYSIS
General Conversion Table

No. 13.913
Date : 20th Febr. 77
Sig :

GENERAL CONVERSION TABLE

Multiply by	To Convert	To	
2.54	Inches	Centimetres	0.3937
30.48	Feet	,, ...	0.3228
0.914	Yards	Metres	1.094
1609.3	Miles	,, ...	0.000621
6.45	Square Inches . .	Sq. cum.	0.155
0.093	Square Feet . .	Sq. Metres	10.764
0.836	Square Yards . .	,,	1.196
16.39	Cubic Inches . .	Cub. cms	0.061
28.3	Cubic Feet . .	Litres	0.0353
6.24	,, ,, . .	Gallons	0.1602
0.765	Cubic Yards . .	Cub. Metres	1.308
0.3732	Pounds (Troy) . .	Kilogrammes	2.68
1016.0	Tons	Kilogrammes	0.000984
4.546	Gallons	Litres	0.22
70.3	Lb. per sq. in. . .	Gm./sq. cm.	0.0142
1.575	Tons per sq. in. . .	Kgms./sq. mm. . .	0.635
4.883	Lb. per sq. ft. . .	Kgm./sq. metre . .	0.205
0.593	Lb. per cub. yd. . .	Kgm./cub. metre . .	1.686
16.02	Lb. per cub. ft. . .	,, ,, ,, . .	0.062
0.1833	Foot lb.	K'grammetres . .	7.23
0.33	Foot-tons	Tonne-metres . .	3.0
197.0	Metres sec. . .	Ft./min.	0.00508
1.488	Lb. per ft.	Kgm. per metre . .	0.672
0.496	Lb. per yd.	,, ,, ,, . .	2.016
3333.33	Tons per ft. . .	,, ,, ,, . .	0.0003
1111.11	Tons per yd. . .	,, ,, ,, . .	0.0009
10.936	Tons per sq. ft. . .	Tonnes/sq. metre . .	0.0914
1.215	Tons per sq. yd. . .	,, ,,	0.823
1.329	Tons per cub. yd. . .	Tonnes cub. metre . .	0.752
25.8	Inch tons	K'grammetre . .	0.0387
	To Obtain	From	Multiply by above

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STRUCTURAL ANALYSIS

Conversion table inches - mm
feet - mm

No :	[illegible]
Date :	[illegible] ebr.77
Sig :	[signature]

CONVERSION TABLE

in.	mm	ft.	mm	ft.	mm
1/16	1·59	1	304·8	25	7620·0
1/8	3·18	2	609·6	26	7924·8
3/16	4·76	3	914·4	27	8229·6
1/4	6·35	4	1219·2	28	8534·4
5/16	7·94	5	1524·0	29	8839·2
3/8	9·53	6	1828·8	30	9144·0
7/16	11·11	7	2133·6	31	9448·8
1/2	12·70	8	2438·4	32	9753·6
9/16	14·29	9	2743·2	33	10058·4
5/8	15·88	10	3048 0	34	10363·2
3/4	19·05	11	3352 8	35	10668·0
7/8	22·23	12	3657 6	36	10972·8
1	25·40	13	3962·4	37	11277·6
2	50·80	14	4267·2	38	11582·4
3	76·20	15	4572 0	39	11887·2
4	101·6	16	4876·8	40	12192·0
5	127·0	17	5181 6	41	12496·8
6	152·4	18	5486·4	42	12801·6
7	177·8	19	5791 2	43	13106·4
8	203·2	20	6096 0	44	13411·2
9	228·6	21	6400·8	45	13716·0
10	254·0	22	6705·6	46	14020·8
11	279·4	23	7010·4	47	14325·6
12	304·8	24	7315 2	48	14630·4

STRUCTURAL ANALYSIS

Mensurations of areas and volumes

No : 5.9?

Date : ?th ... 77

Sig :

MENSURATION — Areas

Square

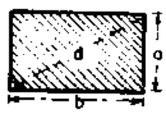
A = area.

$A = s^2$

$A = \frac{1}{2}d^2$

$s = 0.7071\,d = \sqrt{A}$

$d = 1.414\,s = 1.414\sqrt{A}$



Rectangle

A = area.

$A = ab$

$A = a\sqrt{d^2 - a^2} = b\sqrt{d^2 - b^2}$

$d = \sqrt{a^2 + b^2}$

$a = \sqrt{d^2 - b^2} = A \div b$

$b = \sqrt{d^2 - a^2} = A \div a$

Parallelogram

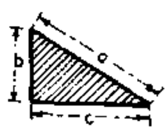
A = area.

$A = ab$

$a = A \div b$

$b = A \div a$

Note that dimension a is measured at right angles to line b.



Right-angled Triangle

A = area.

$A = \frac{bc}{2}$

$a = \sqrt{b^2 + c^2}$

$b = \sqrt{a^2 - c^2}$

$c = \sqrt{a^2 - b^2}$

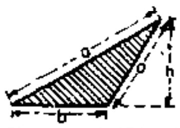
Acute-angled Triangle

A = area.

$A = \frac{bh}{2} = \frac{b}{2}\sqrt{a^2 - \left(\frac{a^2 + b^2 - c^2}{2b}\right)^2}$

If $S = \frac{1}{2}(a + b + c)$, then

$A = \sqrt{S(S-a)(S-b)(S-c)}$



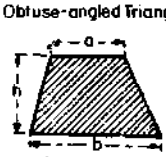
Obtuse-angled Triangle

A = area.

$A = \frac{bh}{2} = \frac{b}{2}\sqrt{a^2 - \left(\frac{c^2 - a^2 - b^2}{2b}\right)^2}$

If $S = \frac{1}{2}(a+b+c)$, then

$A = \sqrt{S(S-a)(S-b)(S-c)}$



Trapezoid

A = area.

$A = \frac{(a+b)h}{2}$

Trapezium

A = area.

$A = \frac{(H+h)a + bh + cH}{2}$

A trapezium can also be divided into two triangles as indicated by the dotted line. The area of each of these triangles is computed and the results added to find the area of the trapezium.

Regular Hexagon

A = area.

R = radius of circumscribed circle

r = radius of inscribed circle.

$A = 2.598s^2 = 2.598R^2 = 3.464r^2$

$R = s = 1.155r$

$r = 0.866\,s = 0.866R$

$s = R = 1.155r$

Circle

A = area; C = circumference

$A = \pi r^2 = 3.1416r^2 = 0.7854d^2$

$C = 2\pi r = 6.2832r = 3.1416\,d$

$r = C \div 6.2832 = \sqrt{A \div 3.1416} = 0.564\sqrt{A}$

$d = C \div 3.1416 = \sqrt{A \div 0.7854} = 1.128\sqrt{A}$

Length of arc for center angle of $1° = 0.008727d$

Length of arc for center angle of $n° = 0.008727nd$

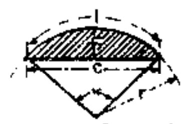
Circular Sector

A = area; l = length of arc; α = angle in deg.

$l = \frac{r \times \alpha \times 3.1416}{180} = 0.01745r\alpha = \frac{2A}{r}$

$A = \frac{1}{2}rl = 0.008727\alpha r^2$

$\alpha = \frac{57.296\,l}{r}$, $r = \frac{2A}{l} = \frac{57.296\,l}{\alpha}$



Circular Segment

A = area; l = length of arc; = angle in deg.

$c = 2\sqrt{h(2r-h)}$ $A = \frac{1}{2}[rl - c(r-h)]$

$r = \frac{c^2 + 4h^2}{8h}$ $l = 0.01745r\alpha$

$h = r - \frac{1}{2}\sqrt{4r^2 - c^2}$ $\alpha = \frac{57.296\,l}{r}$

Circular Ring

A = area.

$A = \pi(R^2 - r^2) = 3.1416(R^2 - r^2)$

$= 3.1416(R+r)(R-r)$

$= 0.7854(D^2 - d^2) = 0.7854(D+d)(D-d)$

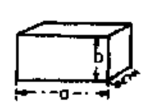
Circular Ring Sector

A = area; α = angle in degrees.

$A = \frac{\alpha\pi}{360}(R^2 - r^2) = 0.00873\alpha(R^2 - r^2)$

$= \frac{\alpha\pi}{4 \times 360}(D^2 - d^2) = 0.00218\alpha(D^2 - d^2)$

MENSURATION — Volumes of Solids



Square Prism

V = volume.

$V = abc$

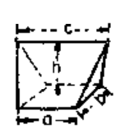
$a = \frac{V}{bc}$ $b = \frac{V}{ac}$ $c = \frac{V}{ab}$

Cube

V = volume.

$V = s^3$

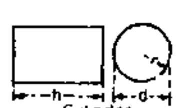
$s = \sqrt[3]{V}$



Wedge

V = volume.

$V = \frac{(2a + c)bh}{6}$



Cylinder

V = volume; S = area of cyl. surface.

$V = 3.1416r^2h = 0.7854d^2h$

$S = 6.2832rh = 3.1416\,dh$

Total area A of cylindrical surface and end surfaces:

$A = 6.2832r(r+h) = 3.1416d(\frac{1}{2}d + h)$

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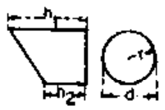
Volumes of Solids Continued.

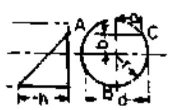


Portion of Cylinder

V = volume; S = area of cylindrical surface.

$V = 1.5708 r^2 (h_1 + h_2) = 0.3927 d^2 (h_1 + h_2)$

$S = 3.1416 r (h_1 + h_2) = 1.5708 d (h_1 + h_2)$



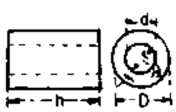
Portion of Cylinder

V = volume; S = area of cylindrical surface.

$V = \left(\frac{2}{3} a^3 \pm b \times \text{area } ABC \right) \frac{h}{r \pm b}$

$S = (ad \pm b \times \text{length of arc } ABC) \frac{h}{r \pm b}$

Use + when base area is larger, and − when base area is less than one-half the base circle.



Hollow Cylinder

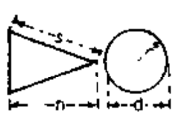
V = volume.

$V = 3.1416 h (R^2 - r^2) = 0.7854 h (D^2 - d^2)$

$= 3.1416 ht (2R - t) = 3.1416 ht (D - t)$

$= 3.1416 ht (2r + t) = 3.1416 ht (D + t)$

$= 3.1416 ht (R + r) = 1.5708 ht (D + d)$



Cone

V = volume; A = area of conical surface.

$V = \frac{3.1416 r^2 h}{3} = 1.0472 r^2 h = 0.2618 d^2 h$

$A = 3.1416 r \sqrt{r^2 + h^2} = 3.1416 rs = 1.5708 ds$

$s = \sqrt{r^2 + h^2} = \sqrt{\frac{d^2}{4} + h^2}$

Frustum of Cone

V = volume; A = area of conical surface.

$V = 1.0472 h (R^2 + Rr + r^2) = 0.2618 h (D^2 + Dd + d^2)$

$A = 3.1416 s (R + r) = 1.5708 s (D + d)$

$a = R - r \quad s = \sqrt{a^2 + h^2} = \sqrt{(R - r)^2 + h^2}$

Sphere

V = volume; A = area of surface

$V = \frac{4 \pi r^3}{3} = \frac{\pi d^3}{6} = 4.1888 r^3 = 0.5236 d^3$

$A = 4 \pi r^2 = \pi d^2 = 12.5664 r^2 = 3.1416 d^2$

$r = \sqrt[3]{\frac{3V}{4\pi}} = 0.6204 \sqrt[3]{V}$

Spherical Sector

V = volume; A = total area of conical and spherical surface.

$V = \frac{2 \pi r^2 h}{3} = 2.0944 r^2 h$

$A = 3.1416 r (2h + \frac{1}{2} c)$

$c = 2 \sqrt{h (2r - h)}$

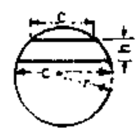
Spherical Segment

V = volume; A = area of spherical surface.

$V = 3.1416 h^2 \left(r - \frac{h}{3} \right) = 3.1416 h \left(\frac{c^2}{8} + \frac{h^2}{6} \right)$

$A = 2 \pi r h = 6.2832 r h = 3.1416 \left(\frac{c^2}{4} + h^2 \right)$

$c = 2 \sqrt{h (2r - h)}, \quad r = \frac{c^2 + 4h^2}{8h}$



Spherical Zone

V = volume; A = area of spherical surface.

$V = 0.5236 h \left(\frac{3 c_1^2}{4} + \frac{3 c_2^2}{4} + h^2 \right)$

$A = 2 \pi r h = 6.2832 r h$

$r = \sqrt{\frac{c_2^2}{4} + \left(\frac{c_2^2 - c_1^2 - 4h^2}{8h} \right)^2}$

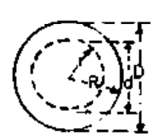
Spherical Wedge

V = volume; A = area of spherical surface.

α = center angle in degrees

$V = \frac{\alpha}{360} \times \frac{4 \pi r^3}{3} = 0.0116 \alpha r^3$

$A = \frac{\alpha}{360} \times 4 \pi r^2 = 0.0349 \alpha r^2$



Hollow Sphere

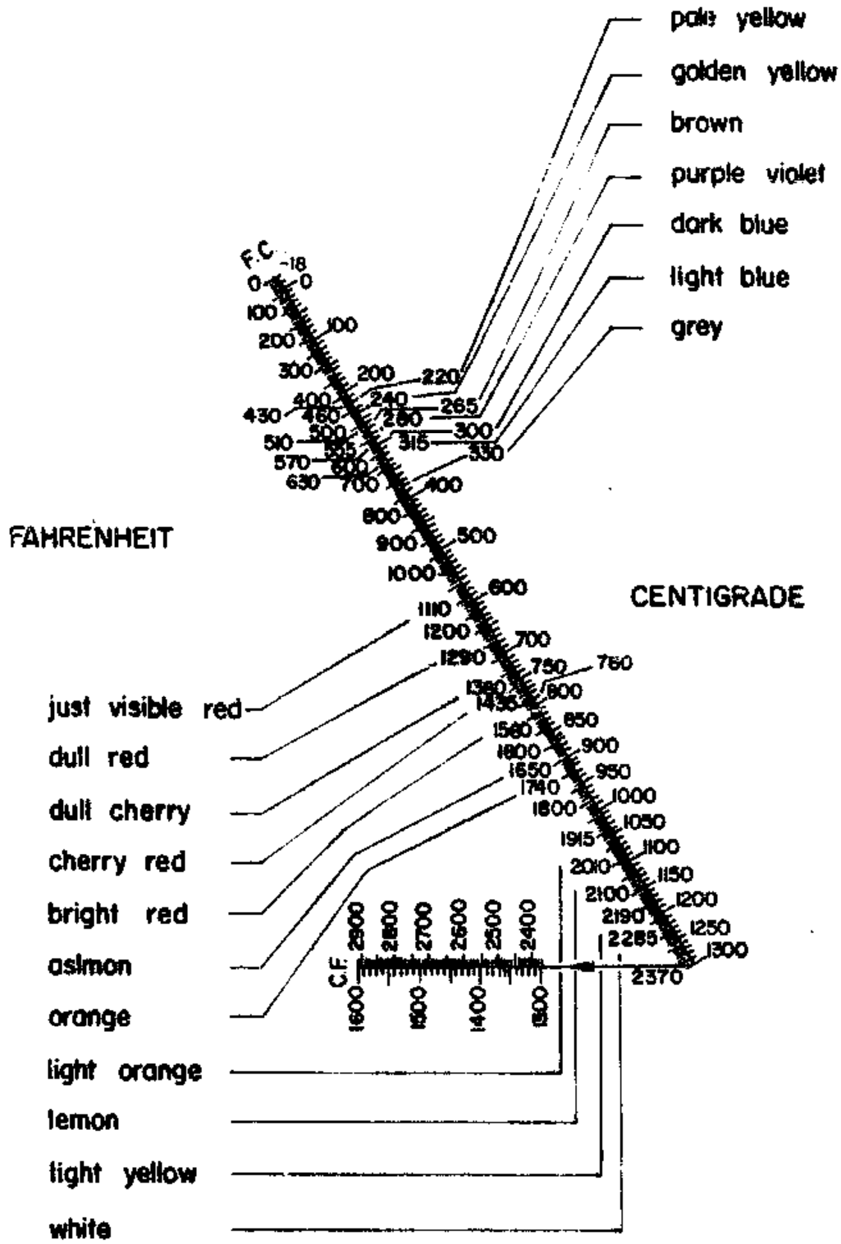
V = volume.

$V = \frac{4 \pi}{3} (R^3 - r^3) = 4.1888 (R^3 - r^3)$

$= \frac{\pi}{6} (D^3 - d^3) = 0.5236 (D^3 - d^3)$

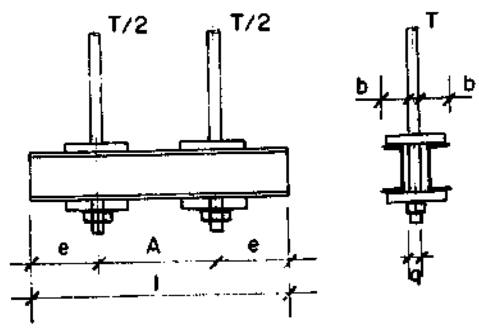
STRUCTURAL ANALYSIS	No. : 3.917
Colour indication of temperature of steel	Date : 21st Febr.7
	Sig :

COLOUR INDICATION OF TEMPERATURE OF STEEL



1st. Possibility

Under the assumption that the influence of transmission through the bond stress of the anchor neglected — due to the uncertainity about the composition of fill concrete- the calculation will be carried out in the following manner: In this case the cross girder will be usually stronger dimensioned then in the second possible calculation which is shown below:



1) $\sigma = \frac{T}{2 \cdot b \cdot l} \leq \sigma$ permissible (concrete)

2) If e > 0.207 l the max. Bending moment is:

$M_{max} = \frac{T \cdot e^2}{2 \cdot l}$

3) If e < 0.207 l the max. Bending moment is:

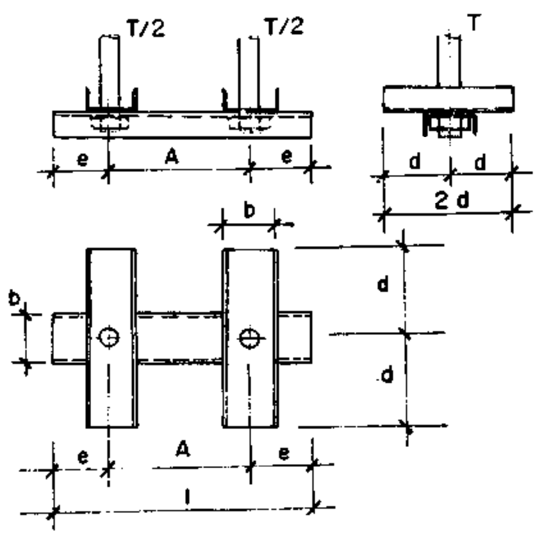
$M = \frac{T}{2} \left(\frac{l}{4} - e \right)$

4) Section of Modulus

$W = \frac{M_{max}}{2 \cdot \sigma_{all.}}$ (cm³)

2nd Possibility

In case the external dimensions require the greater expansion of the different Anchor rods, the calculation should be carried out in the following way:



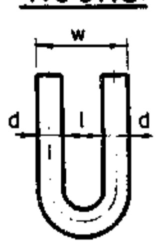
1) $\sigma = \frac{T}{2b\,[(2d-b)+2e]} \leq \sigma$ permissible (concrete)

2) If e = d $\qquad \sigma = \frac{T}{8eb + 2b^2}$

3) If e = d $\qquad M_{max} = \frac{T}{4 \cdot e}$

4) Section of modulus $= \frac{M_{max}}{\sigma_{all}}$ (cm³)

HOOKS:



TECHNICAL DATA

d mm	w mm	l mm	$l_{permissible}$ tons
20	65	25	5.03
25	80	30	7.80
32	100	36	12.87
38	125	49	18.10

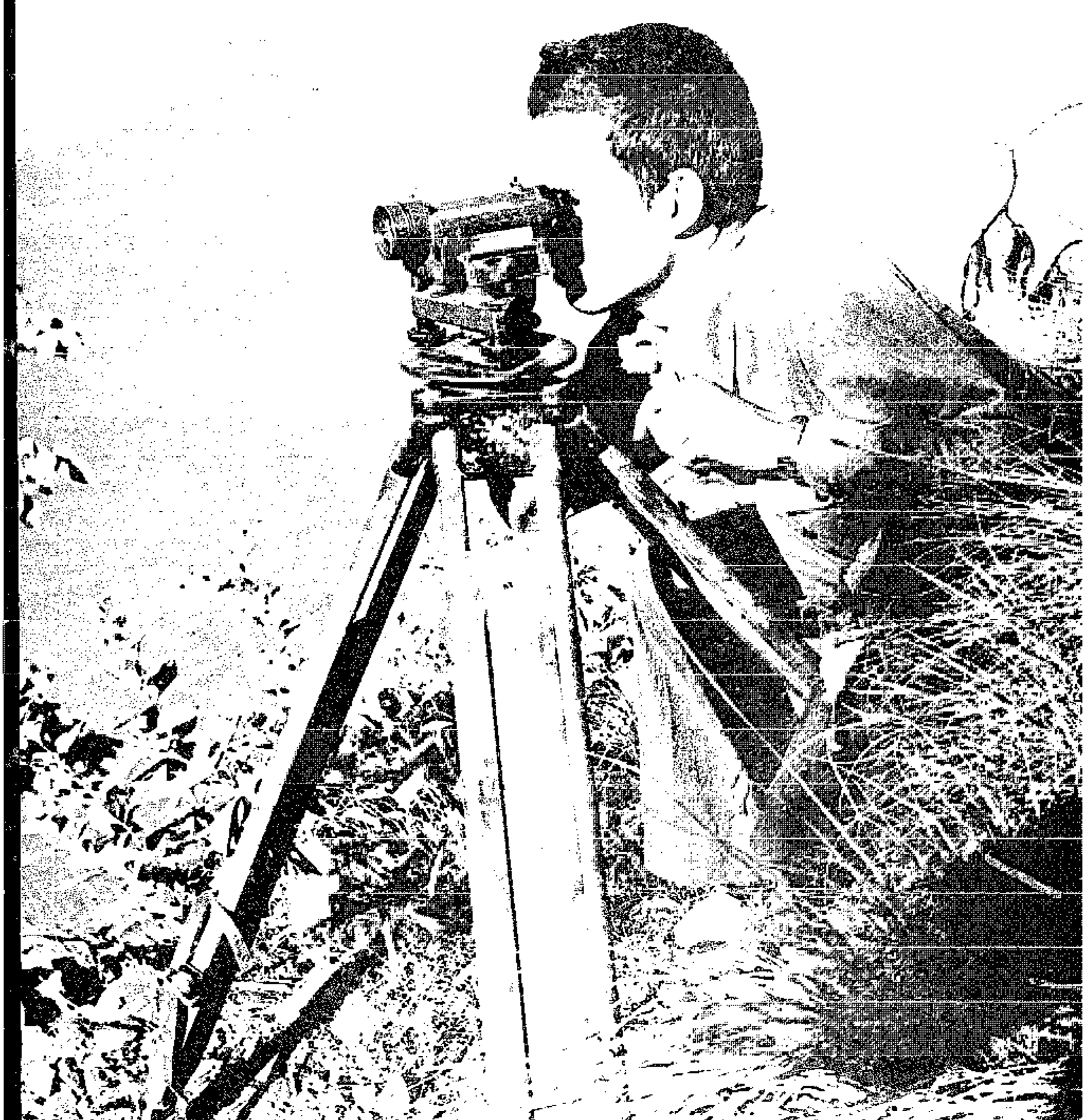
$W_{max} = 3.4\,d$

$l_{perm.} = \frac{2 \cdot d^2 \cdot \pi}{4} \cdot \sigma$

$\sigma_{perm.} = 8\,kg/mm^2$

d in mm

σ in kg/mm²



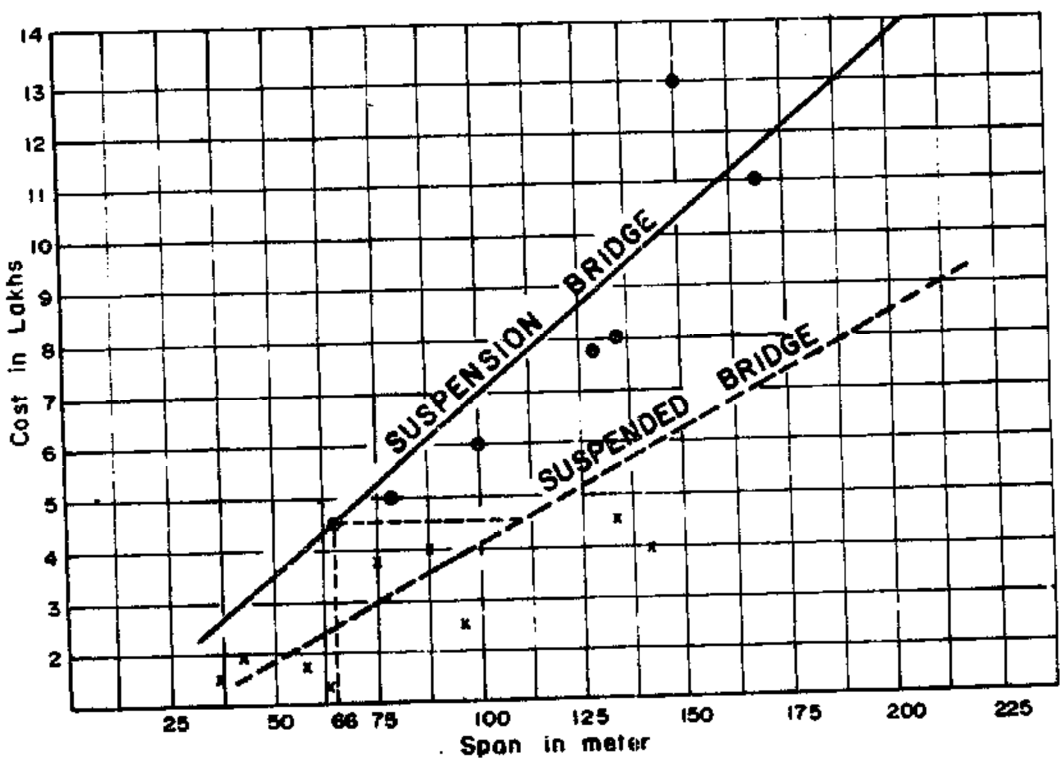
4. SURVEY OF BRIDGE SITES

4.100 Site Selection and Technical Report

1. Site Selection

The location of a bridge site is usually determined by economic, technical and political reasons and arguments. On the economic and technical point the main thought to consider is that there are two different types of bridges. One is the SUSPENDED BRIDGE and the other is the SUSPENSION BRIDGE. The cost of the Suspended Bridge is much less than that of the Suspension Bridge, even when the span is bigger. A general comparison of the costs is shown on the grafic below.

BRIDGE COSTS



e.g. Suspension Bridge of 66 m span

For the price of this Suspension Bridge you can build a Suspended Bridge with a span of 102 m

Also the conditions for the foundation should be considered very carefully. Do not select sites where big rock excavations will be necessary. Do not put foundations in slopes where land slides may occur. Big protection walls, Gabion walls and so on increase the costs of a bridge rapidly. A little bigger span more up- or downstream might still be cheaper. If it is not possible to find the best site in consideration of all these points, you can make two or three surveys in different places, so that an exact comparison can be made at the office.

2. Technical Report

The technical report should include the following points:

a) Location of proposed bridge site

Place:
River:
Trail:
Panchayat:
District:
Zone:
One inch map:
Co-ordinates:
Altitude:
Is there private or public land on the riverbank?

b) Existing crossing facilities

Is there a ferry, a temporary bridge?
Is it also possible to cross with animals?
How many months a year is it possible to cross the river?

c) Trails served and area of influence

Is there a main trail? From - to?

d) Traffic and economic background

How many people are crossing the river? What kind of goods are they carrying mainly? Is it possible that there would be more traffic after the construction of a bridge?

e) Potential benefits from the construction of the bridge
e.g. no ferry charge, shorter way from - to

f) Description of proposed bridge

1. Design caracteristics
   Type of bridge
   Span
   Main cables
   Walkway cables
   Main anchorage types: left bank / right bank
   Hight of towers
   Free board over hight flood level
   State why you selected this type of bridge
2. Foundation conditions
   Left bank, right bank
   Are there fields, rocks or big stones around? How steep is the slope? Are there trees or bushes on the site? May land slides occur? (How to make soil investigations, see chapter 'Soil Investigation'.)
3. Hydrology
   Width of the river
   Width of the river during hight flood
   River bed gradient at centre line of the bridge
   Is the river calm or not?
   Is the riverbed flat ore sloping?
4. Approach trails
   Is it necessary to build approach trails? Is blasting required for that? How long will this trail be?
5. Local materials
   Are the following materials available at the site? Where do they have to be carried from (distances)?:
   Stones
   Rubble
   Gravel
   Sand
   Wood
   Sal wood
   Salla wood
   Bamboo

6. Miscellaneous

General remarks about the site and about existing houses, walls, protection walls, etc.

g) Cost of the proposed bridge

h) Fotos of the bridge site

In the fotos the main survey points should be shown. The fotos should also show the foundation conditions.

i) Transport routes and access to the bridge site

1. Transport routes

Nearest roadhead served by trucks
Is it possible that a road to a nearer point will be finished soon?
Transport distance by porters in miles and days
Porter charge, availability of porters and
Favorable months for the transportation

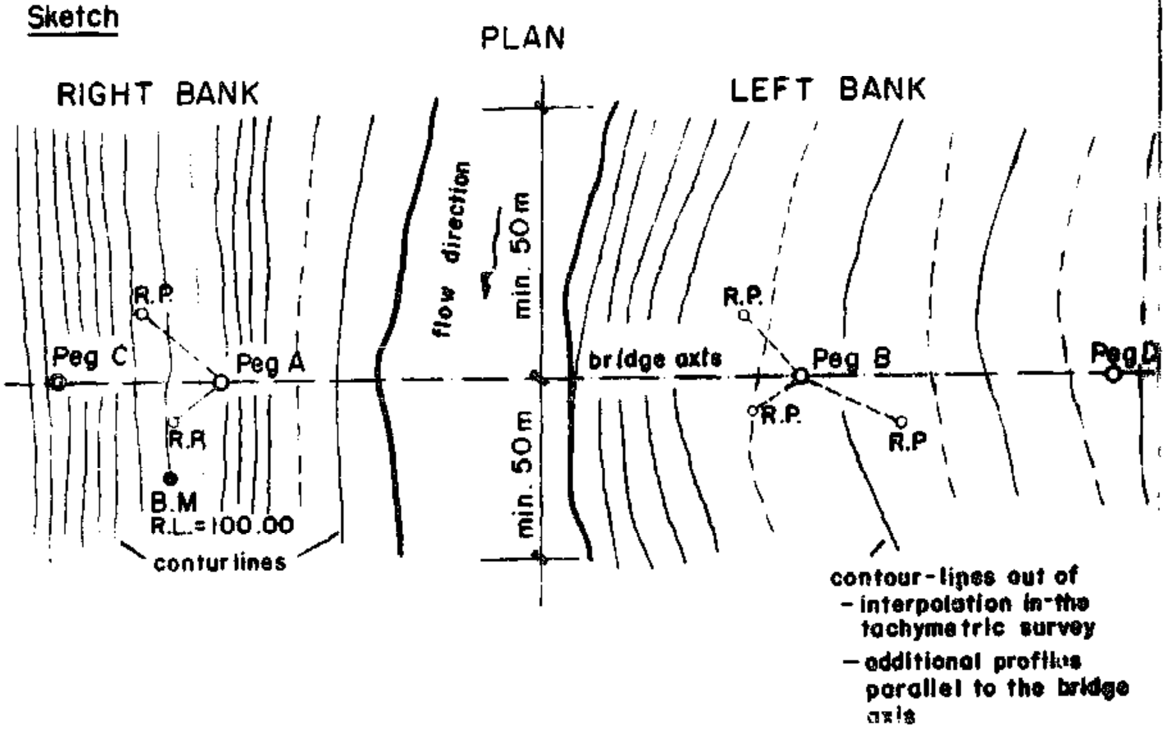
2. Access to the bridge site

Nearest air field (regular flights or not)
Nearest bus or railway station
Walking distance in miles and days
Distance to the nearest wireless station
Distance to the nearest post office
Other possibilities of communication

SURVEY OF BRIDGE SITES	No.: 4.2ol
Site Survey, after the Site Selection (I)	Date: 6. 8.1975
	Sig.:

Material required:
- Theodolite with tripod and levelling-staff
- Measuring tape 2o to 3o meters long
- Carpenter - level (spirit level)
- Steel - tape, 2 to 3 meters long
- Steel - pegs , Paint

Sketch



Description:

1. Determine the future bridge center-line with the aid of two pegs, one on each bank (points "A" and "B"). The pegs should be 4o cm to 5o cm long and driven at least 2/3 of their length into the ground. They must be of good wood or steel and marked with paint.

2. Measure some reference points (R.P.) for these two pegs. Make a sketch with the location of the reference points.

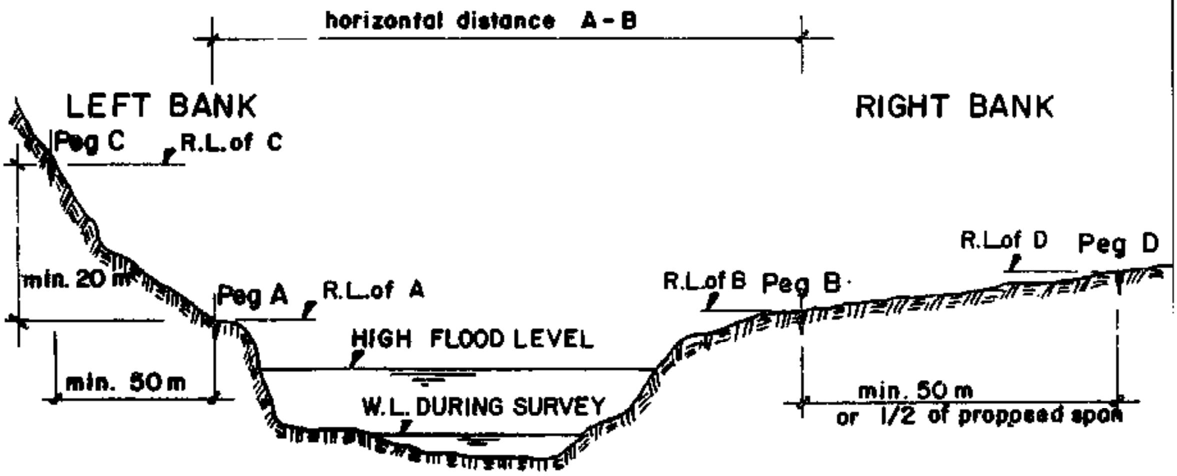
3. Establish a bench mark as point of origin for the elevations (R.L. 1oo.oo m). This can be the top of a big stone or one of the pegs "A" or "B".

4. Set up two additional pegs "C" and "D" in the center-line, at least 3o meters behind "A" or "B" if the ground is flat or at least 2o meters higher than "A" or "B" if the ground is sloped.

SURVEY OF BRIDGE SITES Site Survey, after the Site Selection (II)	**No.:** 4.202 **Date:** 6. 8.1975 **Sig.:** D-Elmer

Sketch

PROFILE



5. With theodolite and staff, determine the distances and differences in elevation between the pegs "A","B","C","D" (see 4.3oo).

   Two independent measurements of the distance "A-B" must be made (see 4.3o3).

6. Obtain the size and form of the area around the proposed bridge site using either a tacheometric survey (described in 4.3oo) or the parallel profile method (described in 4.2o3).
   The survey should extend **min 50 m upstream and downsteam**
   ream.

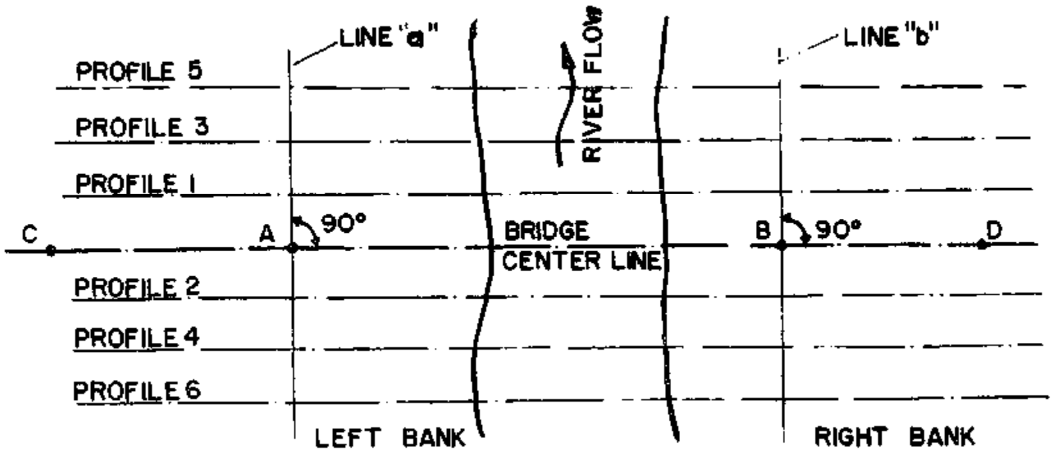
7. Make the profile measurements either by the "step-method" (see 4.3o6) or by the tacheometric method (see 4.3oo).
   - If the ground is flat the profile should extend at least 5o meters behind the probable tower place.
   - If the ground is steep the profile should extend at least 2o meters higher than the probable tower place.

   For long spans (more than 12o meters) the profile should extend further than 5o meters.

8. Make notes on:
   - Soil conditions for the construction.
   - Availability of construction materials.
   - Transport route for bridge-parts and cement; rates.
   - Living conditions (food,housing) for the bridge staff.
   - River-crossing during the construction-period.
   - Availability of labourers and their rates.
   - Slides at the bridge place, upstream from the bridge site and of the highest flood-level of the past. (e.g. Sun Kosi 2o11, Gandaki 2o18).

SURVEY OF BRIDGE SITES Site Survey, After Site Selection (III)	**No.:** 4.2o3 **Date:** 22. 8.1975 **Sig.:** W. Ehrer

Sketch for the survey of the bridge-area with parallel profiles.



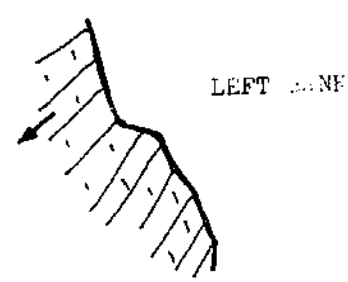
Description:

1. On a perpendicular line to the bridge center-line, set from peg "A" additional pegs at intervals of 5.oo m both upstream and downstream (line "a").
2. Do the same on the other side, starting from peg "B" (along line "b").
3. From the so determined pegs measure the profiles (profile 1,2...) either by the tacheometric method (4.3oo) or the "step-method" (4.3o6).

Information about Rock

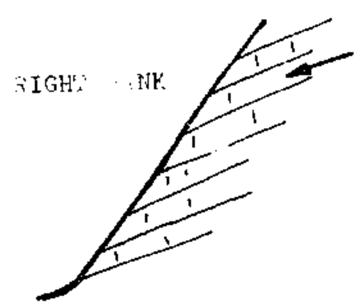
If the construction-site has on one or on both sides rock, make a sketch in which you show the rock formation. (direction of the layers, strike of the rock/layers).

Example:



Note down the nature of the rock.

or:



e.g. - loose rock, soft rock, can be broken with hammer and crow-bar.

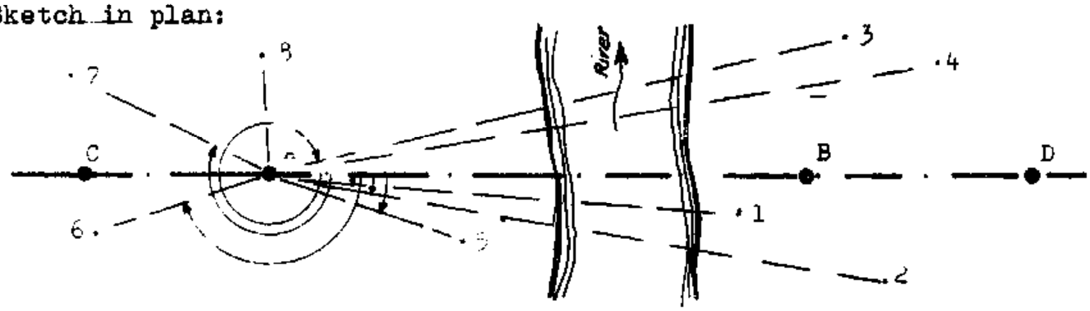
- rock with clearly developed layers, blasting partly required.
- hard homogenous rock, no layers visible, must be blasted.

SURVEY OF BRIDGE SITES	No.: 4.204
Survey methods, Tacheometric survey	Date: 17. 7.1975
	Sig.:

Material required: Theodolite with tripod and levelling-staff

Summary: With the aid of the theodolite and the staff, horizontal distances and differences in elevation between the theodolite-station and the staff-points are determined, independent of the uneveness of the ground between the points.

Sketch in plan:



Description:

1. Set the theodolite on point A, measure the height of instrument.
2. Bring the 0°-reading of the horizontal-circle in coincidence with the bridge axis (Direct the telescope towards point B with the horizontal-circle clamped in 0°-position).
3. After proper alignement take for every staff-point the readings of the horizontal circle, the vertical circle, the top hair, the middle hair, the bottom hair and note it down.
4. The staff should be placed at well-defined points in order to describe the shape of the ground as accurately as possible.
   e.g. changes in the gradient, in the slope, other breaks in the ground; details such as houses, big stones, trees, foot-trail, rock, river-bank, high-flood level, pegs B,C,D, B.M. etc.
5. Using the tables "TACA" calculate the horizontal and vertical distances according to 4.3o1 and 4.3o2. (Ordinary tables for the trigonometrical values can also be used.)

<u>Note:</u>
- The staff must be kept in a vertical position. A slight inclination from the vertical will result in a large error in the calculated distances!
- The accuracy obtained by this method is about 0.3% of the distance. The range can be up to 2oo to 25o meters.
- In the calculations the horizontal distances are rounded off to ± o.1o m and the differences in elevations to ± o.o5 m .

SURVEY OF BRIDGE SITES

Survey methods, Tacheometric survey
Readings and calculation

No.: 4.204A

Date: 15. 7.1975

Sig.: D. E[illegible]

S A T A , Swiss Association for Technical Assistance

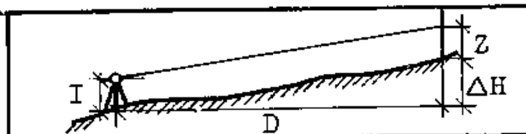
$D = 100 \cdot L \cdot \cos^2\alpha \quad (L = L_1 - L_2)$

$V = 100 \cdot L \cdot \sin\alpha\cos\alpha = 50 \cdot L \cdot \sin 2\alpha$

or $V = D \cdot \tan\alpha$

$\Delta H = V + I - Z$

$H = H_{Stn.} + \Delta H$

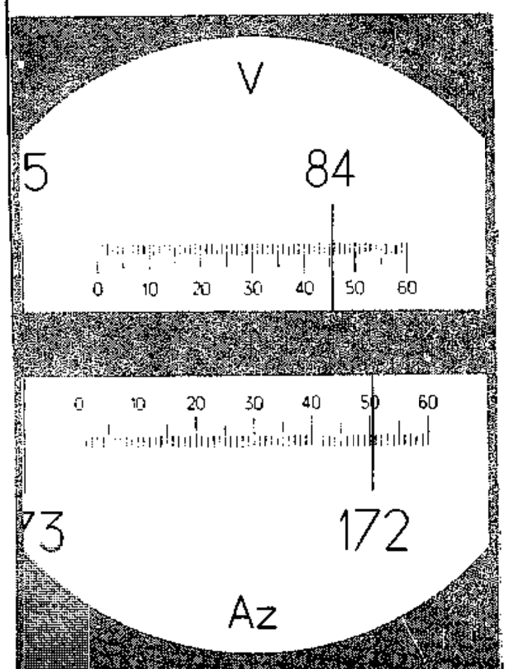


STATION HT.OF INSTR. I ft/m	STAFF STATION	HORIZ. CIRCLE o/g '/c	VERTICAL CIRCLE α ± o/g '/c	TOP HAIR L_1 ft/m	MIDDLE HAIR Z ft/m	BOT. HAIR L_2 ft/m	STAFF INTERC. L ft/m	HORIZ. DISTANCE D ft/m	VERT. DIST. V ± ft/m	DIFF. IN ELEV. ΔH ± ft/m	RED. LEVEL H ft/m
Station	1	172 50.4	84 45.6	1410	1249	1087	0323	3200	+ 295	+ 315	10315
Peg A	2	. . .									
(R.L. = 100.00)	3	. . .									
(I = 1.46m)	:										
	:										

From the tables "TACA":

$100 \times \sin^2 84^\circ 45.6' = 100 \times \cos^2 5^\circ 14.4' = 99.2$

$100 \times \sin\alpha \cos\alpha = 50 \times \sin 2(+5^\circ 14.4') = + 9.09$



Example:

Horiz. circle = 172° 50,4

Vert. circle = 84° 45,6

Top Hair = 1.410 m

Middle Hair = 1.249 m

B. Hair = 1.087 m

(I = 1.46 m)

Remark:

As that theodolite has 0° in the zenith the vertical circle reading of 84° 45,6 gives an angle α of +5° 14,4

HMG Nepal **Roads Department** **Suspension Bridge Division**

SURVEY OF BRIDGE SITE

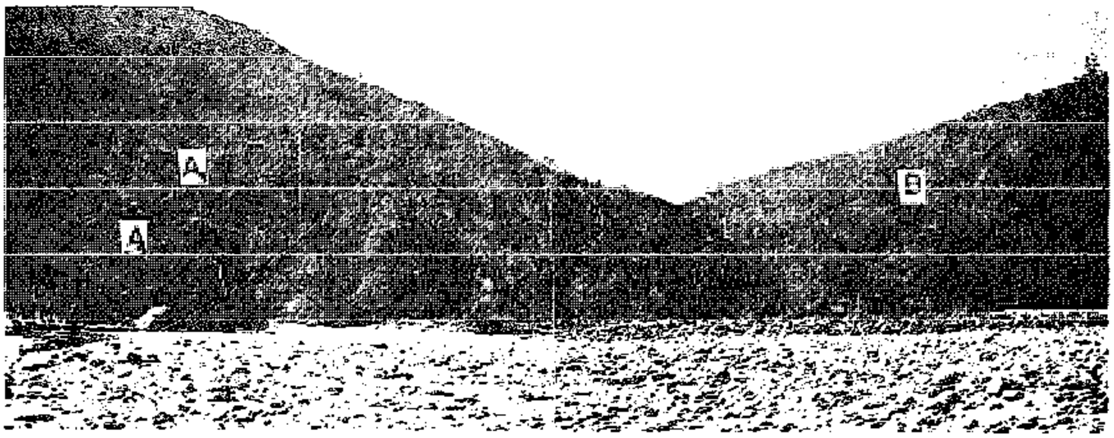
Fotos of surveyed Bridge sites

(525 Pikuwa Khola)

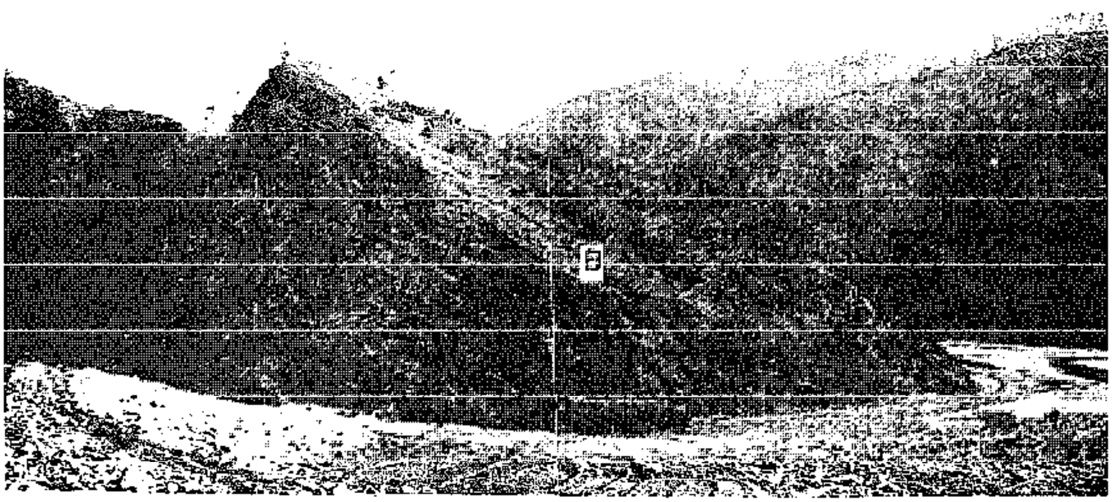
No : 4.205

Date : 28.2.77

Sig : Landvan



- Site view from downstream



Left bank

Right bank

SURVEY OF BRIDGE SITE

Tachimetric Survey with K1-RA

No	4.206
Date	28.12.1976
Sig	Land Han [illegible]

This survey can be done in the same way as shown on page 4.204. There are only some differences in the reading and calculations. With this instrument you will get directly the horizontal distance. No more calculation for that is necessary. You can also get directly the difference in elevation ΔH. This difference you can also get by the calculation ΔH = D. tang. When the slope of the line of sight is small, this method yields better results than direct reading on the rod.

TACHYMETRIC SURVEY with KERN K 1-RA

BRIDGE NR.

JOB: ________ DATE: ________

INSTR.MAN: ________ NOTE-KEEPER: ________

STATION / TARGET	HORIZ. CIRCLE g	c	VERTIC CIRCLE ±	tang	HORIZ DIST. D m	HEIGHT: INSTR. I / SIGHTED Z m	DIFF. IN ELEV. ΔH ±	m	ELEVATION m	REMARKS
PF6						1.50			100.00	
1	170	653	+	0 2047	15 60	1.50	+	3.19	103.19	Bridge Axis

DIFFERENCE IN ELEVATION:

Selector ring on ΔH: I = Z: ΔH = Reading

I ≠ Z: ΔH = Reading + I − Z

With vertic. angle : ΔH = D·tang + I − Z

HMG NEPAL, ROADS DEPARTMENT SUSPENSION BRIDGE DIVISION

e.g. Horizontal circle 170.6530

Vertical circle (tang) +0.2047

Distance (direct reading) 15.60 m

Difference in elevation 0.2047 x 15.60 = 3.19 m

or direct reading

SURVEY OF BRIDGE SITES

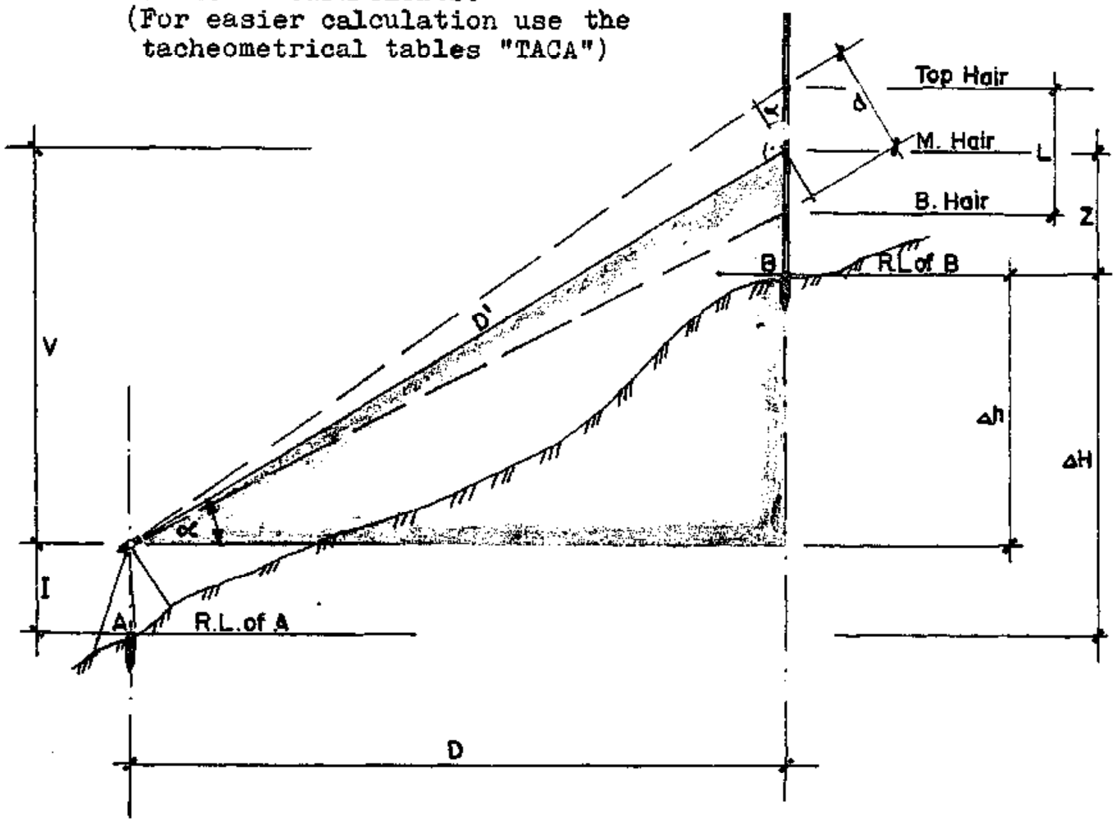
Survey methods, Tacheometric survey

No.: [illegible]07

Date: 1[illegible]. 7.1975

Sig.: [signature]

<u>Sketch</u> to explain the calculation of horizontal distance and difference in level out of inclined tacheometrical measurements.
(For easier calculation use the tacheometrical tables "TACA")



Instrument station A

Staff station B

Readings: L_1 = Top Hair
Z = Middle Hair
L_2 = Bottom Hair

α = Vertical angle
I = Height of instrument

Calculation: $L = L_1 - L_2$

$d = L \times \cos\alpha$

$D' = 100 \times d = 100 \times L \times \cos\alpha$

$D = D' \times \cos\alpha = \underline{100 \times L \times \cos^2\alpha}$

$V = D \times \sin\alpha = \underline{100 \times L \times \sin\alpha \times \cos\alpha}$

or $\frac{V}{D} = \tan\alpha$, $V = \underline{D \times \tan\alpha}$

$\Delta h = V - Z$

$\Delta H = \Delta h + I = V + I - Z$

R.L. of B = R.L. of A + ΔH

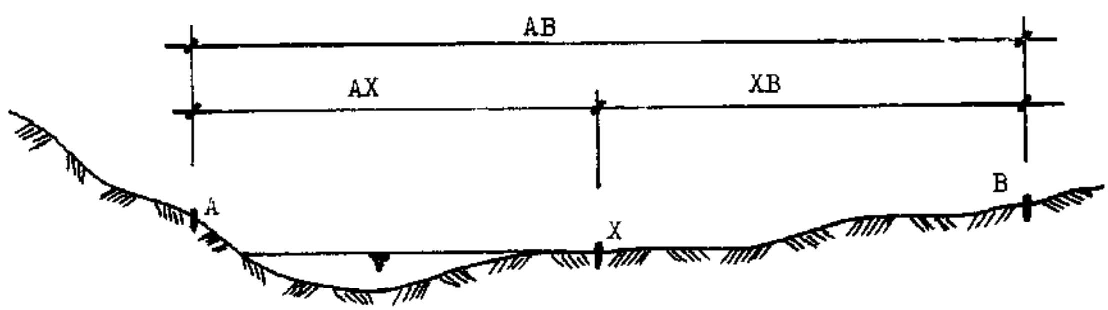
SURVEY OF BRIDGE SITES	No.: 4.208
Survey methods, Distance across the river	Date: 1.5.1975
	Sig: D. Elmer

After the distance-measurement by the tachymetric method (see 4.3-1) across the river, a second independent measurement must be made.

a) Dividing of the total distance into two parts

If the river-bed is partly free of water the distance AB can be divided by the help of an additional peg X into two parts. The distances A to X and X to B can then be measured by the tachymetric method and their sum will give the total distance.

Sketch:

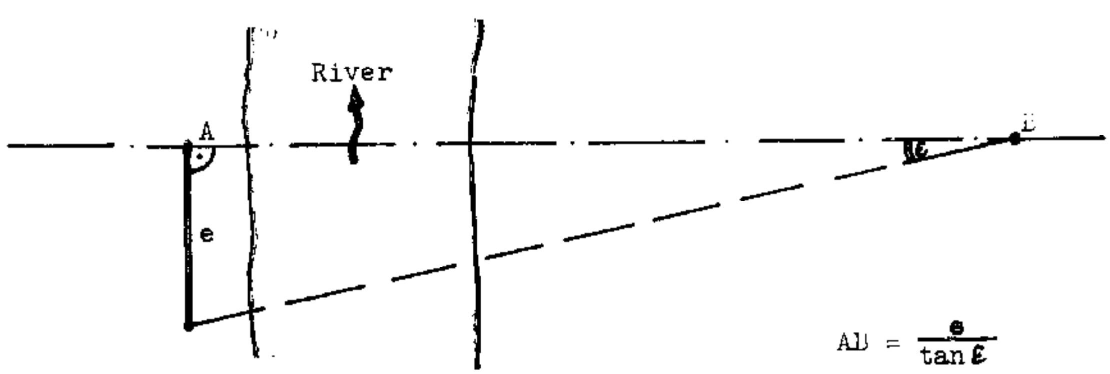


$AB = AX + XB$

b) Triangulation Method

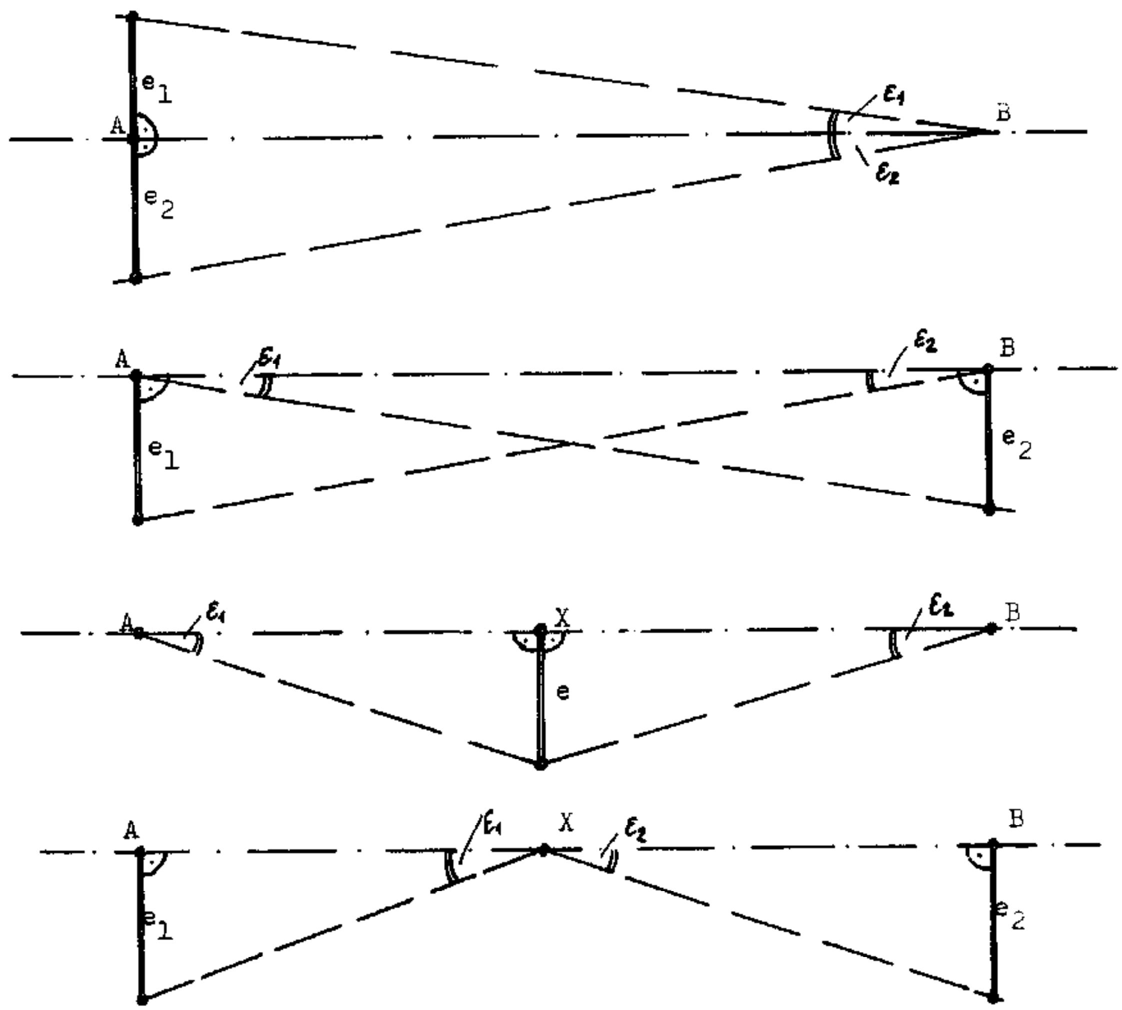
Pegging out of a baseline e perpendicular to the bridge center-line in A or B . The length of e should be at least 10% of the distance A to B.
Measurement of the distance e by tape.
Measurement of the opposite angle ε. ε and e must be measured as accurate as possible.
Calculation of the Distance AtoB by the formula $AB = e \times \cot\varepsilon = \frac{e}{\tan\varepsilon}$

Sketch in plan:



$AB = \frac{e}{\tan\varepsilon}$

Other possible arrangements for the triangulation method to obtain higher accuracy:



c) Measurement by Rope or Tape

The distance from A to B can also be checked by measuring directly with a tape in several steps or with a rope (rope-length afterwards measured by the tape).
These methods are often not very accurate because the river-banks may be steep and therefore not favorable for a good measurement of horizontal distances. They should only be used for a rough check of the distance.

In order to facilitate control of the construction process Bench Marks (B.M.), indicating elevations, should be set up on both banks.
There should be a Bench Mark for every main anchorage as well as for the tower foundations (abutments) and the wind-guy-anchorages.

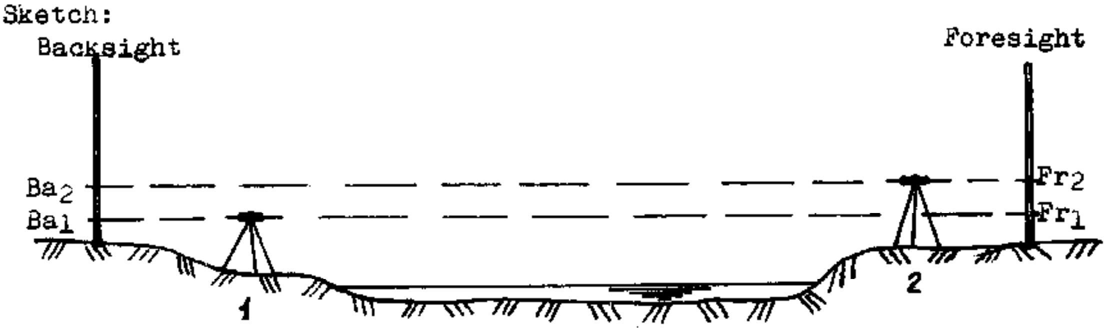
The tops of solid stones or strong pegs may be chosen as Bench Marks. They must be marked clearly with paint and a sketch of their location (reference distances) should be prepared.

One Bench Mark is fixed as point of origin with R.L. 100.00 m and then all the others are levelled by the "rise and fall method".

Remarks concerning levelling across a river:

To eliminate errors of the instrument as far as possible the following procedure should be applied.

Sketch:



- Mark the two staff points "Back" and "Front".
- Set the instrument on the left bank (position 1) and take the readings Back (Ba 1) and Front (Fr 1).
- Set the instrument on the right bank and take again the readings Back (Ba 2) and Front (Fr 2).
- Calculate the difference of level (Backsight-reading minus Foresight-reading) for:

  instrument-position 1 $\Delta L_1 = Ba\ 1 - Fr\ 1$
  and instrument-position 2 $\Delta L_2 = Ba\ 2 - Fr\ 2$

  The mean of the two is to be taken as the difference of level

$$\Delta L = \frac{1}{2}(\Delta L_1 + \Delta L_2)$$

Important note for all levellings

A levelling must always be checked by closing it on a point already known in elevation.
That point may be either the B.M. from which the levelling was started or another B.M. whose elevation has been determined in a previous levelling.

SURVEY OF BRIDGE SITES	No.: 4.211
Survey methods, "Step-method" for profile measurements	Date: 27. 7.1975
	Sig.: D.S[signature]

Material required: Levelling-staff (4.oo m), Carpenter's level (spirit level), Steel-tape (2.oo to 3.oo m).

Summary: After the measurement of distances and differences in elevation between the pegs A,B,C,D (see 4.2o1) the profile between these pegs is measured in "steps". The levelling-staff will be the horizontal line and the steel-tape the vertical line of such a step. The staff is kept horizontal with the aid of the carpenter's-level, the steel-tape vertical with a plumb bob, a stone being dropped or just by eye.

Description

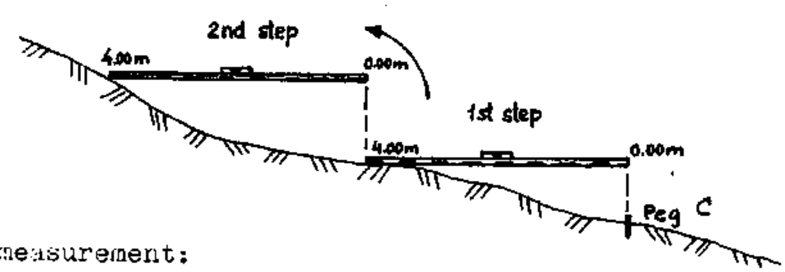
The measurement starts from a peg, preferably C or D (sketch on 4.2o2). The first one or two steps should be measured from this peg uphill and then only downhill towards peg A and B respectively.

Four persons are needed; one to watch the bubble and, together with a second one, to keep the staff in horizontal position, a third one to read and measure horizontal and vertical distances and the fourth one to note down the measurements.
The carpenter's-level must be attached to the levelling-staff.

Uphill measurement:

- Move the staff (0.oo m - end in the air, 4.oo m - end on the ground) uphill until the zero-end is directly above peg C.
- For the next step the staff must again be moved uphill until the zero-end is now directly above the point touched by the 4.oo m-end of the first step, and so on.

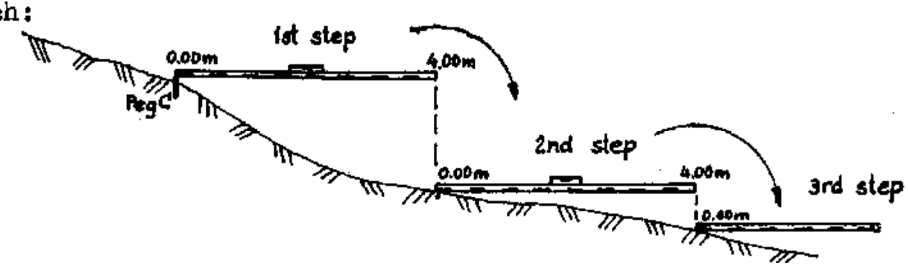
Sketch:



Downhill measurement:

- Set the zero-end of the staff on the peg (4.oo m - end in the air) and mark the end of the step directly down to the ground.
- Now bring the zero-end down to this mark; the 4.oo m - end will then give the origin of the next step, and so on .

Sketch:

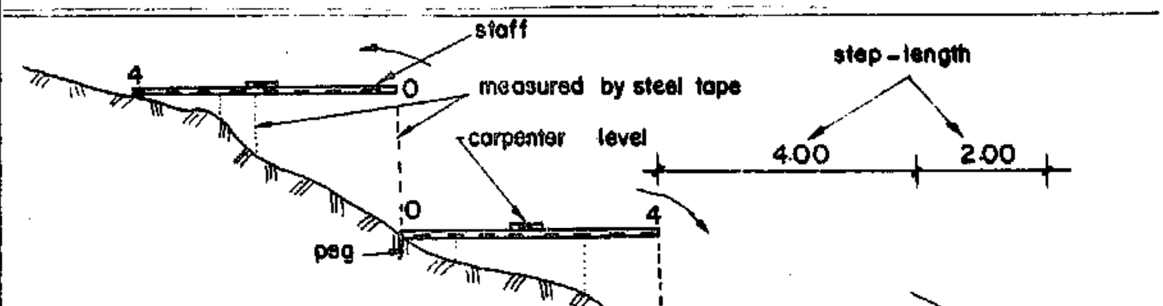


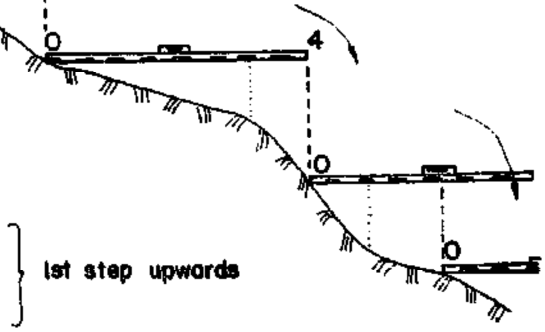
SURVEY OF BRIDGE SITES Survey methods, "Step-method" for profile measurements, details	No.: 4.212 Date: 27. 7.1975 Sig.: D. Elmer

Detail measurements:

- In addition to the "step-heights" at the zero-end and 4.oo m - end, vertical distances are also measured at breaks in the gradient of the ground.
- For all these points the horizontal distances are read on the staff (always starting from the zero-end) and the vertical distances measured with the steel-tape.
- In steep places the "step-length" may be reduced to 3.00 m , 2.oo m or 1.5o m .

Sketch:





EXAMPLE FOR THE NOTES,

horiz. distance	vertical distance	remarks	
	from peg upwards		
0.00	2.20	on the peg	1st step upwards
2.10	0.90	field, earth	
2.70	0.30	field, earth	
4.00	0.00	field, earth	
	from peg downwards		
0.00	0.00	on the peg	1st step downwards
0.80	0.40	field earth	
2.80	0.90	field mixed	
4.00	1.80	field with	
0.00	0.00	field stones	2nd step downwards
3.10	0.90	"	
4.00	1.90	bushes, stones	
0.00	0.00	" , stones	3rd step downwards
0.90	1.10	" "	
2.00	1.40	" "	
0.00	0.00	bushes ,stones	

Note: The measurements between two pegs (e.g. C and A) should be checked.

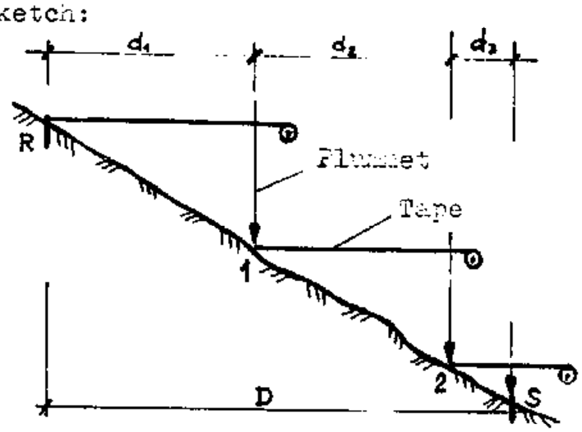
- The sum of all the step-lengths should give the horizontal distance between the pegs.
- The sum of the vertical distances at the step-ends (zero-end and 4.oo m - end) should give the difference in elevation between the pegs.

- With Measuring Tape and Plummet (Plumb bob)

Judging by eye the tape is kept horizontal.
At least two persons are needed, one at each end of the tape.

If the difference in elevation becomes too great (more than 1.80 m) the distance should be divided into two, or more parts.

Sketch:



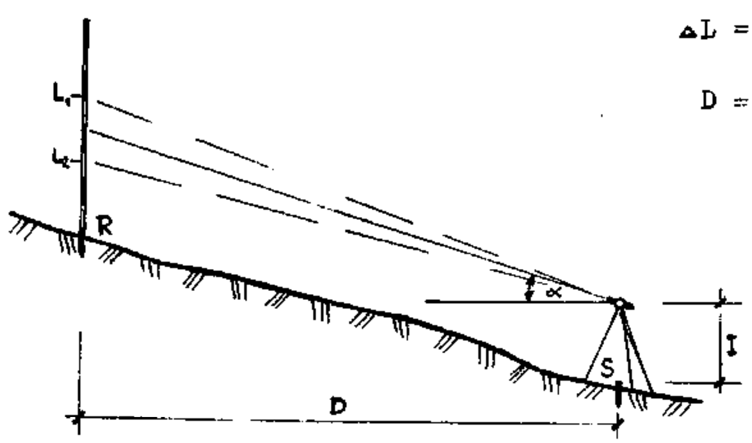
$D = d_1 + d_2 + d_3$

Note: The zero-end of the tape should always be on the side touching the ground.
Start measuring from the higher point towards the lower one.
For greater accuracy put a peg at every intermediate point.
(at the points 1,2 ...)

- With Theodolite and Levelling-Staff (see also 4.300)

With the aid of top and bottom hair, the staff - interception ΔL is determined. Together with the also measured vertical angle α the horizontal distance can then be calculated.

Sketch:



$\Delta L = L_1 - L_2$

$D = 100 \times \Delta L \times \cos^2\alpha$

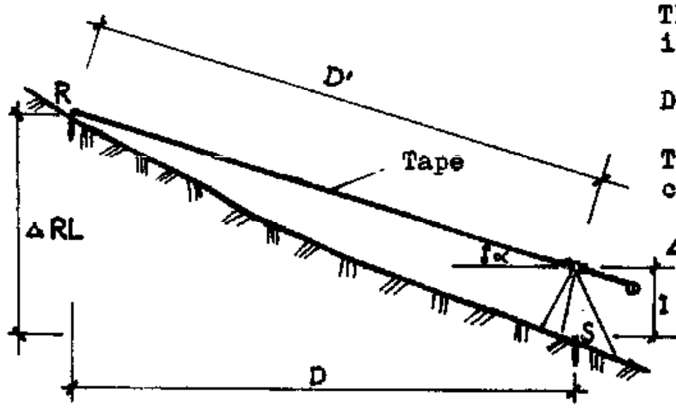
Note:
The staff must be kept vertical (check with plummet or spirit level).
Possible accuracy obtainable by this method is about 0.3 % of the distance.

SURVEY OF BRIDGE SITES	No.: 4.214
Survey methods, Measurement of horizontal distances on slopes (II)	Date: 28. 7.1975
	Sig.:

- <u>With Theodolite and Measuring Tape</u>

With the tape measure the direct distance "D'" from the theodolite-axis to the peg "R". With the theodolite measure the vertical angle " " by aiming at the peg "R".

Sketch:



The horizontal distance is found by

$$D = D' \times \cos\alpha$$

The difference of level can also be calculated by

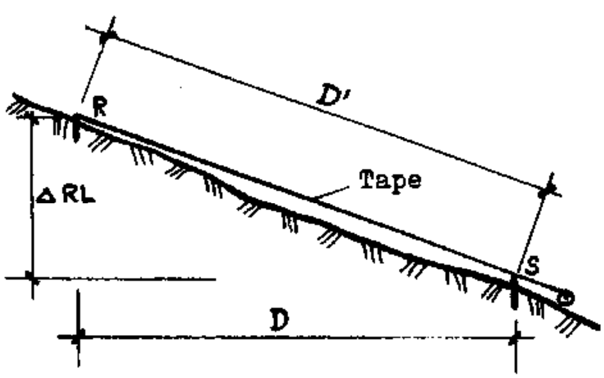
$$\Delta RL = D' \times \sin\alpha + I$$

<u>Note:</u> This method is limited to distances up to the length of the tape.
It can also be applied in very steep places (rock), when R is not accessible by staff or theodolite.

- <u>With Measuring Tape and known RL of the two points</u> (R and S)

If the RL of the pegs "R" and "S" are known from a levelling, we can measure the direct distance D' between the two pegs by tape.

Sketch:



The horizontal distance is found by

$$D = \sqrt{D'^2 - \Delta RL^2}$$

or by

$$\sin\alpha = \frac{\Delta RL}{D'}$$

and then

$$D = D' \times \cos\alpha$$

<u>Note:</u> This method is limited by the length of the tape and the **presence of obstructions between the two pegs.**

- Both of these methods, applied carefully, can give high accuracy.

SURVEY OF BRIDGE SITES Survey methods, Measurement of horizontal distances on slopes (III)	No.: 4.215 Date: 30. 7.1975 Sig.: D. Sch[illegible]

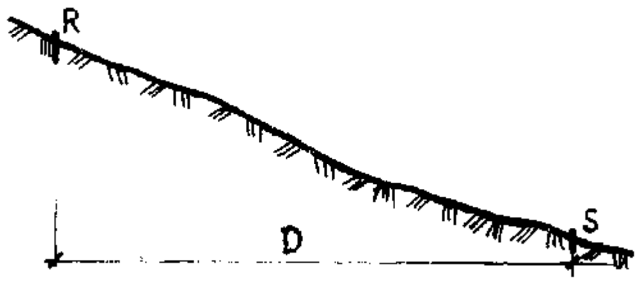
- <u>With "Triangulation"</u> (see also 4.3o3)

Starting from "R" or "S" set peg "P" on a line perpendicular to "RS". The distance from "RS" to "P" should be at least 1o % of "D".

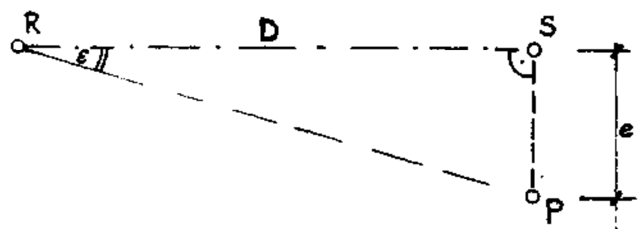
Measure the horizontal distance "e" by tape.
Measure the angle " " opposite to "e" by theodolite.

Sketches:

Section



Plan



Horizontal distance is found by:

$$D = \frac{e}{tg\,\varepsilon} \quad \text{or}$$

$$D = e \times \text{cotan}\,\varepsilon$$

<u>Note:</u> Always measure the angle opposite to distance "e" and not the angle in "P".
Measure angle "ε" at least four times, using different positions of the horizontal circle, and calculate the mean.
Measure the distance "e" as accurately as possible.

Accuracy obtainable by this method is about 0.2% of the distance "D".

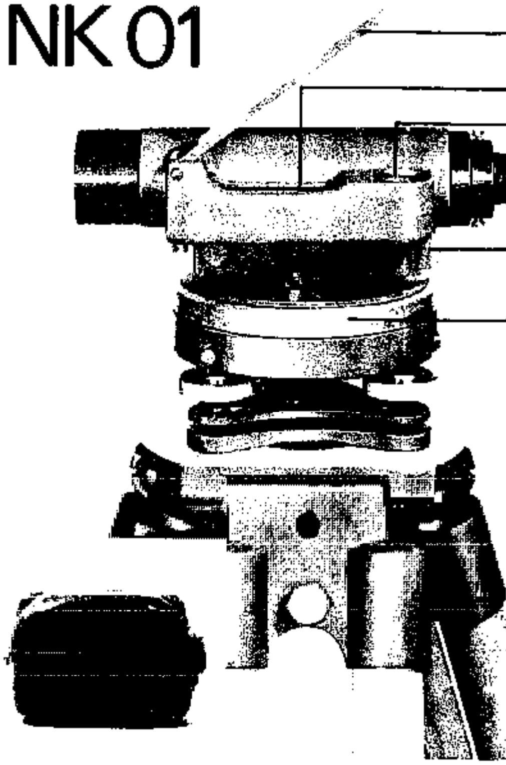
<u>Example:</u>

Theodolite in "R". Distance "e" = 6.86 m

	ε_1	ε_2	ε_3	ε_4
Reading on "S" Reading on "P"	1o3°37' 1o9°58'	146°49' 153°11.5'	215°o3,5' 221°26 '	278°59.5' 285°22 '
Angle "ε_i"	6°21'	6°22.5'	6°21.5'	6°22.5'

Mean for "ε" = 6°22' → cotan 6°22' = 8.962 → Distance <u>"D" = 61.5om</u>

NK 01



Observation Mirror

Tubular Level Bubble

Circular Level Bubble

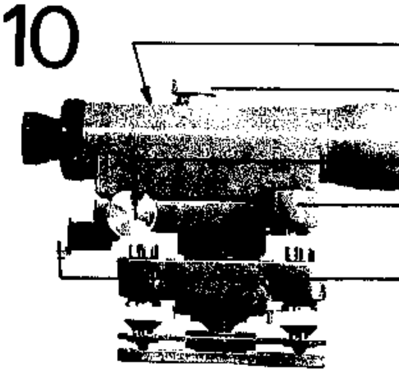
Telescope Eyepiece

Index Mark

Horizontal Circle

The Wild NK 01 Dumpy Level is a most convenient level for the building site. The telescope rotates under a friction-braked action, thus requiring no horizontal clamp. Fine pointing is completed by means of a drive screw. Readings on the metal horizontal circle are made by eye against a fixed index mark, with estimation possible to a tenth of a degree or grade, according to the circle division. The circle itself can be turned by hand to set any desired initial bearing. Four dots around the circle indicate rapidly the right angle settings. The circular and tubular level bubbles are seen free from parallax, in the hinged observation mirror which, when closed, protects the glass vials

N 10



Tubular Level Bubble

Focussing Screw

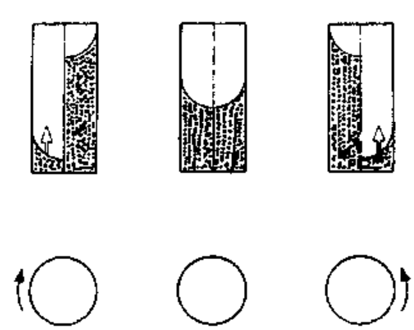
Drive Screw (fine pointing)

Circular Level Bubble

Tilting Screw

The Wild N 10 (NK 10) Engineers' Level is small in size but big in performance. It has all the qualities of a larger level and gives accurate results under all conditions. It is suitable for general levelling, route surveys, irrigation works, civil and constructional engineering. When fitted with a glass circle (NK10) it can be used in flat terrain for tacheometric work and for measuring and setting out horizontal angles. Rotation is friction-braked and an endless drive screw is used for fine pointing. The line of sight is levelled with the aid of a tilting screw and the well known Wild "split-bubble" image system. The tubular level is ventilated in order to avoid excessive accumulation of internal heat and it is also well protected against damage. The N10 has an extremely short minimum focussing distance of 1 m (3.3 ft.), which is most useful in restricted spaces.

Containers. The smaller instruments (NK01, N10 and NK10) have a shock-proof plastic container which is exceptionally strong and long lasting, although very light and easy to handle. The lid of the container can be used to protect the instrument at the working site.



"Split-Bubble" - Image of the tubular level bubble

WILD N2

Engineer's Level with rotatable telescope and reversible tubular level

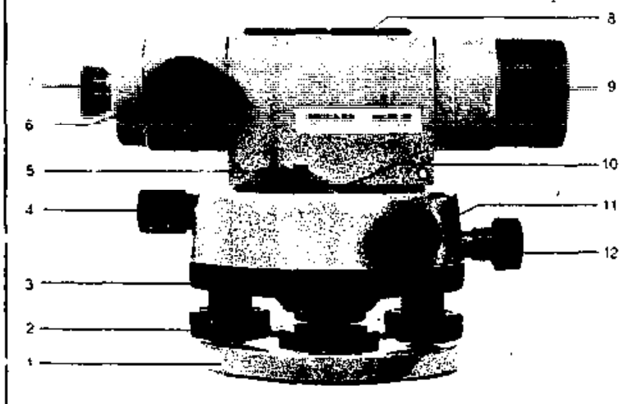


Fig. 1a Wild NK2 Engineer's Level with horizontal circle

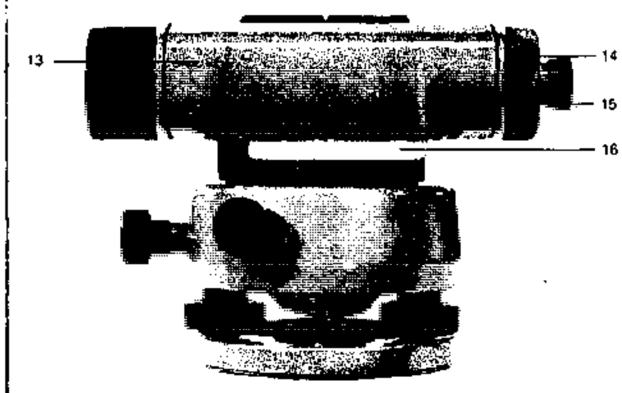


Fig. 1b Wild N2 Engineer's Level without horizontal circle

Figs. 1a and 1b

1 Base plate
2 Footscrew
3 Milled ring for setting the horizontal circle (only on NK2)
4 Reading microscope for circle (only on NK2)
5 Release lever for rotating the telescope and reversing the level
6 Focussing knob
7 Telescope eyepiece
8 Open sight with notch marking instrument centre for centring under a roof point
9 Telescope objective
10 Circular level
11 Endless horizontal drive with knob at each end
12 Tilting screw

13 Protective cover for tubular level
14 Eyepiece for observing the split bubble
15 Adjusting screw for the split bubble (tubular level)
16 Fixed reflector

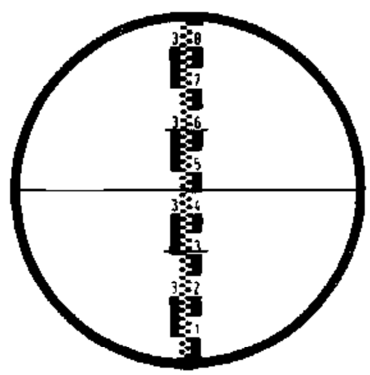


Fig. 4 Staff reading with the Wild N2 (Height: 3.456 m Distance: 29.2 m)

The circle, divided into either 360 or 400 intervals, is viewed through a scale microscope (4) left of and below the telescope eyepiece. The circle graduations and the scale are brought into focus by turning the eyepiece of the reading microscope (4). The numbered degree (360° model) or grade (400ᵍ model) graduation lines of the circle are on the left of the image, the scale is on the right. The scale is divided into 6 intervals of 10' each (360° model) or 10 intervals of 10ᶜ each (400ᵍ model). The zero of the scale is the long upper line with two short index lines.

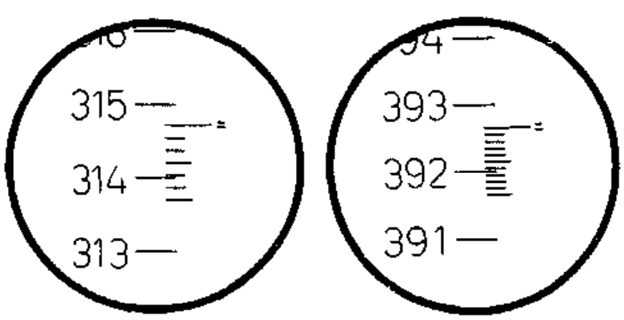
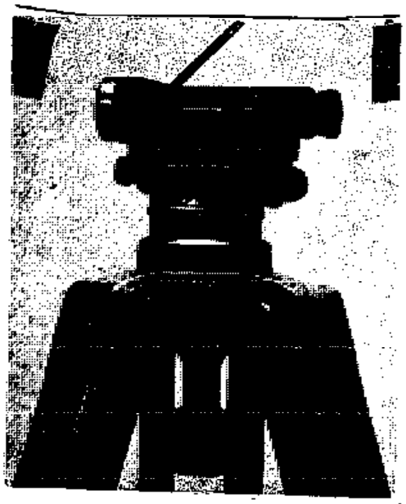


Fig. 5 Circle reading, model NK2 (314°42' 392.65ᵍ)

Kern GK0
Simple Construction Level



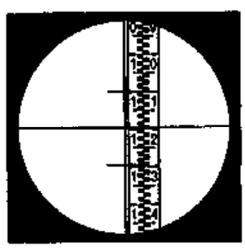
The operation of the GK0 is extremely simple and, therefore, no special skill is required to use it. This manual shows how reliable results may be obtained in the simplest way.

Measuring

Height

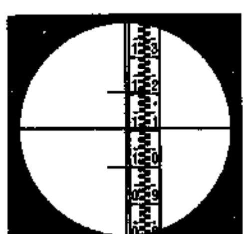
- Open the bubble mirror (6)
- Center the vertical hair on the rod using the horizontal slow-motion screw (7)
- Use the tilting screw (8) to center the telescope bubble

- Take the reading of the horizontal hair on the rod: 1.195 m (Fig. GK0)



Distance

- Set the upper stadia hair (the lower stadia hair in the case of the GK0-E) on the nearest decimeter using the tilting screw (8)
- Read the rod intercept between the two stadia hairs
- Multiply the rod intercept by 100 to obtain the horizontal distance: 20.5 m (Fig. GK0-E)

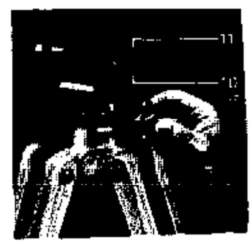


Specifications

Mean error in 1 km (double run)		± 0.02 ft/7 mm
Telescope magnification		18 ×
Objective aperture		0.94 in (24 mm)
Shortest focusing distance		3 ft (0.9 m)
Sensitivity of bull's-eye level		12–15′ per 2 mm
Sensitivity of telescope level		40–50″ per 2 mm
Centering precision, telescope level		± 4″
Circle reading, by estimation		0.1°/0.1°
Weight of instrument	GK0	1.8 lb (0.8 kg)
Weight of carrying case	GK0	1.1 lb (0.5 kg)
Dimensions of carrying case	GK0	6.7 × 3.9 × 3.9 in (17 × 10 × 10 cm)

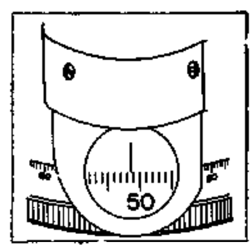
Testing and Adjusting

- To lower the reticule (negative correction), first loosen the lower adjusting screw (10), then tighten the upper adjusting screw (11)
- To raise the reticule (positive correction), first loosen the upper adjusting screw (11), then tighten the lower adjusting screw (10)



Angle (GK0-C, GK0-EC)

- Suspend the plumb bob (found in the carrying case) from the hook within the fastening screw (1)
- Center the instrument over the ground point by lengthening or shortening the telescoping tripod legs
- Level the instrument roughly
- Set the vertical hair on the initial point
- Orient the graduated circle, i.e., set it to zero, by turning the knurled ring (9)
- Turn the telescope to sight the second point
- Read the circle: 51.3°



Kern & Co. Ltd.
Optical and
Mechanical Precision Instruments
5001 Aarau Switzerland

SURVEY OF BRIDGE SITES

Survey Instruments, Theodolite

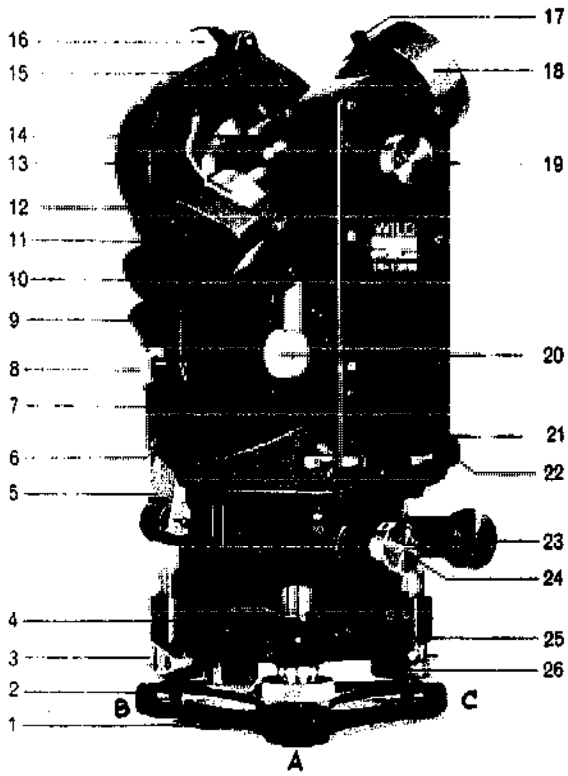
No.: 4.219

Date: 15. 7. 1975

Sig.: D Slenc

WILD T16 Direct Reading Theodolite (face left position)

1 Base plate
2 Spring plate
3 Swivel locking device for tribrach
4 Tribrach
5 Circle locking lever
6 Resting and holding bolt
7 Plate level
8 Index level setting screw
9 Illumination mirror
10 Telescope eyepiece
11 Bayonet holding ring for 10
12 Reading microscope eyepiece
13 Focussing sleeve
14 Knob for reticle illumination, with pin for rear sight and roof centring
15 Vertical circle housing
16 Index level mirror
17 Fore sight
18 Objective
19 Vertical clamp
20 Vertical drive screw
21 Adjusting screw for plate level
22 Optical plummet eyepiece
23 Horizontal drive screw
24 Horizontal clamp
25 Adjusting screw for 26
26 Footscrew

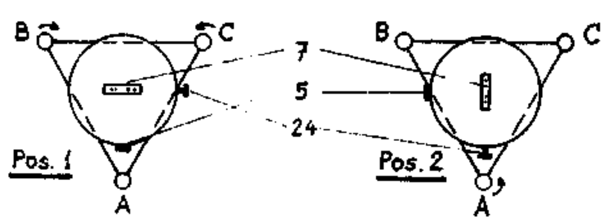


The Wild T16 (T16E) Direct Reading Theodolite is a tacheometric theodolite suitable for all low-order triangulation, tacheometric detail and traverse surveys, mine surveys, property surveys, building site measurements, marking out etc.

The easily read scales of the horizontal and vertical circles with estimation to one tenth of a minute of arc (0.2ᶜ), allow work to be carried out quickly. All clamps and drive screws are placed logically so that they can be manipulated safely and comfortably. The combination of the simple circle scale reading and the operation of the instrument itself makes the T16 a most useful instrument for use by trainees.

The detachable tribrach ensures that the T16 can be used with all Wild traversing equipment and, of course, the normal accessories and attachments all provide additional uses.

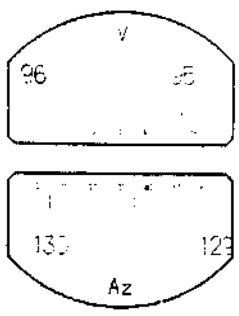
"Levelling Up" of a theodolite



1. Horizontal clamp (24) open and circle locking lever (5) over a footscrew A. Footscrews B and C are turned by equal and opposite rotations until the plate level bubble (7) is centred.
2. Turn the alidade through 90° in a clockwise direction and centre the bubble with footscrew A. **Repeat point 1 and 2 two times.**
3. Turn the alidade clockwise through 90°. Note the position of the bubble. Bring the bubble to a point halfway between this position and the central position by turning B and C by equal and opposite rotations.
4. Turn the alidade in the same direction through 90°. By turning A, set the bubble to the mean (halfway) position obtained in step 3.
5. The bubble should now remain in this position for all directions of the alidade. If it does not, repeat the procedure, but this time use the mean position obtained in step 3 as if it were the central position for the bubble.

The instrument is levelled up when the bubble remains in the same, though not necessarily central position, for all directions of the alidade. It is convenient to keep the plate level in adjustment so that the bubble remains in the central position.

Example for the reading of the circles



Vertical circle 95°64.4ᶜ
Horizontal circle 130°04.6ᶜ

SURVEY OF BRIDGE SITE

Survey Instruments, Theodolite

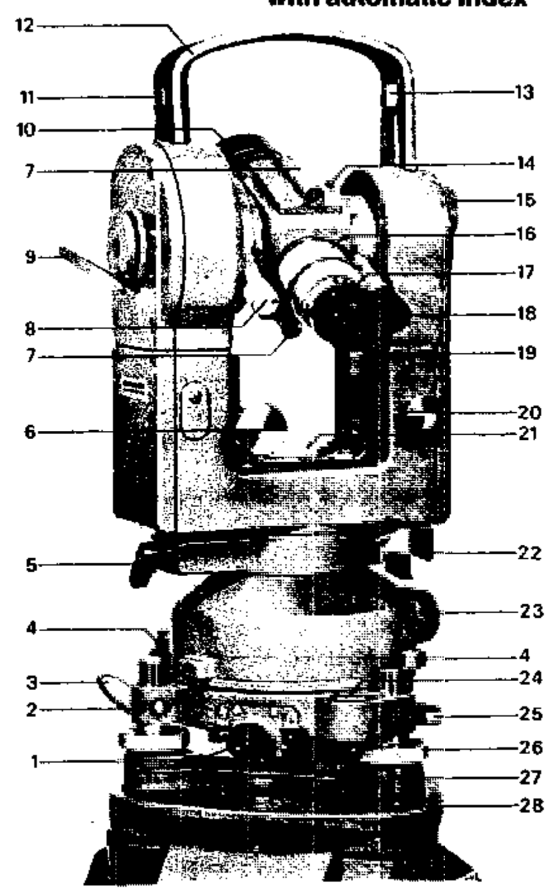
No : 4.220

Date : 28.12.1976

Sig : [signature]

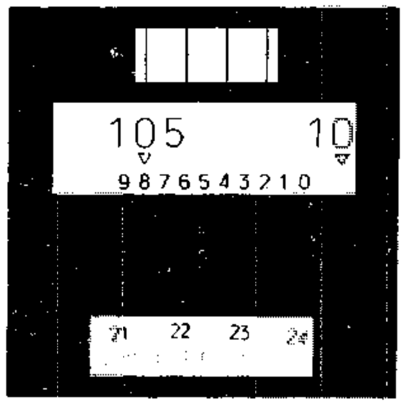
WILD T2

Universal Theodolite with automatic index

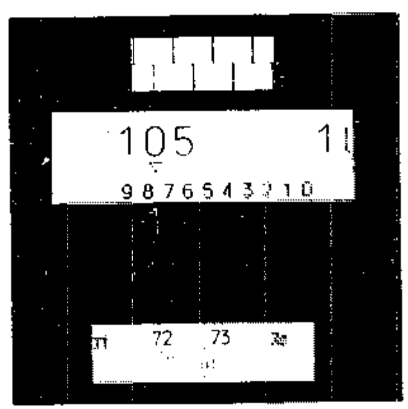


Wild T2 Universal Theodolite

1 Optical plummet
2 Tribrach GDF6
3 Illumination mirror for horizontal circle
4 Support point. When in container instrument rests on three support points
5 Horizontal clamp
6 Vertical drive screw
7 Optical sight, with point for centring under roof points
8 Vertical clamp
9 Illumination mirror for vertical circle
10 Telescope objective
11 Safety catch for carrying handle
12 Carrying handle
13 Locking screw for carrying handle
14 Lever for field of view (reticle) illumination. When using electric lighting, move lever towards objective until it reaches its stop
15 Micrometer knob
16 Focussing sleeve
17 Bayonet ring, locks eyepiece in position
18 Eyepiece of reading microscope
19 Telescope eyepiece with dioptric scale
20 Selector knob for Hz and V reading
21 Plate level
22 Horizontal drive screw
23 Cover for circle drive knob
24 Circular bubble
25 Swivel locking knob
Arrow DOWN = locked
Arrow UP = unlocked
Knob is secured in arrow DOWN position by recessed screw when instrument leaves factory
26 Footscrew
27 Base plate
28 Spring plate



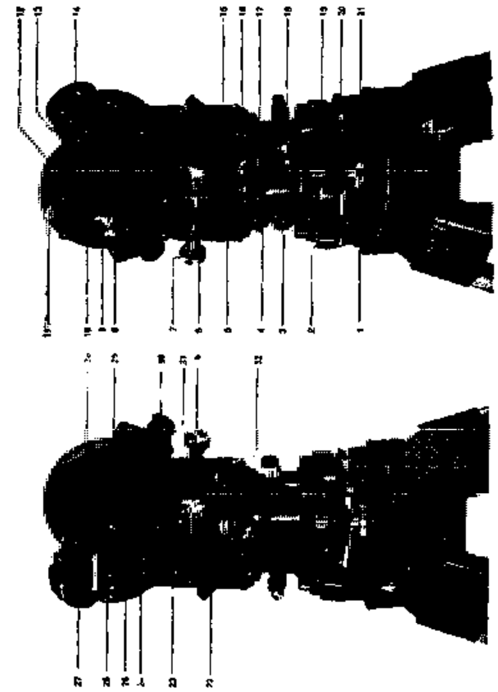
Reading example 400ᵍ model, horizontal or vertical circle. Graduation lines in coincidence, reading=105.8224ᵍ



400ᵍ model
Field of view of the reading microscope before setting the graduation lines in coincidence

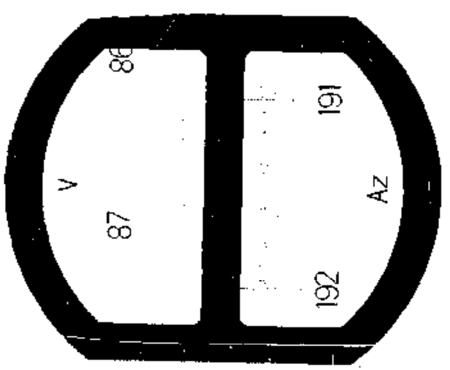
WILD RDS

Self-Reducing Tacheometer



Wild RDS Self-reducing Tacheometer on GST20 tripod (Face Left position)

1 Footscrew
2 Circular level
3 Horizontal clamp
4 Holding bolts
5 Adjusting screw for 15
6 Vertical drive screw
7 Regulating screw for 6
8 Focussing knob
9 Diagram housing
10 Recessed hexagonal screws
11 Vertical clamp
12 Diagram plate adjustment screw (objective side)
13 Foresight
14 Objective
15 Plate level
16 Optical plummet
17 Cover screw for the adjustment of 16
18 Horizontal drive screw
19 Adjusting screw for 1
20 Swivel knob locking device (with safety screw)
21 Base plate
22 Illumination mirror
23 Index level setting screw
24 Vertical circle housing
25 White dot indicating height of tilting axis
26 Adjusting screw for 27
27 Index level
28 Adjusting screw for the horizontal collimation error
29 Open sight
30 Telescope eyepiece
31 Reading microscope eyepiece
32 Circle locking lever



Levelling Up

As a memory aid in levelling-up, it should be noted that the level bubble follows the direction of the left thumb when turning the footscrews. The alidade level should be protected from direct sun rays as these may cause the bubble to run off, giving a false level. An approximate levelling is made by using the footscrews to centre the circular bubble. Then proceed as follows:

1. Horizontal clamp (3) open and circle locking lever (32) over a footscrew A. Footscrews B and C are turned by equal and opposite rotations until the plate level (15) bubble is centred.
2. Turn the alidade through 90° in a clockwise direction until the horizontal clamp is over footscrew A. Centre the bubble again with this footscrew remembering the rule of the left thumb.
3. Turn the alidade clockwise through 90°. Note the position of the bubble. Bring the bubble to a point halfway between this position and the central position by turning B and C by equal and opposite rotations.
4. Turn the alidade in the same direction through 90°. By turning A, set the bubble to the mean (halfway) position obtained in step 3.
5. The bubble should now remain in this position for all directions of the alidade. If it does not, repeat the procedure, but this time use the mean position obtained in step 3 as if it were the central position for the bubble. The instrument is levelled up when the bubble remains in the same, though not necessarily central position, for all directions of the alidade. It is convenient to keep the plate level in adjustment so that the bubble remains in the central position. See section 6.3 for the adjustment procedure.

Measuring Vertical Angles

With the telescope in the Face Left position (open sights of the telescope are above) bring the short horizontal cross hair (43, fig. 2) on to the target by means of the vertical drive (6). Centre the index level (27) by turning its setting screw (23) until the two ends of the split bubble are seen in coincidence in the prism. Now take the vertical circle reading. If the observer knows that the instrument is properly adjusted for vertical collimation (index) error and an accuracy of 1' (2^c) is needed it will be sufficient to observe in Face Left only. If more accuracy is required transit to Face Right (open sights below the telescope) and repeat the observation. The mean vertical angle from the Face Left and Face Right readings is free from vertical collimation error.

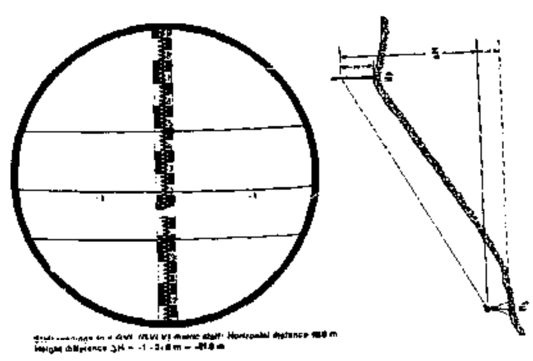
The reading A_L in Face Left is the zenith angle ζ, the reading A_R in Face Right is ($360°-\zeta°$) or ($400^g-\zeta^g$). The vertical angle β (elevation + or depression −) can be derived from the vertical circle readings as follows: –

$\beta_L = 90° - A_L°$ or $100^g - A_L^g$
$\beta_R = A_R° - 270°$ or $A_R^g - 300^g$
$\beta = \frac{1}{2}(\beta_L + \beta_R)$
$\zeta = \frac{1}{2}(A_L - A_R)$ ($360°$ or 400^g has to be added to A_L)

Example

360°	A_L = 83°23.2'	β_L = +6°36.8'
	A_R = 276°36.4'	β_R = +6°36.4'
	$A_L + A_R$ = 359°59.6'	β = +6°36.6'
	$A_L - A_R$ = 166°46.8'	ζ = 83°23.4'
	$2i$ = −0.4'	
400^g	A_L = 107.864^g	β_L = -7.864^g
	A_R = 292.154^g	β_R = -7.846^g
	$A_L + A_R$ = 400.018^g	β = -7.855^g
	$A_L - A_R$ = 215.710^g	ζ = 107.855^g
	$2i$ = $+0.018^g$	

Reduction by this method is self-checking. The sum $A_L + A_R$ should always be constant within ±0.2' or ±0.3^c. The difference of $A_L + A_R$ from 360° or 400^g is twice the vertical collimation error i, which can be adjusted if necessary as described in 6.6.



SATA, Swiss Association for Technical Assistance

WILD TO

Compass Theodolite

3. Description

(In this booklet, face left (right) position means that the vertical circle is left (right) of the line of sight)

3.1 The Instrument

3.1.1 The Lower Part (fig. 1 at the end of the booklet)

The lower part of the instrument is firmly secured to the base plate (1) of the metal container by means of three screws inserted from below. It has the usual three footscrews (3), each of which can be regulated by an adjustment screw (4). The lower part also contains the compass circle with a jewel bearing (fig. 4). By pressing down the lever (2) and then moving it slowly left (clockwise) until it reaches the stop, the compass circle is lowered onto a sharp steel pivot and is free to rotate. Moving the lever to the right (anticlockwise) lifts the circle from the pivot and, before moving the instrument, the lever must always be raised and pushed into the small notch.

3.1.2 The Alidade (figs. 1 and 2)

The lower part of the alidade, together with the horizontal clamp (21) and drive (22), is fastened to the upper part by means of three capstan-headed screws (5) which are screwed into the circular housing from below. The upper part of the alidade has the telescope standards, the telescope and the vertical circle reading microscope (17). One of the standards holds the vertical circle housing (13), the vertical circle illumination window (fig. 2, 25), the vertical circle index level (12), the setting screw (8) for the index level, and the two reading eyepieces (10) for the horizontal circle. The change-over knob (9) enables readings to be made from the observer's side of the instrument in either the face left or face right position. The other standard holds the vertical clamp (15), the vertical drive (16), and the micrometer drum (19) which is graduated in one minute (2ᶜ) intervals and is used for setting the horizontal circle graduations in coincidence. Between the standards there is a circu-- bubble (20) and two windows (6) for the illumination of the compass or horizontal circle. The telescope has 20× magnification, coated optics and internal focussing which is controlled by the focussing sleeve (11). The telescope can be transmitted via the objective end and has a vertical sighting range of +45° to −55° in both face left and face right positions. The reticle (fig. 6) has two sets of stadia hairs with multiplication constants 50 and 100.

3.1.3 The Compass Circle and its Reading System (figs. 2 and 3)

Below the horizontal circle, there is a strong magnet (29), which brings the zero of the freely-swinging circle to Magnetic North, so that the subsequent horizontal circle reading is a magnetic bearing. Depending on the earth's magnetic field the inclination of the compass circle will vary, but inclination from the horizontal can be counter-balanced by moving the balance weights (31) along their slots. For adjustment see 6.2.3. To eliminate the influence of eccentricity, as the circle swings on a pivot instead of being rigidly centred, it is read at two diametrically opposed positions. As in a precision theodolite (T2 or T3), the images of the diametrically opposed graduation lines, which are observed in the eyepieces (10), are brought into coincidence by turning the micrometer drum (19). On turning the change over knob (9) for face right readings, the combined image of the diametrically opposed parts of the circle is inverted with the result that the same image is seen in face right as in face left; i.e. the circle readings are the same in both positions and do not differ by 180° as is usually the case.

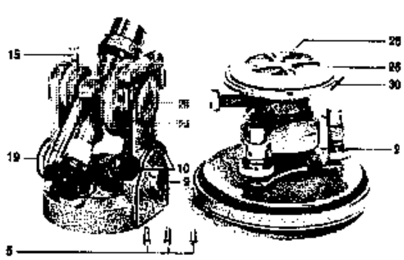


Fig. 2 T0 with the upper part of the alidade removed

2 Lever for damping and lifting the compass circle	24 Adjustment screw for index level
5 Fastening screws	25 Illumination window for the vertical circle
9 Change-over knob for 10	26 Compass circle
10 Reading eyepiece for compass circle	28 Bearing (pivot point) for the compass circle
15 Vertical clamp	30 Fitting position or flange
19 Micrometer drum	

Measuring Methods

The Wild T0 allows the measurement of:

- an individual magnetic bearing to each target
- sets of directions with the circle oriented to magnetic north
- angles or sets of directions with the circle not oriented.

For accurate measurements, readings should be taken in both positions, i.e. face left and face right. Note that the two readings will not differ by 180° (200ᶢ) as is the case with other theodolites (see 3.1.3).

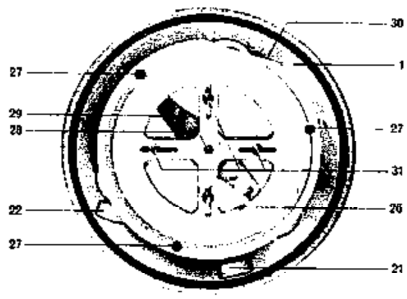


Fig. 3 The Compass circle

1 Base plate	28 Compass bearing
21 Horizontal clamp	29 Magnet
22 Horizontal drive screw	30 Fitting position or flange
26 Compass circle	31 Balance weights
27 Capstan screw holes	

4.5.2 The Horizontal (Compass) Circle (fig. 5)

On each side of the standard carrying the vertical circle there is a reading eyepiece (10) for viewing and reading the compass circle. The change-over inverter knob (9) always allows the reading to be made from the observer's side of the instrument. The circle reading is made by looking obliquely downwards into the eyepiece lens from a distance of about 4 in (10 cm) (i.e. the distance from the telescope eyepiece). Two images are seen, corresponding to the diametrically-opposite parts of the circle, one being inverted and on top of the other. For accurate observation the eye level must be moved until the upper and lower graduation lines appear to be the same length. As the images cover fairly large sectors of the circle, only the lines in the centre of the field of view appear to be parallel (fig. 5) and are used for coincidence setting. The micrometer drum (19) is turned until the upper and lower lines in the centre of the field coincide. The first upright number of the lower image, to the left of the centre of the field of view, gives the tens of degrees (grades).

The inverted number of the upper image differing from this value by exactly 180° (or 200ᶢ) represents the corresponding diametrically-opposite graduation line and each interval between the two numbers represents 1° (1ᶢ). The intervals are counted and are added to the tens of degrees (grades). The inverted number will always be to the right of the upright one except when the circle reading is an exact number of tens of degrees (grades), in which case the two numbered graduations will coincide in the centre, i.e. the inverted number will appear above the upright one. The reading on the micrometer drum is then taken - direct reading to 1' (2ᶜ). The total reading, circle and micrometer, is the mean reading for the two diametrically opposite parts of the circle.

Fig. 5 Horizontal circle reading

(360°) 79° 42' (400ᶢ) 19.24ᶢ

4.5.3 The Vertical Circle (fig. 6)

Before reading the vertical circle via the microscope (17), the index level (12) must be centred by turning the setting drive screw (8). The field of view provides an image of two diametrically-opposite parts of the circle. There is no micrometer, however, and consequently no coincidence setting is possible.

In the face left position zenith angles are read and in face right nadir angles. In the upper image the numbering is upright and increases from left to right, whilst in the lower image it is inverted and increases from right to left. Each graduation image is marked with either I or II (i.e. face left or face right), the upper number always indicating the telescope position.

To read the circle, the upright number (in the upper image) nearest to the middle and on the left side, is taken as the number of degrees (grades). The intervals between this number and the same, but inverted, number

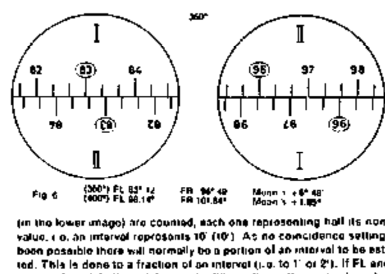


Fig 6 (360°) FL 83° 12' (400ᶢ) FL 98.14ᶢ FR 96° 48' FR 101.84ᶢ Mean α +6° 48' Mean α +1.85ᶢ

(in the lower image) are counted, each one representing half its nominal value, i.e. an interval represents 10' (10ᶜ). As no coincidence setting has been possible there will normally be a portion of an interval to be estimated. This is done to a fraction of an interval (i.e. to 1' or 2ᶜ). If FL and FR are the face left (I) and face right (II) readings, the vertical angle α is obtained as follows:

$$\alpha_L = 90° - FL \quad (100^g - FL)$$
$$\alpha_R = FR - 90° \quad (FR - 100^g)$$

or the mean can be found from:

$$\alpha = \tfrac{1}{2}(FR - FL)$$

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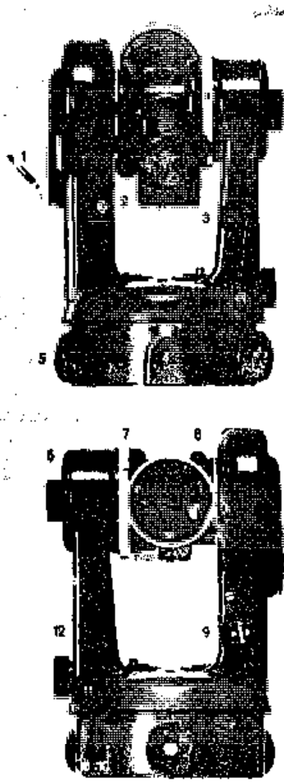
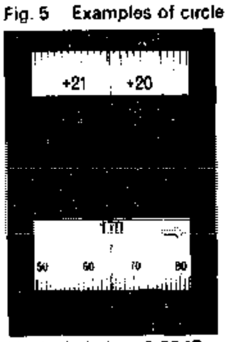
Self-reducing Engineer's Tachymeter Theodolite K1-RA

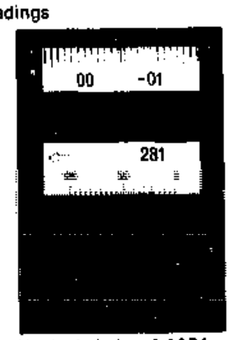


1 Illuminating mirror
2 Circle reading eyepiece
3 Vertical slow-motion screw
4 Coarse-fine circle orienting drive with safety cover
5 Leveling knob
6 Focusing knob
7 Selector ring for horizontal distance or difference in elevation
8 Finder-collimator
9 Switch-over knob for clockwise or counterclockwise reading on the horizontal circle
10 Terminal for electric illumination
11 Horizontal slow-motion screw
12 Micrometer knob

Fig. 5 Examples of circle readings



Vertical circle + 0.2047
400° Horizontal circle with micrometer. Clockwise scale 170° 65ᶜ 30ᶜᶜ



Vertical circle – 0.0054
400° Horizontal circle with scale microscope. Counterclockwise scale 281° 22ᶜ

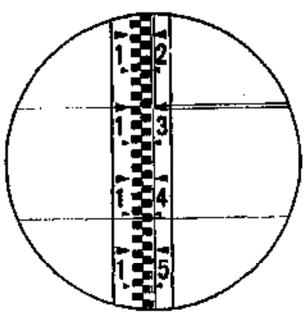


Fig. 6 Horizontal distance reading 15.6 m
Setting of selector ring D

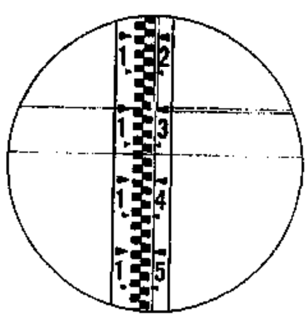
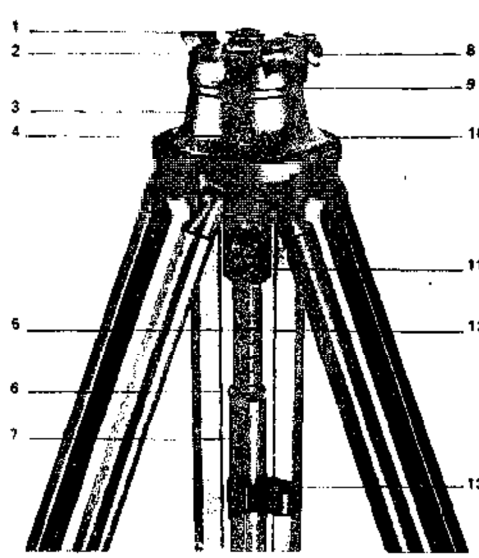


Fig. 7 Difference in elevation reading 6.4 m
Setting of selector ring ΔH
Sighting height on rod 1.30 m

Fig. 3 Centering tripod

1 Centering socket
2 Instrument support plate
3 Tripod head
4 Release button
5 Centering rod
6 Guard ring
7 Bullseye level housing
8 Bayonet locking lever
9 Spherical zone
10 Tripod plate
11 Clamping grip
12 Centimeter scale (height of instrument above station point)
13 Bullseye level



3.1 Introduction

The purpose for soil investigation is to obtain information as bases for:

1. The selection of type and depth of foundation
2. The determination of boring capacity of the selected foundation
3. The evaluation of the earth pressure against walls, abutments
4. The provisions against constructional difficulties.

In general, any investigation should start with the collection and examination of the already existing data about the soil and geological conditions of the site. In many areas the existing local knowledge and the behaviour of existing structures are very helpful. If the existing information is not sufficient or is inconclusive, the site should be explored in detail.

An inspection of the site and study of topographical features is after helpful in getting useful informations about the soil and in deciding the future programme of exploration. On going over the site, a study of the following features may be useful: local topography, excavations, cuttings, evidence of erosion or land slides, fills, water level in the river, flood marks etc. If there has been an earlier use of the site, informations should be gathered, in particular about the underground workings, if any, and about the locations of fills and excavations.

3.2 Field tests

The various methods of site exploration may be grouped as follows:

1. Open excavation
2. borings
3. Sub-surface sondings
4. Geophysical methods.

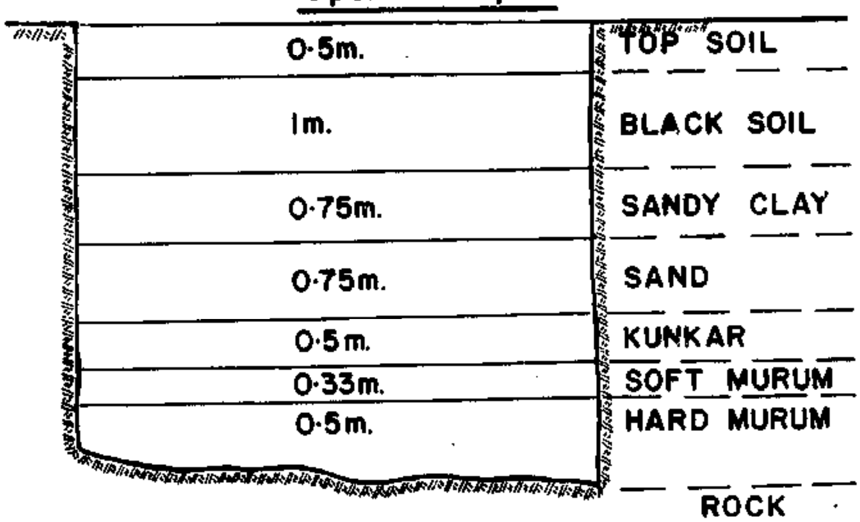
The first two methods are described in this chapter.

3.2.1 Open excavation

Test pits and trenches can be used for all types of soils. Soils can be inspected in their natural condition and samples, disturbed or undisturbed can be conveniently taken. There are generally considered depths of excavation up to 3 m.

Open test pits are suitable for the examination of comparatively shallow foundations, for determining the difficulty or ease of excavation, the necessity or otherwise of sharing etc. But afford, within their limits, the most satisfactory evidence regarding the true nature of the strata. A test pit should be minimum 0.6 m by 1.2 m in plan so that a labourer can easily bend down and ply his tools.
It should be remembered that the locations for a test pit should be so selected that it will not later come under the foundation of the structure. A typical open test pit is shown in the sketch below.

Open test pit



3.2.2 Borings

a) Probing

Probing is confined to shallow foundations in soft strata like clay, sand, gravel etc. A steel bar of about 32 mm diameter, painted at one end, and of suitable length (Fig. 1) according to the depth of the soft or loose material, is forced vertically into the ground and worked like a jumper until a hard substratum is tapped. A hammer may be used with advantage for driving the bar down. It may be withdrawn from time to time and the point examined for traces of the material met with, sticking to it. The nature of the final hard stratum

encountered may be recognized by the feel, sand, and the particles sticking to the point and the depth of the bore measured.
For testing shallow foundations in clay or sand, an instrument called "wood auger" is often very useful. It is just like the auger for drilling holes in wood, but a little stronger (Fig. 2).

Fig.1

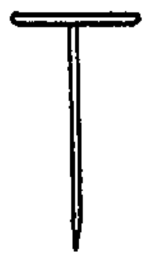
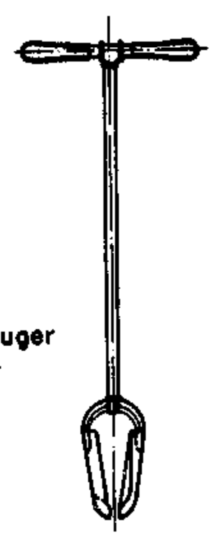


Fig.2

b) Auger boring

Auger are used in cohesive and other soft soils above water table. Hand-augers are used for depths up to about 6 m. Samples recovered from the soil brought up by augers are badly disturbed and are useful for identification purposes only. The sketch below shows a posthole auger and a helical (spiral) auger.

HAND AUGERS



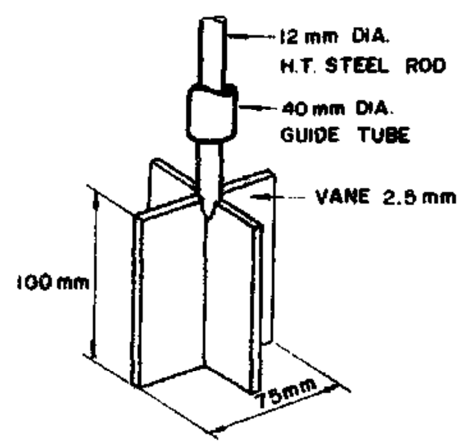
(a) Post hole auger

(b) Helical auger

c) Vane test

This test is applied particularv to soft clays or silts, which, on account of their softness, do not stand other tests. The device as illustrated in the sketch below, consists of an assembly of four vanes fixed to the bottom of the central vertical vod. It is pushed into soil at the bottom of a borehole and rotated. The torque required to rotate the vane is measured at the top, which gives a measure of the consistency of the soil.

Apparatus for Vane test



3.3 Laboratory tests

Some of the various experiments which can be done in the laboratory are described roughly in this chapter.

a) Determination of water content by ovendrying method

The object of this test is to determinate the water content of a soil sample in the laboratory by ovendrying method. This experiment forms an essential part of many other laboratory experiments.
Reference to Indian Standard:IS:2720 (Part II) - 1969, Method of Test for Soils: Part II: Determination of Moisture content.

b) Determination of specific gravity of soil by detensity bottle

The object of the test is to determine the specific gravity of soil fraction passing 4.75 mm IS sieve bv density bottle. This test can also be done by pycnometer.

SURVEY OF BRIDGE SITE Soil investigation Laboratory tests,Classification,	No : 4.305 Date : 28.12.1976 Sig : [signature]

c) Determination of grain size distribution by sieving

The object of this experiment is to determine grain size distribution of coarse grained soil by sieving. The test covers both coarse sieve analysis (for gravel fraction) as well as fine sieve analysis (for sand fraction).

d) Determination of grain size distribution by hydrometer

The object of this experiment is to determine the distribution of particle size, finer than 75 micron sieve, by sedimentation analysis, using a density hydrometer, and then to plot the grain size distribution curve. This test can also be done by using a sampling pipette.

3.4 Classification

General

The purpose of soil classification is to arrange various types of soil into groups according to their engineering properties and various other characteristics. Soil possessing similar characteristics can be placed in the same group. From the engineering point of view, the classification may be done with the objective of finding the suitability of the soil for construction of foundations etc.

Particle size classification

In this system, soils are arranged according to the grain size. Terms such as gravel, sand, silt and clay are used to indicate grain sizes. These terms are used only as distinction of particle sizes and do not signify the naturally occurring soil types, which are mixtures of particles of different sizes and exhibit definite characteristics. It is preferable to use the word 'silt size' and 'clay size' in place of simply 'silt' or clay' in this system. There are various grain size classifications in use. The more commonly used systems are: The M.I.T. classification proposed by Prof. G. Gilbay of Massachusetts Institute of Technology as a simplification of the Bureau of Soils classification, and Standard classification (IS:1948-1970) based on the M.I.T. system. This system is shown in the sketch below.

Clay (Size)	0.002	Silt (Size)	0.075		0.425		2		4.75		20		80	Cobble	300	Boulder
				Fine		Med.		Coarse		Fine		Coarse				
				Sand						Gravel						

SURVEY OF BRIDGE SITE

Soil investigation

Classification

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Date : 20.1.1977

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UNIFIED SOIL CLASSIFICATION CHART

UNIFIED SOIL CLASSIFICATION

INCLUDING IDENTIFICATION AND DESCRIPTION

FIELD IDENTIFICATION PROCEDURES (Excluding particles larger than 3 inches and basing fractions on estimated weights)				GROUP SYMBOLS	TYPICAL NAMES
COARSE GRAINED SOILS More than half of material is larger than No. 200 sieve size.	GRAVELS More than half of coarse fraction is larger than No.4 sieve size.	CLEAN GRAVELS (Little or no fines)	Wide range in grain size and substantial amounts of all intermediate particle sizes.	GW	Well graded gravels, gravel-sand mixtures, little or no fines.
			Predominantly one size or a range of sizes with some intermediate sizes missing.	GP	Poorly graded gravels, gravel-sand mixtures, little or no fines.
		GRAVELS WITH FINES (Appreciable amount of fines)	Non-plastic fines (for identification procedures see ML below).	GM	Silty gravels, poorly graded gravel-sand-silt mixtures.
			Plastic fines (for identification procedures see CL below).	GC	Clayey gravels, poorly graded gravel-sand-clay mixtures.
	SANDS More than half of coarse fraction is smaller than No.4 sieve size. (For visual classification, the size may be used as equivalent to the No.4 sieve size.)	CLEAN SANDS (Little or no fines)	Wide range in grain sizes and substantial amounts of all intermediate particle sizes.	SW	Well graded sands, gravelly sands, little or no fines.
			Predominantly one size or a range of sizes with some intermediate sizes missing.	SP	Poorly graded sands, gravelly sands, little or no fines.
		SANDS WITH FINES (Appreciable amount of fines)	Non-plastic fines (for identification procedures see ML below).	SM	Silty sands, poorly graded sand-silt mixtures.
			Plastic fines (for identification procedures see CL below).	SC	Clayey sands, poorly graded sand-clay mixtures.

		IDENTIFICATION PROCEDURES ON FRACTION SMALLER THAN No. 40 SIEVE SIZE				
		DRY STRENGHT (Crushing characteristics)	DILATANCY (Reaction to shaking)	TOUGHNESS (Consistency near plastic limit)	GROUP SYMBOLS	TYPICAL NAMES
FINE GRAINED SOILS More than half of material is smaller than No. 200 sieve size.	SILTS AND CLAYS Liquid limit less than 50	None to slight	Quick to slow	None	ML	Inorganic silts and very fine sand, rock flour, silty or clayey fine sands with slight plasticity.
		Medium to high	None to very slow	Medium	CL	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays.
		Slight to medium	Slow	Slight	OL	Organic silts and organic silt-clays of low plasticity.
	SILTS AND CLAYS Liquid limit greater than 50	Slight to medium	Slow to none	Slight to medium	MH	Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts
		High to very high	None	High	CH	Inorganic clays of high plasticity, fat clays.
		Medium to high	None to very slow	Slight to medium	OH	Organic clays of medium to high plasticity
HIGHLY ORGANIC SOILS		Readily identified by color, odor, spongy feel and frequently by fibrous texture.			Pt	Peat and other highly organic soils.

(The No. 200 sieve is about the smallest particle visible to the naked eye)

SURVEY OF BRIDGE SITE
Soil investigation
Classification

No : 4.3.

Date : 20.1.1977
Sig :

UNIFIED SOIL CLASSIFICATION CHART

UNIFIED SOIL CLASSIFICATION

INCLUDING IDENTIFICATION AND DESCRIPTION

FIELD IDENTIFICATION PROCEDURES (Excluding particles larger than 3 inches and basing fractions on estimated weights)				GROUP SYMBOLS	TYPICAL NAMES
COARSE GRAINED SOILS More than half of material is larger than No. 200 sieve size. (The No. 200 sieve size is about the smallest particle visible to the naked eye)	GRAVELS More than half of coarse fraction is larger than No. 4 sieve size. (For visual classification, the size may be used as equivalent to the No. 4 sieve size.)	CLEAN GRAVELS (Little or no fines)	Wide range in grain size and substantial amounts of all intermediate particle sizes.	GW	Well graded gravels, gravel-sand mixtures, little or no fines.
			Predominantly one size or a range of sizes with some intermediate sizes missing.	GP	Poorly graded gravels, gravel-sand mixtures, little or no fines.
		GRAVELS WITH FINES (Appreciable amount of fines)	Non-plastic fines (for identification procedures see ML below).	GM	Silty gravels, poorly graded gravel-sand-silt mixtures.
			Plastic fines (for identification procedures see CL below).	GC	Clayey gravels, poorly graded gravel-sand-clay mixtures.
	SANDS More than half of coarse fraction is smaller than No. 4 sieve size.	CLEAN SANDS (Little or no fines)	Wide range in grain sizes and substantial amounts of all intermediate particle sizes.	SW	Well graded sands, gravelly sands, little or no fines.
			Predominantly one size or a range of sizes with some intermediate sizes missing.	SP	Poorly graded sands, gravelly sands, little or no fines.
		SANDS WITH FINES (Appreciable amount of fines)	Non-plastic fines (for identification procedures see ML below).	SM	Silty sands, poorly graded sand-silt mixtures.
			Plastic fines (for identification procedures see CL below).	SC	Clayey sands, poorly graded sand-clay mixtures.

FINE GRAINED SOILS More than half of material is smaller than No. 200 sieve size.	IDENTIFICATION PROCEDURES ON FRACTION SMALLER THAN No. 40 SIEVE SIZE	DRY STRENGHT (Crushing characteristics)	DILATANCY (Reaction to shaking)	TOUGHNESS (Consistency near plastic limit)	GROUP SYMBOLS	TYPICAL NAMES
	SILTS AND CLAYS Liquid limit less than 50	None to slight	Quick to slow	None	ML	Inorganic silts and very fine sand, rock flour, silty or clayey fine sands with slight plasticity.
		Medium to high	None to very slow	Medium	CL	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays.
		Slight to medium	Slow	Slight	OL	Organic silts and organic silt-clays of low plasticity.
	SILTS AND CLAYS Liquid limit greater than 50	Slight to medium	Slow to none	Slight to medium	MH	Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts.
		High to very high	None	High	CH	Inorganic clays of high plasticity, fat clays.
		Medium to high	None to very slow	Slight to medium	OH	Organic clays of medium to high plasticity.
HIGHLY ORGANIC SOILS		Readily identified by color, odor, spongy feel and frequently by fibrous texture.			Pt	Peat and other highly organic soils.

SATA, Swiss Association for Technical Assistance

SURVEY OF BRIDGE SITE
Soil investigation
Classification

No	: 4.307
Date	: 20.1.1977
Sig	: Caudrau

ENGINEERING USE CHART FOR SOILS CLASSIFIED BY UNIFIED SOIL CLASSIFICATION SYSTEM *

Description		Important properties			
Typical names of soil groups	Group symbols	Permeability when compacted	Shearing strength when compacted and saturated	Compressibility when compacted and saturated	Workability as a construction material
Well-graded gravels, gravel-sand mixtures, little or no fines	GW	Pervious	Excellent	Negligible	Excellent
Poorly graded gravels, gravel-sand mixtures, little or no fines	GP	Very pervious	Good	Negligible	Good
Silty gravels, poorly graded gravel-sand-silt mixtures	GM	Semipervious to impervious	Good	Negligible	Good
Clayey gravels, poorly graded gravel-sand-clay mixtures	GC	Impervious	Good to fair	Very low	Good
Well-graded sands, gravelly sands, little or no fines	SW	Pervious	Excellent	Negligible	Excellent
Poorly graded sands, gravelly sands, little or no fines	SP	Pervious	Good	Very low	Fair
Silty sands, poorly graded sand-silt mixtures	SM	Semipervious to impervious	Good	Low	Fair
Clayey sands, poorly graded sand-clay mixtures	SC	Impervious	Good to fair	Low	Good
Inorganic silts and very fine sands, rock flour, silty or clayey fine sands with slight plasticity	ML	Semipervious to impervious	Fair	Medium	Fair
Inorganic clays of low to medium plasticity: gravelly, sandy, silty, and lean clays	CL	Impervious	Fair	Medium	Good to fair
Organic silts and organic silt-clays of low plasticity	OL	Semipervious to impervious	Poor	Medium	Fair
Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts	MH	Semipervious to impervious	Fair to poor	High	Poor
Inorganic clays of high plasticity, fat clays	CH	Impervious	Poor	High	Poor
Organic clays of medium to high plasticity	OH	Impervious	Poor	High	Poor
Peat and other highly organic soils	Pt				

* Bureau of Reclamation, 1953.

SURVEY OF BRIDGE SITE Soil investigation Classification	No : 4.308 Date : 28.12.1976 Sig : Pandian

Classification of Rocks

Rocks are classified into three major groups, namely, igneous, metamorphic, and sedimentary. The most notable properties of each group are summarized in the following sections:

a) Igneous rocks (granite, diorite, basalt, etc)
Good structural characteristics - hard, dense and durable - good construction material. High bearing capacity - good foundation material. Joints in three dimensions - actual as potential joints are in three sets at approximately right angle to each other.

b) Metamorphic rocks (gneiss, schist, marble, slate, serpentine etc.)
Hard and strong if the rock is not weathered. Jointed, folded, laminated or foliated - metamorphic rocks commonly have two or three sets of joints. The strength of the rocks is greatly influenced by the joints and the folded, laminated or foliated structures.
Containing weak layers between very hard ones.

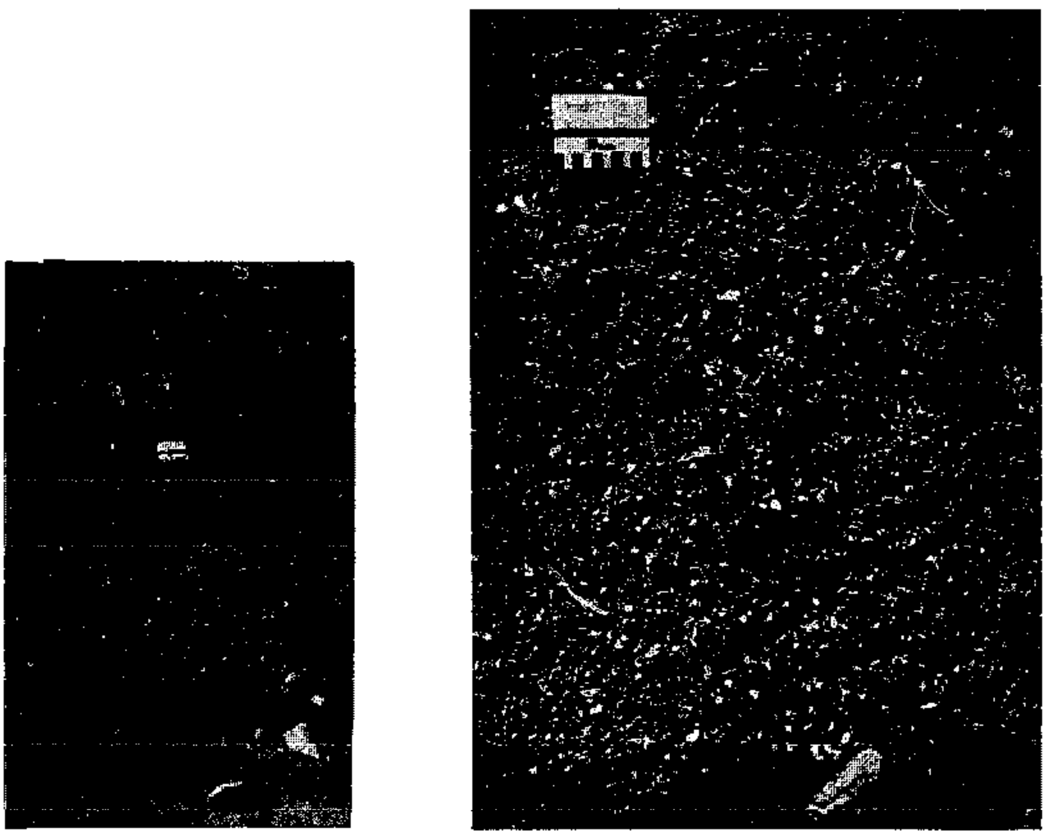
c) Sedimentary rocks (limestones, sandstones, shales)
Limestones: The strength of limestones varies considerably, from soft calcareous limestones to hard limestones and dalomites. It may vary even within one limestone formation. The strength depends generally upon the texture of the rock. A limestone with porous or cavernous texture has very low compressive strength, and one with dense texture has very high strength.
Sandstones: the strength of sandstones depends largely upon the degree of cementation and the type of cementing material:

Cementing material	Usual color	Strength
Iron oxide	Brown, red, orange	Variable, cement often in irregular bands
Clay	Dull, whitish grey	Low, treacherous when wet
Calcite $(CaCo)_3$	Grey, white, buff	Good
Silica $(SiO)_2$	White (often stained by iron oxide), buff, yellow, pink	Excellent

The durability is generally in proportion to the strength.
Three sets of joints exist in sandstones. Joints are generally spaced several feet apart.

Shales: The strength of shales varies widely. Soft shales may be scratched by a fingernail or excavated by hand without the use of explosives. Hard shales however, require blasting to excavate.

Sources: - Wayne C. Teng, Foundation Design
- B.C. PUNMIA, Soil, Mechanics and Foundations
- Deshpaude, Vartak, A Treatise on Building Construction



Pikuwa Khola: Sand and Gravel depots on the bank of the Arun river

SURVEY OF BRIDGE SITE Evaluation of the Survey	No. : 4.401 Date : 28.12.1976 Sig : Coundran

Plotting Work

In the office the plotting work has to be done. It is good to make these work soon after returning from the survey. So you still remember how the site is looking and to draw the counter-lines is much easer.

The survey should be plotted on tracing paper.

The scale is 1 : 200 (1 cm = 2 m)

The drawing must contain:

- Plan wiew of the Bridge Site
- Section along the Bridge Axis
- Copy of the 1" = 1 mile map showing the Bridge Location

The plotting is done in the same order as the maesurements in the field:

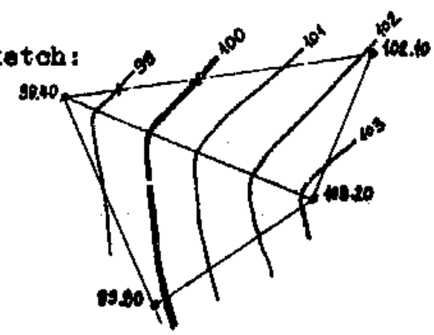
- Main points such as the pegs A,B,C....
- Other points along the bridge center line.
- Points up- and downstream from the bridge center line
- Interpolation of contour lines

Interpolation of Contour Lines (in the plan view)

From the tacheometric-survey we determine the location and the elevation of points which will be scattered all over the bridge-site. In order to show the form of the bridge-area more clearly, contour lines of 1m-intervals are interpolated between these points.

Analytical Interpolation

Sketch:



1. **Connect neighbouring points with lines.**
2. **Measure the distances (d) along these lines and calculate the differences in elevation (ΔH) between two corresponding points.**
   e.g. for 98.40 to 102.10
   d = 4.8cm   ΔH = 3.70m
3. **Calculate differences in elevation and distances from the lower point to the contour lines between the two points.**
   e.g. from 98.40 to 99.00 ΔL = 0.60m $d = \frac{4.8cm}{3.70m} \times 0.60m = 0.8cm$
   from 98.40 to 100.00 ΔL = 1.60m $d = \frac{4.8cm}{3.70m} \times 1.60m = 2.1cm$ .... etc.
4. **Make these calculations for all the connecting lines, use the slide rule.**
   Mark the so calculated contour line-points on the connecting lines. Draw the contour lines by joining the corresponding points.

SURVEY OF BRIDGE SITES Interpolation of Contour Lines (II), Graphical Method	No.: 4.402 Date: 24. 8.1975 Sig.: [signature]

1. Connect neighbouring points with lines (line ①, sketch 1).
2. Draw a perpendicular line to line ① at the higher of the two points (line ②, sketch 1).

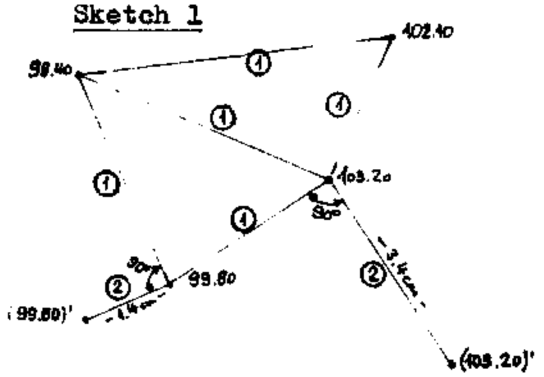
   Mark on line ② the difference in elevation between the two points.

   e.g. for the connecting line 98.40 - 99.80
   difference in elevation is ΔL = 1.40 m, mark 1.4 cm

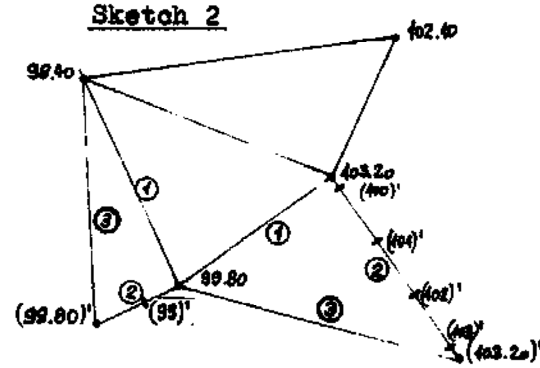
   for the connecting line 99.80 - 103.20
   difference in elevation is ΔL = 3.40 m, mark 3.4 cm

   This gives the revolved points (99.80)', (103.20)' etc....

Sketch 1



Sketch 2

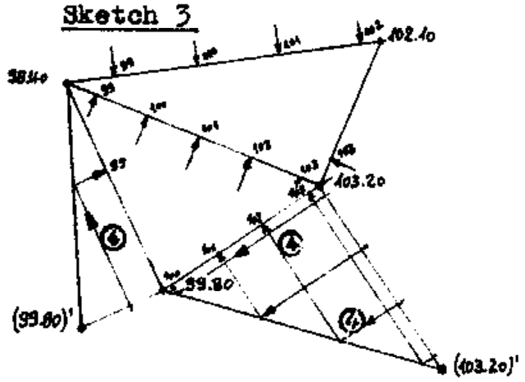


3. Draw line ③ (sketch 2). Lines ② and ③ show the revolved section along line 1.
   Mark on line ② the contour line points in elevation (sketch 2).

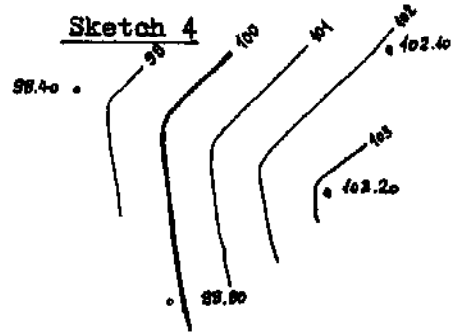
   e.g. for 99.80 - 103.20
   contour line 100 is 0.20 m higher → 0.2 cm from point 103.20
   contour line 101 is 1.20 m higher → 1.2 cm from point 103.20
4. Project these contour line points to the base line as shown with line ④ in sketch 3. Make this for all the connectings ①.
5. This projection gives the point of the contour line in plan.

   The points of the same elevation can then be connected to contour lines (sketch 4).

Sketch 3



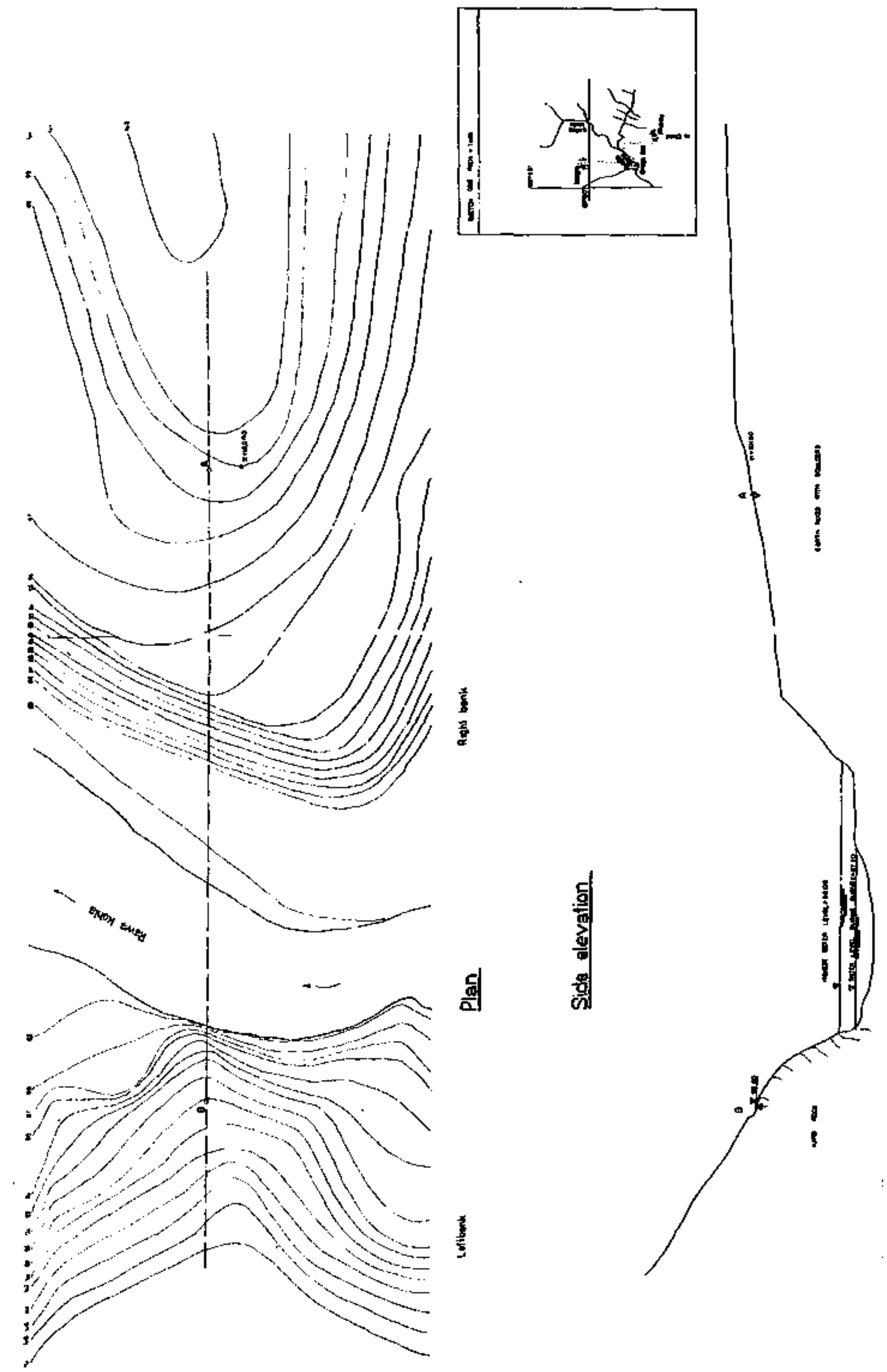
Sketch 4

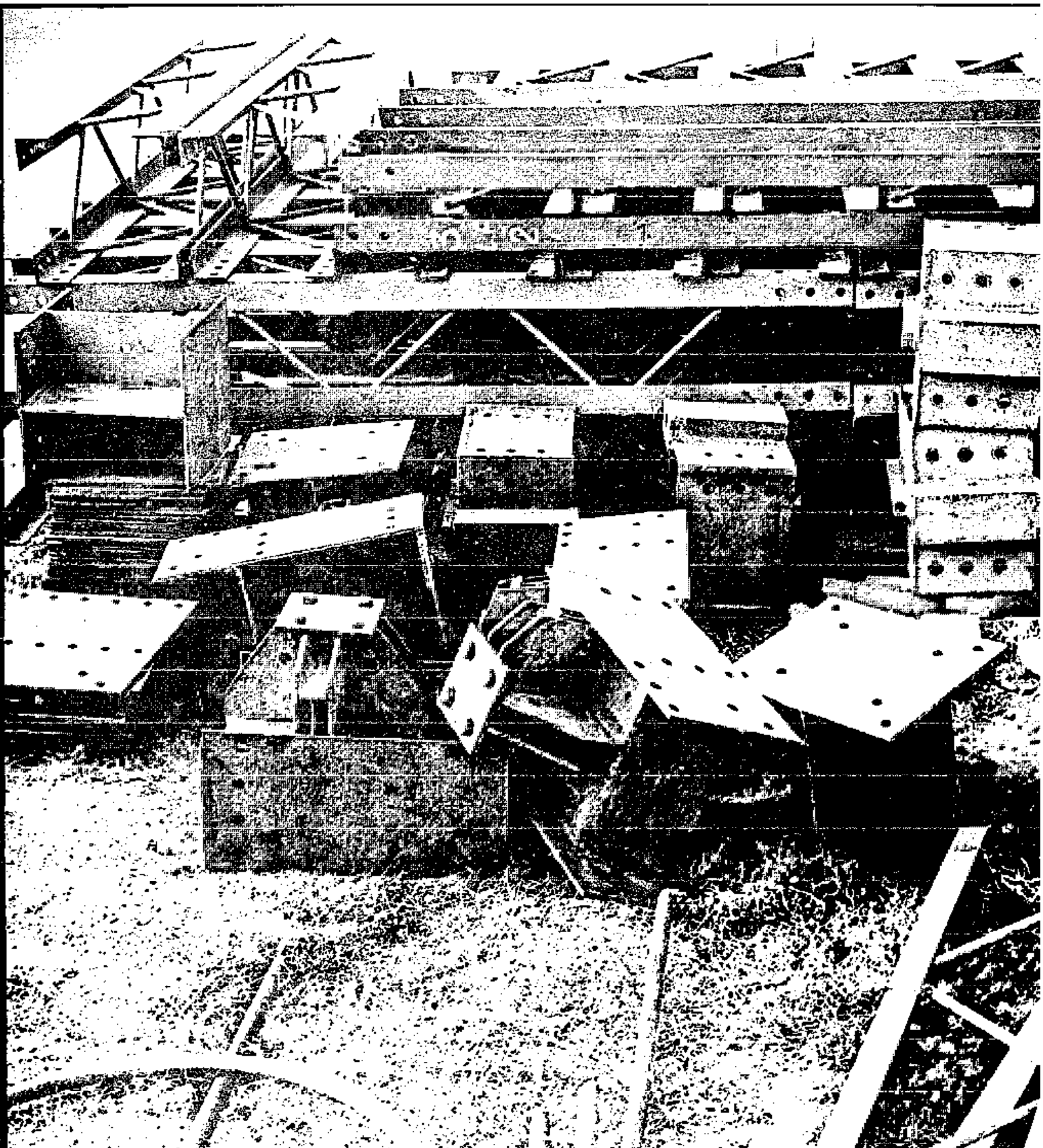


SURVEY OF BRIDGE SITE

Evaluation of the Survey

No.	: 4.403
Date :	28.12.1976
Sig :	Landsau

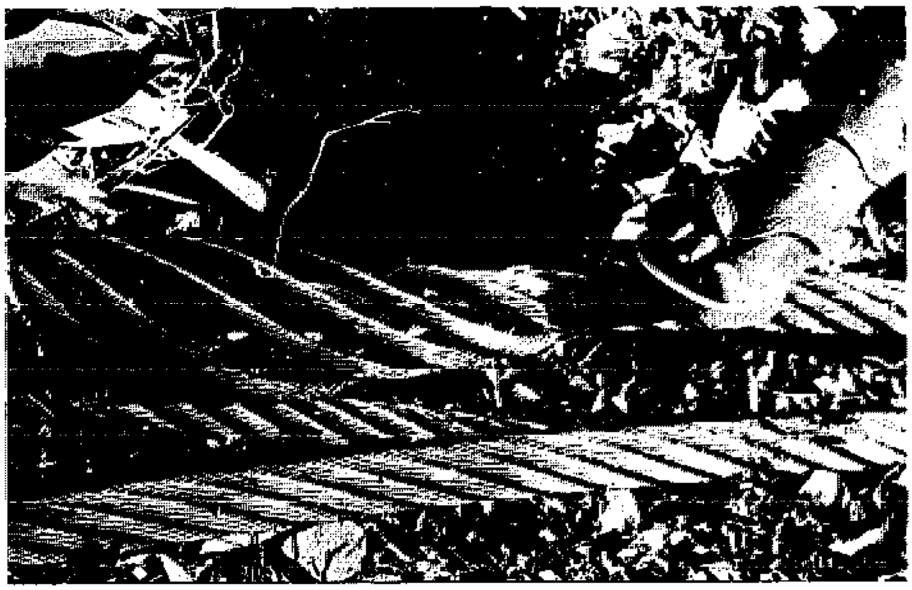




5. CONSTRUCTION MATERIAL

CONSTRUCTION MATERIAL		No.: 5.101
Steel cables,	Damage during transport and unreeling	~~Date: 6.5.75~~ ~~Sig.:~~

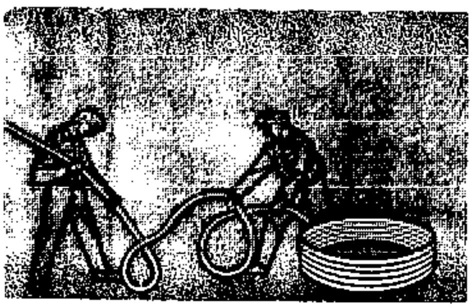
Some kinks, as seen on many construction sites



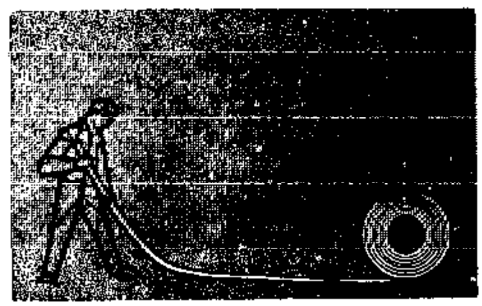
Kinking will damage the cables and greatly reduce the life and strength. Already existing loops cannot be straightened by pulling the rope taut. Twist the rope from the end towards the kink. Use for practice a thin cable.

CONSTRUCTION MATERIAL	No.: 5.1o2
Steel cables, Unreeling the cables	Date: 6.7.75 Sig.: [signature]

Cables should be unreeled in a manner that prevents small loops from forming. Do not attempt to unreel or uncoil cables from stationary coil or reel, as this will cause kinking (forming of loops)

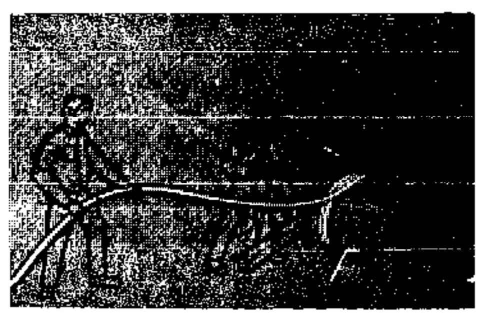


Wrong method



Correct method

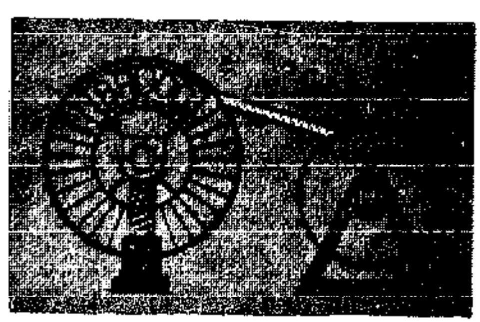
The most satisfactory method of unreeling cables is to mount the reel on a pipe or rod supported by two uprights.



Correct method

Reeling cables from one reel to another

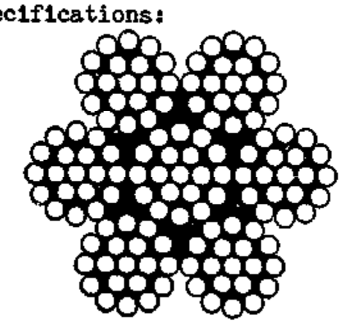
Wrong method



Correct method

<u>All metallic</u> steel cables or strands are used for suspension bridges.
The Indian Standard gives the following specifications:

IS 2266 - 1970
Specifications for steel wire ropes for general purposes.
Table 1 : 6x19 (12/6/1) with W.S.C. (wire strand core).
Tensile strength of wire 160 kg/mm^2

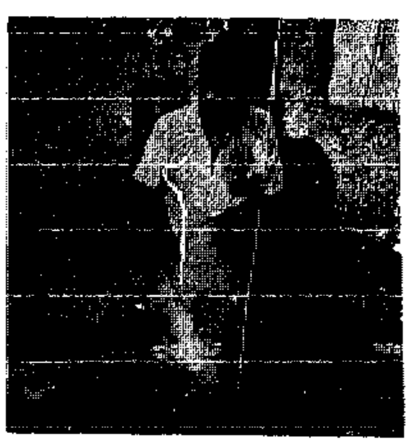


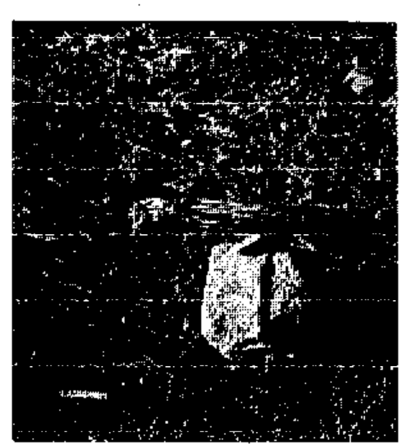
Cable diameter inches	mm	sectional area mm^2	Min. breaking load, tons	Weight per m kg
½"	13	56.07	8.79	0.64
1"	26	224.37	35.90	2.57
1¼"	32	340.00	54.40	3.90
1½"	38	481.00	77.00	5.53

IS 1835 - 1972 Secifications for steel wire ropes (2nd revision)
IS 2363 - 1965 Glossary of terms relating to wire ropes
IS 3973 - 1967 Code of practice for selection, installation and maintenance of wire ropes

Cable cutting

After welding the single strands on both sides of the cutting point, the steel cable is separated by the cutting-torch.





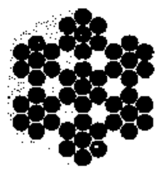
CONSTRUCTION MATERIAL

Steel cables — cables from Japan

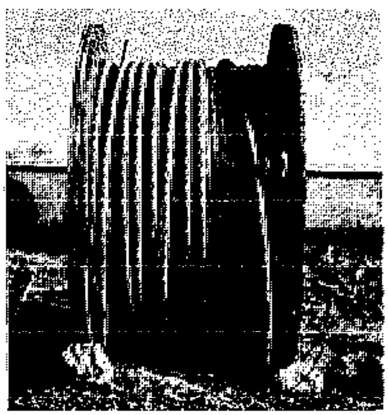
No. : 5.104

Date : 2.1.77

Sig : [signature]



6x7 with W.S.C. (Wire Strand Core) steel core construction for suspension bridges, galvanized, regular lay-right hand, tensile strength of the wire 170 - 185 kg/mm^2



Cable-drum in Amlekhganj

Right hand-regular lay (Z)

Cable diameter inches	mm	Wire diameter mm	Min. breaking load, tons	Weight per m kg
½"	12.5	1.40	11.3	0.61
1"	25.0	2.80	45.3	2.46
1¼"	32.0	3.55	71.0	4.02
1½"	38.0	4.18	102.0	5.51

The construction of this cable is again hexagonal, similar to the 6x19 W.S.C. according to Indian Standard. All cables constructed with less wires like 6x7 W.S.C. are less flexible but more economical due to higher breaking load and lower price.

CONSTRUCTION MATERIAL

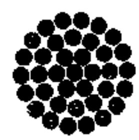
Steel cables — Used ropeway cables

No. : 2.105
Date : 2.1.77
Sig : R. Grob

The Kathmandu-Hetauda Ropeway is continuously replacing steel cables. The used ropeway cables are available and are an excellent and economic material to build suspension and suspended bridges, but always anchoraged on drums. Orders for such cables can be placed to

Ropeway Company
Teku Station
Kathmandu

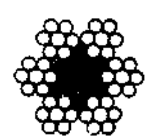
<u>1¼" Spiral Construction</u>, used ropeway track cable, ungalvanized.
37 wires with 4.6 mm dia
weight per metre 5 kg
Design breaking strength: 70 tons



Minimum bending diameter for fixing not less than 0.80 m. End fixing with drum anchorage according to the standard drawings.

drum anchorage
(refer to standard drawing)

<u>3/4" Fibre Core Construction</u>, used ropeway haulage cable, ungalvanized.
6 strands with 7 wires each and fibre core
weight per metre 1.3 kg
Design breaking strength: 12 tons


6 x 7 (6/1)

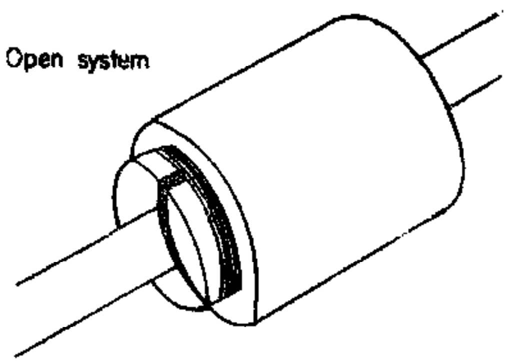
For end fixing the use of ordinary thimbles and 5 bulldog grips is recommended.

Equivalent to cable W.S.C. 6x19(12/6/1)	Bridge Wire (Ø 5 mm) Requirement for equivalent strength, breaking strength 160 Kg/mm². Allowable strength 72 Kg/mm² (German Standard). Area 19.6 mm². Weight per wire 0.154 Kg/m		
Ø inch	Area (mm²)	No. of Wires required	Weight of Wires (kg./m)
$\frac{1}{2}$"	40	2	0.31
1"	158	8	1.23
$1\frac{1}{4}$"	251	13	2.00
$1\frac{1}{2}$"	357	18	2.77

WEDGE AND CONE ANCHORAGE

The size of this anchorage system is manufactured for 1 wire or 7 wires

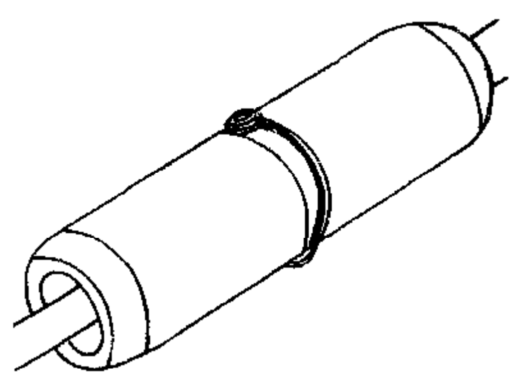
Open system



Closed system

Closed (coupling) connecting system

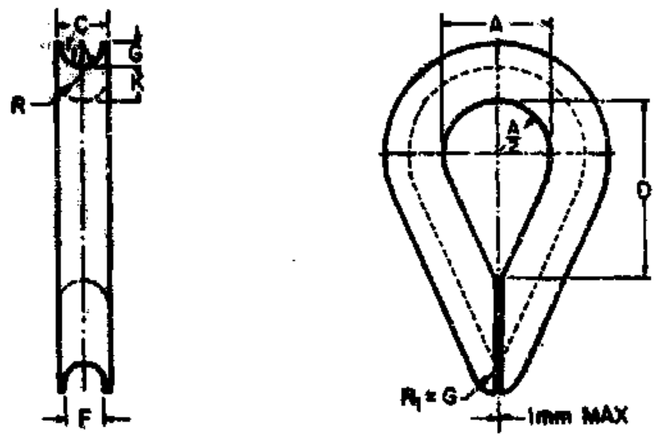
(connection of 2 wires)



CONSTRUCTION MATERIAL		No. : 5.201
Cable fittings	Thimbles	Date : 2.1.77
		Sig : R. Grk

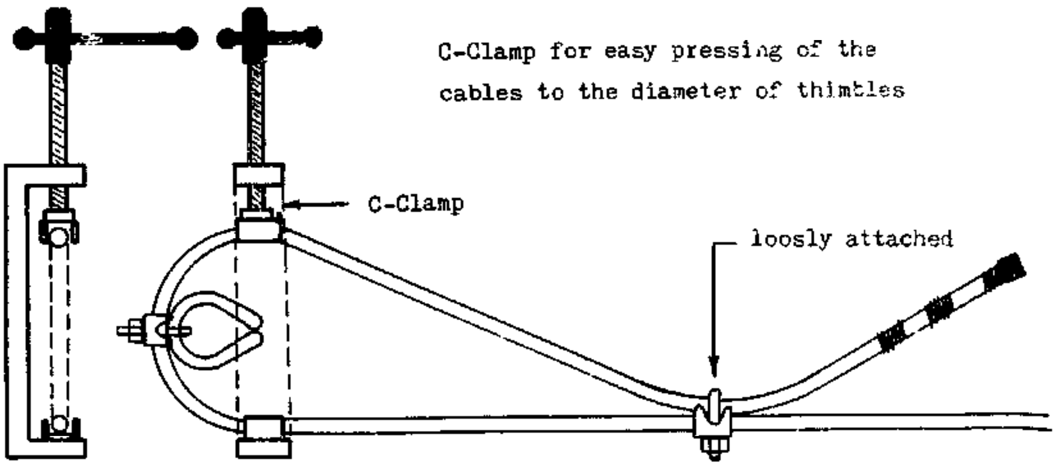
OPEN TYPE THIMBLES IS : 2315 - 1963

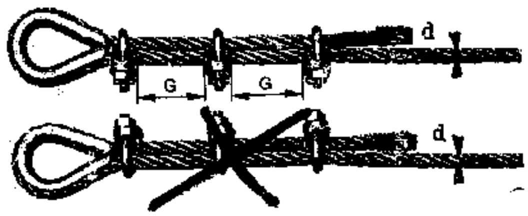
All dimensions in millimetres



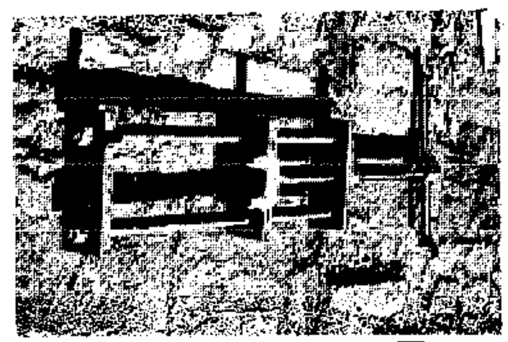
Nominal size of rope	A	C	D	F	G	K	r_1	R	Weight p.pc. (kg)
8	27	13	45	9	5	7	4.5	6.5	0.040
10	30	15	50	11	7	8	5.5	7.5	0.061
12	35	17	58	13	8	11	6.5	8.5	0.077
14	41	19	68	15	9	12	7.5	9.5	0.125
16	46	22	77	17	10	13	8.5	11.0	0.190
18	52	25	86	19	11	15	9.5	12.5	0.290
20	57	27	95	22	12	16	10.5	13.5	0.330
22	64	31	106	24	14	18	12.0	15.5	0.500
24	73	36	122	26	16	21	13.5	18.0	0.600
25	73	36	122	27	16	21	13.5	18.0	0.710
29	82	39	135	31	17	23	15.0	19.5	1.200
32	92	43	152	34	19	26	17.0	21.5	1.500
35	98	46	162	38	21	28	18.0	23.0	1.750
38	110	52	185	41	23	32	20.5	26.0	2.100

CONSTRUCTION MATERIAL		No. : 5.202
Cable fittings	Cable end fixed with bulldog grips and thimbles	Date : 13.7.75 Sig : [signature]





Gap (G) = 5-6 d



Specification for bulldog grips IS:2361-1970	Gap mm	Cable mm	Diameter inches	No. of grips minimum	Weight * Kg./Pc.
	35	2 - 3.5	1/8	3	0.011
		4 - 5	3/16	3	0.015
		5.5 - 6.5	1/4	3	0.018
	55	7 - 8	5/16	3	0.052
		8.5 - 9.5	3/8	3	0.065
		10 - 11	7/16	3	0.070
	85	12 - 13	1/2	3	0.130
		14 - 15	9/16	3	0.140
		16 - 17	5/16	5	0.200
	130	18 - 19	3/4	5	0.250
		20 - 23	7/8	5	0.400
		24 - 26	1	5	0.480
	200	27 - 30	1 1/8	5	0.640
		31 - 33	1 1/4	7	0.790
		34 - 40	1 1/2	7	0.950

* according to Kabelwerke Brugg Ltd. Switzerland

Very important:

After completion of the bridge construction, all bulldog grips must be tightened once again.

CONSTRUCTION MATERIAL

Cable fitting	Cable end fixed by drum and clamp	No : 5.202 Date : 16th March 77 Sig : [signature]

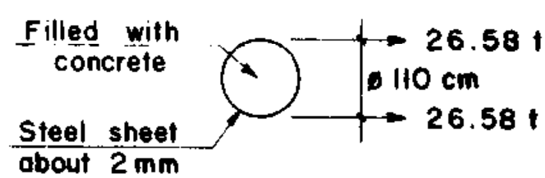
It is very difficult to get the cable anchored by socket end, especially at the spot. The cable sockets would have to be placed very correct or, the required hoisting sags could not be applied. Therefor, a high skill and accurate execution are necessary.
Beside of the execution work, there are other reasons why the socket end fixed cable ends are developing difficulties. The fixation of cable ends by using the standardized drum anchoroage does not include any problem. Recent experience has shown and proved, that the drum anchored cables can be suspended to the right sags surprisingly easy and quick.
The system of the drum anchorage has, however, the advantage that either spiral cable - e.g. used rope way acble - or steel wire cable - e.g. 6 x 19 (12/6/1) - can be fixed and safely anchored. It is important to point out, that the drum anchorage can be used for any kind of cable - even the parallel bridge wire cluster (single wire) - and, the needed steel is only about 1/5 of the normal anchor rod system.
The following example indicates how the drum cable anchorage might be calculated :

Given : 2 cables of ø 1 ½ " (38 mm)
max. Total Tension = 53.16 tons (from the statical calculation)
Cable end anchorad by drum and cable end clamp with eight bolts M 24 mm
Factor of static friction steel on steel = 0.15

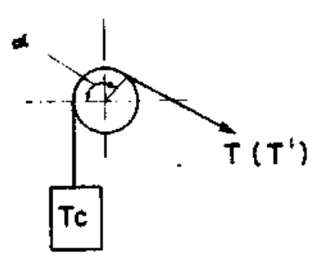
To be calculated : How many times the cable must be wrepped on ?
What is the capacity of the cable end clamp (cable clip)

. STEP :

Single cable force :
53.16 : 2 = 26.58 t



If on both sides of the drum the same force will be anchorad, the Torsion Moments will be neglected.
The sheave pulley is the basic system to anchor the force by utilizing the static friction cable on steel sheet of the drum.



Cable friction :

Friction $T_F = (e^{\mu\alpha} - 1) \cdot Tc$

Forces :

Upwards $T = e^{\mu} \cdot Tc$

Downwards $T' = \frac{Tc}{e^{\mu\alpha}} = Tc \cdot \frac{1}{e^{\mu\alpha}}$

α = radian measure

$\mu = \frac{\text{Static friction steel on steel}}{\text{1.5 (Safety factor)}} = 0.10$

$e = 2.71828183...$

CONSTRUCTION MATERIAL		No : 5.204
Cable fitting	Cable end fixed by drum and clamp (II)	Date : 16th March77
		Sig : [signature]

α radian $= \frac{\alpha^\circ \times \pi}{180^\circ}$ $\mu = \frac{0.15}{1.5} = 0.10$

$\pi = 3.14159654 \ldots$

Angle (degree)	0°	90°	180°	360°	540°	720°	900°	1080°
Radian measure	0	$\frac{\pi}{2}$	π	2π	3π	4π	5π	6π
$e^{\mu\alpha}$	1	1.170	1.369	1.874	2.566	3.514	4.810	6.586
$\frac{1}{e^{\mu\alpha}}$	1	0.855	0.730	0.533	0.390	0.285	0.207	0.152

$\alpha = 3 \cdot 360^\circ = 1080^\circ \triangleq 6\pi$

Tc = Cable force = 26.58 tons

T'c = Remaining force (to be kept as downwards by the cable clip)

$T' = Tc \cdot \frac{1}{e^{\mu\alpha}} = Tc\ 0.152 = 26.58 \cdot 0.152 = 4.04$ tons

Controll as upwards force (cable force)

$Tc = T' \cdot e^{\mu\alpha} = 4.04 \cdot 6.586 = 26.6 \triangleq 26.58$ tons

The calculation above shows that after turning the cable three times round the drum 4.04 tons are only left - i. e. the cable drum will take due to friction cable on steel = 26.58 - 4.04 = 22,54 tons. Total anchore force kept by the drum will be 2 x 22,54 = 45.08 tons.

2. S T E P :

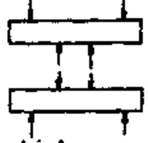
The remaining 4.04 tons on each cable must be anchored now with the cable clip (cable end clamp)

Total 8 nuts M24 (allowable tension force 3.14 tons)

To be anchore = 4.04 tons

Cable clip (cable end clamp)

System:



Action $8 \cdot 3.14$ tons $= 25.12$ tons

Reaction $8 \cdot 3.14$ tons $= 25.12$ tons

Total force which can kept:

$$T' > F_T = \frac{\text{Number of bolts} \cdot \text{tension allow.} \cdot 2 \cdot \mu \text{ (static friction)}}{1.5}$$

$$T' > F_T = \frac{8 \cdot 3.14 \cdot 2 \cdot 0.15}{1.5} = 5.024 > 4.04$$

SAFETY FACTOR :

$$\frac{T' \cdot e^{\mu\alpha}}{\text{cable force}} = \frac{5.024 \cdot 6.586}{26.58} = 1.24$$

The safety against bond failure is greather than just by calculation, because the drum and the cables will be encased in concrete. At the discharge point the cable will be safed against corosion with a joint sealer application (see 5.205 ff).

CONSTRUCTION MATERIAL		No. : 5.205
Cable fittings	joint sealer	Date : 2.1.77
		Sig : R. Grüli

Everytime when main cables are fixed by drum-anchorages and the final concrete work is finished, there is a joint between the main cables and the concrete. In such cases it is useful to apply (as it is shown on page 5.206) an elastic joint sealer to prevent rust in these sections.

Thanatar is a black, elastic fuel-resistant sealant for horizontal joints. It is delivered in two components which, when mixed in the required proportions, combine to an elastomeric compound which is applied cold.

Mixing proportions

THANATAR is supplied in two components which must be mixed thoroughly: 10 parts by weight of component A and one part by weight of component B.

Condition of joints

Preparation The cable in this part must be thoroughly dry and free of dust, oil and grease.

Cross-section The thickness should be ∾ 10 mm.

Application

Priming Apply THANA-PRIMER on dry cables and ensure complete coverage. THANA-PRIMER will be dry after 3 hours.

Mixing Stir well component A, then add component B to component A and mix thoroughly during appr. 3 minutes with a spatula until the mixture is homogeneous. During cold weather, component A can be warmed in a water bath up to 20°C.

Pot life Appr. ½ hour for a 2 kg mixture. Larger quantities should be mixed only if they can be applied within 20 minutes as the pot life diminishes as the quantity mixed increases.

Curing

At normal temperatures (appr. 20°C), THANATAR will not stick any more after 4 to 6 hours and will be completely hardened after appr. 24 hours.

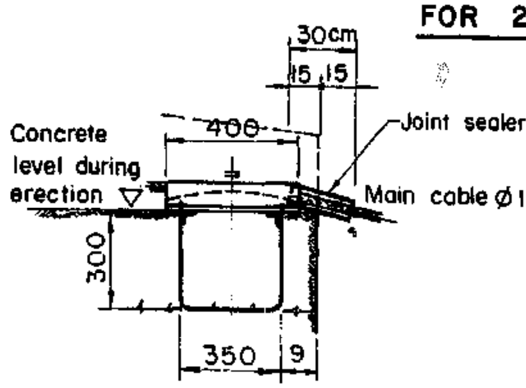
PRECAUTIONS

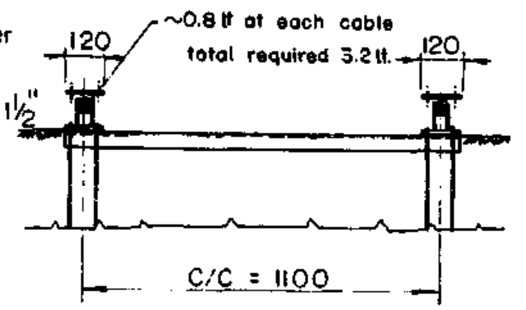
Fully hardened THANATAR is not soluble and can almost not be removed mechanically. Clean tools immediatly after use! THANATAR IS INFLAMMABLE! Keep it away from fire!

THANATAR stands for an example. Each other product in this manner is applicable. (Meynadier Ltd. Vulkanstr. 110 8048 Zurich, Switzerland)

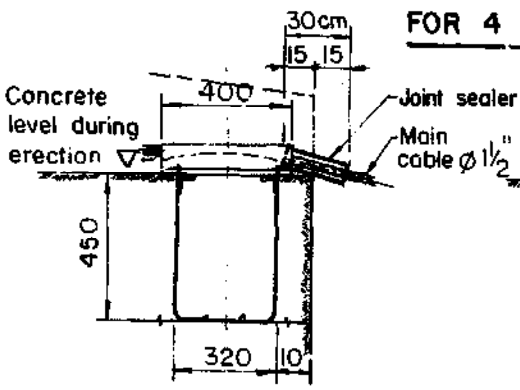
APPLICATION OF THE JOINT SEALER

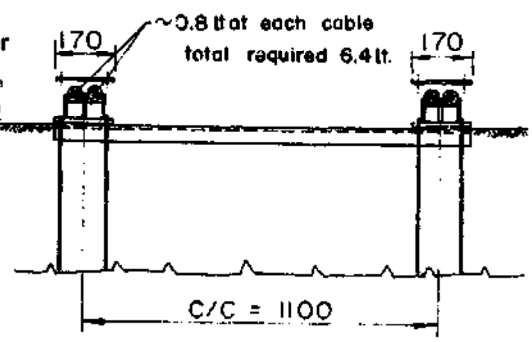
FOR 2 MAIN CABLES (39-60 m Span)



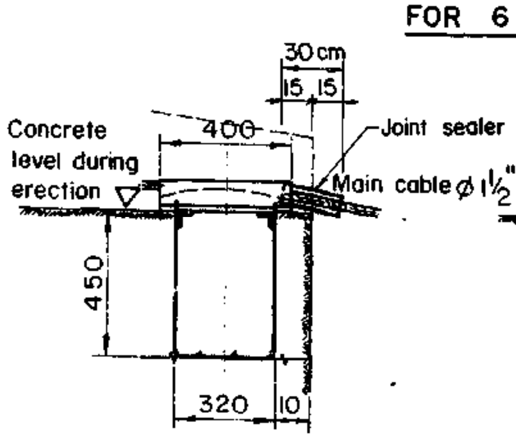


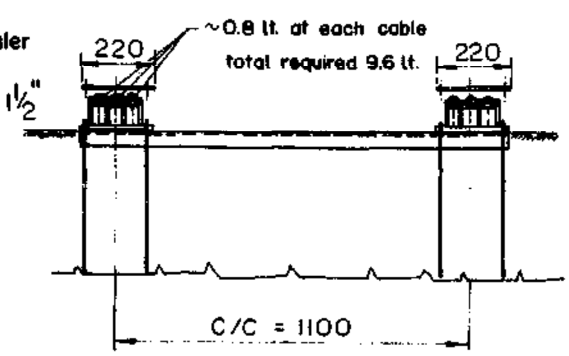
FOR 4 MAIN CABLES (63 -87 m Span)





FOR 6 MAIN CABLES (87-126 m Span)

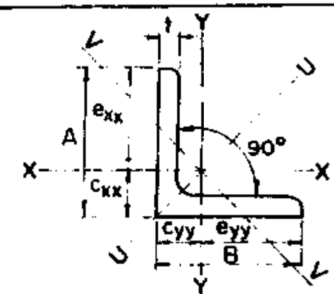




SATA, Swiss Association for Technical Assistance

ROLLED STEEL EQUAL ANGLES

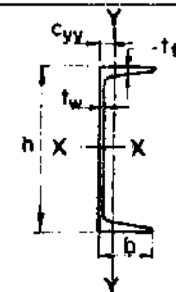
DIMENSIONS AND PROPERTIES



Designation	Size A x B mm. mm.	Weight per Meter w kg.	Sectional Area a cm^2	Thickness t mm.	Centre of Gravity $c_{xx}=c_{yy}$ cm.	Distance of Extreme $e_{xx}=e_{yy}$ cm.	Moments of Inertia $I_{xx}=I_{yy}$ cm^4	Moments of Inertia I_{uu} cm^4	Moments of Inertia I_{vv} cm^4	Radii of Gyration $r_{xx}=r_{yy}$ cm.	Radii of Gyration r_{uu} cm.	Radii of Gyration r_{vv} cm.	Modulus of Section $z_{xx}=z_{yy}$ cm^3
ISA 2020	20X20	0.9	1.12	3.0	0.59	1.41	0.4	0.6	0.2	0.58	0.73	0.37	0.3
ISA 5050	50X50	3.8	4.79	5.0	1.41	3.59	11.0	17.6	4.5	1.52	1.92	0.97	3.1
		4.5	5.68	6.0	1.45	3.55	12.9	20.6	5.3	1.51	1.90	0.96	3.6
ISA 6565	65X65	4.9	6.25	5.0	1.77	4.73	24.7	39.4	9.9	1.99	2.51	1.26	5.2
		5.8	7.44	6.0	1.81	4.69	29.1	46.5	11.7	1.98	2.50	1.26	6.2
ISA 8080	80X80	9.6	12.21	8.0	2.27	5.73	72.5	115.6	29.4	2.44	3.08	1.55	12.6
		11.8	15.05	10.0	2.34	5.66	87.7	139.5	36.0	2.41	3.04	1.55	15.5
ISA100100	100X100	12.1	15.39	8.0	2.76	7.24	145.1	231.8	58.4	3.07	3.88	1.95	20.0
		14.9	19.03	10.0	2.84	7.16	177.0	282.2	71.8	3.05	3.85	1.94	24.7
		17.7	22.59	12.0	2.92	7.08	207.0	329.3	84.7	3.03	3.82	1.94	29.2
ISA 110110	110X110	16.5	21.06	10.0	3.08	7.92	238.4	380.5	96.3	3.36	4.25	2.14	30.1
		19.6	25.02	12.0	3.16	7.84	279.6	445.3	113.8	3.34	4.22	2.13	35.7
ISA130130	130X130	19.7	25.06	10.0	3.58	9.42	402.7	643.4	162.1	4.01	5.07	2.54	42.7
		23.4	29.82	12.0	3.66	9.34	473.8	755.9	191.8	3.99	5.03	2.54	50.7
ISA150150	150X150	22.8	29.03	10.0	4.06	10.94	622.4	995.4	249.4	4.63	5.86	2.93	56.9
		27.2	34.59	12.0	4.14	10.86	735.4	1174.8	296.0	4.61	5.83	2.93	67.7

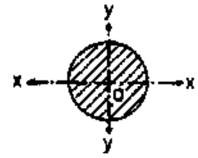
ROLLED STEEL CHANNELS

DIMENSIONS AND PROPERTIES



Designation	Weight per Meter w kg	Sectional area a cm^2	Depth of Section h mm	Width of Flange b mm	Thickness of Flange t_f mm	Thickness of Web t_w mm	Centre of Gravity c_{yy} cm	Moments of Inertia I_{xx} cm^4	Moments of Inertia I_{yy} cm^4	Radii of Gyration r_{xx} cm	Radii of Gyration r_{yy} cm	Moduli of Section Z_{xx} cm^3	Moduli of Section Z_{yy} cm^3
ISLC 75	5.7	7.26	75	40	6.0	3.7	1.35	66.1	11.5	3.02	1.26	17.6	4.3
ISLC 100	7.9	10.02	100	50	6.4	4.0	1.62	164.7	24.8	4.06	1.57	32.9	7.3
ISLC 125	10.7	13.67	125	65	6.6	4.4	2.04	356.8	57.2	5.11	2.05	57.1	12.8
ISLC 150	14.4	18.36	150	75	7.8	4.8	2.38	697.2	103.2	6.16	2.37	93.0	20.2
ISLC 175	17.6	22.40	175	75	9.5	5.1	2.40	1148.4	126.5	7.16	2.38	131.3	24.8
ISLC 200	20.6	26.22	200	75	10.8	5.5	2.35	1725.5	146.9	8.11	2.37	172.6	28.5
ISMC 75	6.8	8.67	75	40	7.3	4.4	1.31	76.0	12.6	2.96	1.21	20.3	4.7
ISMC 100	9.2	11.70	100	50	7.5	4.7	1.53	186.7	25.9	4.00	1.49	37.3	7.5
ISMC 125	12.7	16.19	125	65	8.1	5.0	1.94	416.4	59.9	5.07	1.92	66.6	13.1
ISMC 150	16.4	20.88	150	75	9.0	5.4	2.22	779.4	102.3	6.11	2.21	103.9	19.4
ISMC 175	19.1	24.38	175	75	10.2	5.7	2.20	1223.3	121.0	7.08	2.23	139.8	22.8
ISMC 200	22.1	28.21	200	75	11.4	6.1	2.17	1819.3	140.4	8.03	2.23	181.9	26.3

ROUNDS: Dimensions and properties



Diameter d mm	Weight w kg	Sectional Area a cm^2	Moduli of Section $Z_{xx} = Z_{yy}$ cm^3
6	0·222	0·283	0·021
8	0·395	0·502	0·050
10	0·617	0·785	0·098
13	1,042	1·337	0·216
16	1·578	2·011	0·402
20	2·466	3·142	0·785
25	3·853	4,119	1·534
32	6·313	8·042	3·217
38	8·903	11·340	5·357
42	10·876	13·850	7·274

Rectangular Bars: Dimensions and properties

Designation	Weight w kg	Sectional Area a cm^2	Moduli of Section Z_{xx} cm^3	Z_{yy} cm^3
32/20	5 024	6 40	3 41	2 13
32/20	8 000	10 24	5 46	5 46

Flats and Plates

Weights

Flat						Plate							
Designation	Weight kg	Designation	Weight kg	Designation	Weight kg	Thickness mm	Weight kg	Thickness mm	Weight kg	Thickness mm	Weight kg	Thickness mm	Weight kg
6/38	1·790	8/360	22·608	10/480	14·130	2	15·70	8	62·80	16	125·60	25	196·25
6/65	3·062	9/38	2·685	10/290	22·765	5	39·25	10	78·50	20	157·00	28	219·80
6/180	11·305	9/65	4·592	10/360	28·260	6	47·10	12	94·20	22	172·70	32	251·20

CONSTRUCTION MATERIAL

Steel

Rivets and bolts

No. : 5.304

Date : 2.1.77

Sig : [signature]

SATA, Swiss Association for Technical Assistance

RIVETS AND BOLT VALUES

FOR WORKSHOPS AND STEEL FRAMED BUILDINGS

	Dia of hole in inches	Area in cm^2	Shear value in tons per rivet: Single	Double	Bearing value in tons per rivet for a plate thickness (in mm) of +: 6	8	10	12	13	14	16	18	20	Axial tension in tons value of one: Rivet	Bolt*		Tons per cm^2
SHOP RIVETS AND T.F. TURNED BOLTS	1/2	1.27	1.18	2.36	1.42	1.90	2.36	2.84	–	–	–	–	–	0.98	.81		
	5/8	1.98	1.84	3.68	1.78	2.36	2.95	3.54	3.84	–	–	–	–	1.53	1.02	Single shear =	0.93
	3/4	2.85	2.65	5.30	2.13	2.83	3.55	4.25	4.61	4.96	5.68	–	–	2.21	1.82	Double shear =	1.86
	13/16	3.34	3.11	6.23	2.31	3.07	3.84	4.61	5.00	5.37	6.15	6.90	–	2.59	2.20	Bearing =	1.86
	7/8	3.88	3.61	7.21	2.49	3.31	4.14	4.95	5.38	5.79	6.61	7.44	–	3.01	2.53	Axial stress on: rivets =	0.78
	15/16	4.45	4.14	8.26	2.66	3.55	4.43	5.31	5.77	6.19	7.09	7.96	8.86	3.45	2.98	bolts less than 3/4" =	0.78
	1	5.07	4.71	9.42	2.84	3.78	4.73	5.67	6.14	6.62	7.56	8.50	9.45	3.93	3.32	3/4" dia & up =	0.93
SITE RIVETS	1/2	0.89	0.98	1.96	1.18	1.57	1.97	2.36	–	–	–	–	–	0.79	–	Single shear =	0.78
	5/8	1.98	1.53	3.07	1.47	1.97	2.46	2.95	3.20	–	–	–	–	1.23	–	Double shear =	1.55
	3/4	2.85	2.21	4.42	1.78	2.36	2.95	3.56	3.84	4.14	4.73	–	–	1.77	–	Bearing =	1.55
	13/16	3.34	2.60	5.19	1.92	2.56	3.20	3.83	4.16	4.48	5.12	5.75	–	2.07	–	Axial stress on	
	7/8	3.88	3.01	6.01	2.07	2.75	3.44	4.13	4.49	4.82	5.51	6.20	–	2.41	–	rivets =	0.62
	15/16	4.45	3.45	6.90	2.21	2.95	3.70	4.42	4.80	5.17	5.91	6.64	7.38	2.76	–		
	1	5.07	3.93	7.85	2.36	3.16	3.94	4.73	5.12	5.52	6.30	7.09	7.86	3.14	–		
BLACK BOLTS	1/2	1.27	0.79	1.57	0.95	1.26	1.58	1.89	–	–	–	–	–	–	0.61	Single shear =	0.62
	5/8	1.98	1.23	2.45	1.18	1.57	1.97	2.36	2.56	–	–	–	–	–	1.02	Double shear =	1.24
	3/4	2.85	1.77	3.53	1.42	1.90	2.36	2.84	3.07	3.31	3.78	–	–	–	1.89	Bearing =	1.24
	13/16	3.34	2.07	4.15	1.54	2.05	2.56	3.06	3.33	3.59	4.09	4.59	–	–	2.20	Axial stress on:	
	7/8	3.88	2.41	4.81	1.65	2.21	2.76	3.302	3.58	3.86	4.42	4.95	–	–	2.53	bolts less than 3/4"	0.93
	15/16	4.45	2.76	5.52	1.78	2.36	2.95	3.54	3.84	4.14	4.73	5.32	5.90	–	2.98	3/4" dia & up =	0.93
	1	5.07	3.14	6.28	1.89	2.52	3.15	3.78	4.10	4.41	5.04	5.67	6.30	–	3.32		

* Axial stress on the area at the bottom of the bolt thread.

\+ The bearing values to the right of the upper zigzag line are greater than the corresponding double shear value.
" " " " " " lower " " " " " " single " "

CONSTRUCTION MATERIAL		No. : [illegible]
Steel	Ribbed Torsteel for concrete reinforcement	Date : [illegible]
		Sig : R. [illegible]

RIBBED-TORSTEEL

HIGH BOND HIGH STRENGTH STEEL FOR CONCRETE REINFORCEMENT

RIBBED-TORSTEEL fully conforms to the best known international standards and Codes of Practices of reinforced concrete including:
Indian Standard: IS 1786-1966: Indian Code of Practice IS 456-1964: British Standard B.S. 1144 and B.S.4461 (metric): British Code of Practice C.P. 114: French Standards B.A. 1968: German Standards DIN 1045:

PERMISSIBLE STRESS:		
Tension Reinf.	ø< 20mm	2300kg/cm² (33,000 psi)
	ø>20mm	2100kg/cm² (30,000psi)
Shear Reinf.		1750kg/cm² (25,000psi)
Compression Reinf.		1750kg/cm² (25,000psi)
Bond		50% more than Plain Bar

USEFUL DATA OF STANDARD SIZES		
Size (mm)	Area (cm²)	Wt. kg/metre
8	0.50	0.4
10	0.78	0.6
12	1.13	0.9
16	2.01	1.6
20	3.14	2.5

ø mm	Wt kg/m	Area per bar cm²	No. of bars per m length of the concrete construction (cm²/m)			
			3⅓	4	5	6⅔
			Distance between the bars			
			30 cm	25 cm	20 cm	15 cm
8	0.395	0.503	1.68 cm²	2.01cm²	2.51cm²	3.35cm²
10	0.617	0.785	2.62 cm²	3.14cm²	3.93cm²	5.23cm²
12	0.888	1.130	3.77 cm²	4.52cm²	5.65 cm²	7.54cm²
16	1.580	2.010	6.70 cm²	8.04cm²	10.10cm²	13.40cm²
20	2.470	3.140	10.50 cm²	12.60cm²	15.70 cm²	20.90cm²
ø	Wt kg/m	Area per bar cm²	Area per m width of the concrete structure			

Licensed Producer in Nepal:

HIMAL IRON & STEEL (P) LTD.
Regd. Office: 'JYOTI BHAWAN' KANTIPATH
KATHMANDU, NEPAL
Telephone: 11490/14902· Cable: HIMALIRON
Factory: PARWANIPUR, NEPAL

RECOMMENDED MIXES FOR VARIOUS TYPES OF CONSTRUCTION

Depends on whether concrete is to be tamped, rodded or vibrated and on absorption of water by aggregate.

Nature of Work	Mixture Recommended Vol. Proport.	Maximum Size of Aggregate to use	Water in gallons per bag of C.	Bast Consistency
Long span reinforced concrete arches, high load reinforced concrete columns	1:1:2	½" to 3/4"	3.5 to 4.0	Medium
Heavily stressed members of structures, small precast work such as Posts and Poles for Fencing, Telegraphs, Signals, Garden, furniture and decoratives and other work of very thin sections, watertight constructions for high heads, long piles.	1:2:2	½" to 3/4"	4.5 to 5.0	Medium or Soft.
R.C. Columns and members subjected to medium loads, wall and floors of reservoir and tanks, cisterns, sewers, well kerbs and platforms and other watertight constructions for moderate heads nonsurfaced roof slabs, concrete deposited under water.	1:3:2 or 1.2:2:4	3/4"	5.5	Medium
General R.C. Building work subjected to ordinary stresses such as beams, slabs, columns, panel walls basement and retaining, walls, stairs, lintels, sills, roads, pavements, driveways, side walls, floors, steps, bunkers, silos, bridge construction, dams and pier etc. exposed to action of water and frost, machine foundations subjected to vibrations, R.C. footings, R.C. piles.	1:2:4	½" to 1½" as required	6.0 to 6½	Stiff for Roads Medium for others.
Mass concrete work in culverts, retaining walls, compound walls and ordinary machine bases, foundation, walls which need not be water-tight.	1:3:5 1:3:6 + 40% boulders	1" to 2"	7.5	Stiff or Medium
Mass concrete for heavy walls, foundations under column footings and under heavy duty floors, concrete blocks, hollow block construction (½" AGG).	1:4:8 (or 1:3:6 + 40% boulder)	1½" to 2½"	10.0 to 10.5	Medium

The two important Nepali – timbers are SAL (Shorea robusta) and DEBDARU well known as SALLA.

SAFE PERMISSIBLE STRESSES IS: 883 – 1966

Trade name	Average weight kg/m^3	Modulus of elasticity t/cm^2	Bending and tension along grain kg/cm^2	Shear		Compression	
				horizontal kg/cm^2	along grain kg/cm^2	parallel to grain kg/cm^2	perpendicular to grain kg/cm^2
SALLA	515	92	70	7	10	50	10
SAL	865	127	112	9	13	78	29

Example for timber design :

1. Design of a round column

P = 700 kg
h = 4.00m

A = Area of section, cm^2
l_B = length of buckling
r = radius of gyration
$l_a = \frac{l_B}{r}$ = slenderness ratio

approximate formula for round timbers : $A = (12 \cdot P) + (8 \cdot l_B^2)$

P in tons, l_B in m

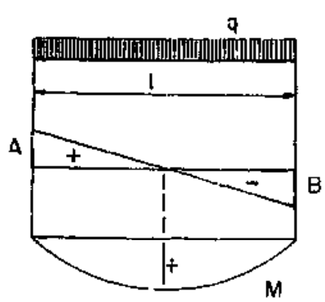
$A = 12 \cdot 7 + 8 \cdot 4^2 = 212 cm^2$

$\varnothing$ 18cm with $A = 254 cm^2$ $\quad r = \frac{d}{4} = 4.5 cm \quad l_a = \frac{400}{4.5} = 88.8 \cong 89$

w = 2.54 (according to DIN 1052) on page 5.502 $\quad f = \frac{w \cdot P}{A} = \frac{2.54 \cdot 7000}{254} = 70 kg/cm^2 < 78$

permissible compression parallel to grain for SAL timber $= 78 kg/cm^2$

2. Design for planks (beam)



q = 300 kg/m
l = 2.0 m
$A = B = 300 kg = \frac{q \cdot l}{2}$

z = Section modulus

$z_{min} = \frac{M_{max}}{f_{max}}$

$M_{max} = \frac{q \cdot l^2}{8} = 150 mkg \qquad z_{min} = \frac{15000}{112} = 134 cm^3$

Section : 6/23 $\qquad z = \frac{23 \cdot 6^2}{6} = 138 cm^3$

Bending : $f = \frac{15000}{138} = 109 kg/cm^2 < 112 kg/cm^2$

$\tau = \frac{3 \cdot Q}{2 \cdot A}$

Shear : $f = \frac{3 \cdot 300}{2 \cdot 138} = 3.26 kg/cm^2 < 13 kg/cm^2$

(for rectangular sections only; Q = Max. shearing force, A = Area of section)

CONSTRUCTION MATERIAL		No. : 5.502
	Buckling – numbers	Date : 26.2.77
Timber	for wooden buildings.	Sig. : R Grüli

BUCKLING-NUMBERS FOR WOODEN BUILDINGS (according to DIN 1052)

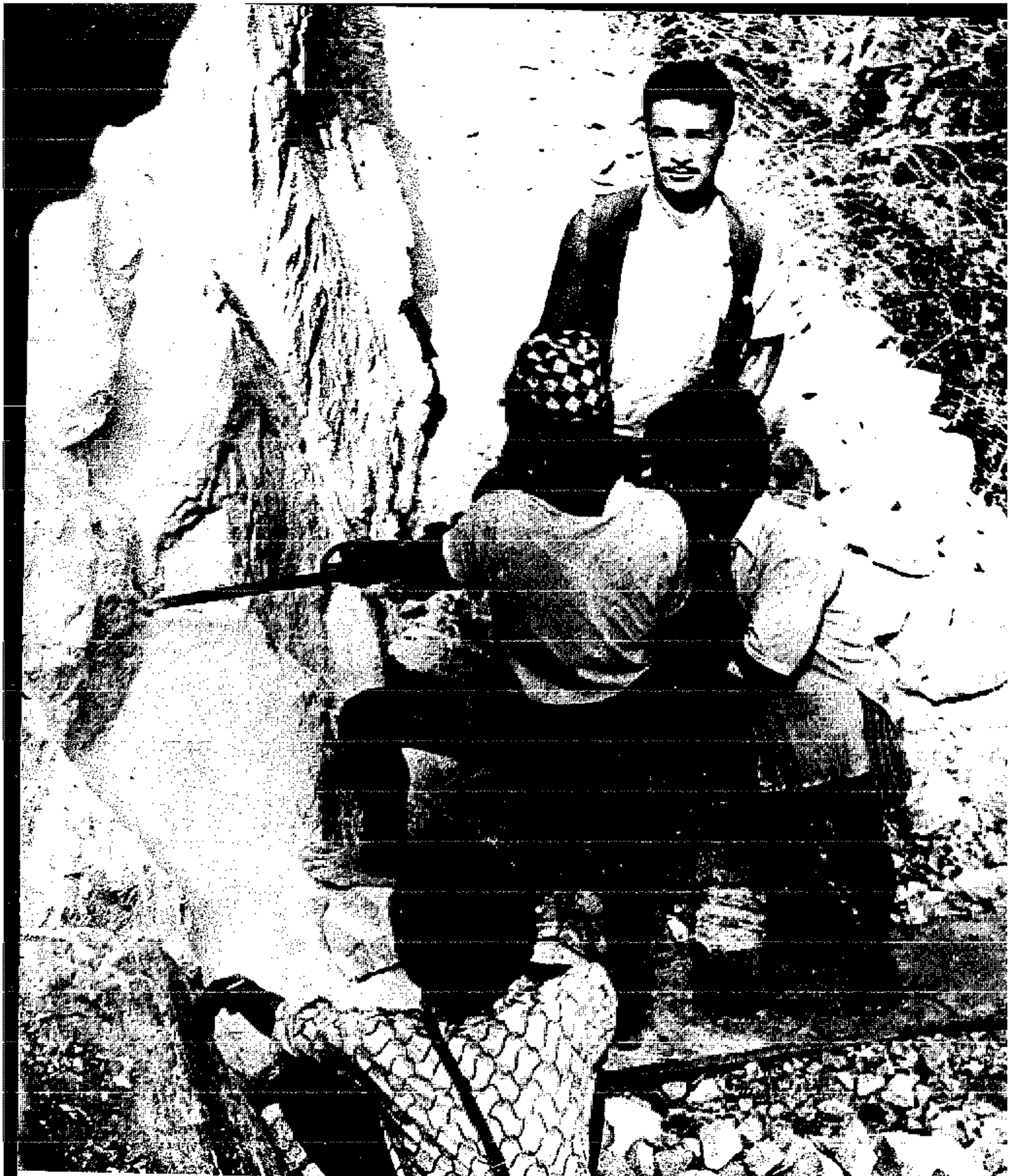
l_a	0	1	2	3	4	5	6	7	8	9	l_a
0	1.00	1.00	1.01	1.01	1.02	1.02	1.02	1.03	1.03	1.04	0
10	1.04	1.04	1.05	1.05	1.06	1.06	1.06	1.07	1.07	1.08	10
20	1.08	1.09	1.09	1.10	1.11	1.11	1.12	1.13	1.13	1.14	20
30	1.15	1.16	1.17	1.18	1.19	1.20	1.21	1.22	1.24	1.25	30
40	1.26	1.27	1.29	1.30	1.32	1.33	1.35	1.36	1.38	1.40	40
50	1.42	1.44	1.46	1.48	1.50	1.52	1.54	1.56	1.58	1.60	50
60	1.62	1.64	1.67	1.69	1.72	1.74	1.77	1.80	1.82	1.85	60
70	1.88	1.91	1.94	1.97	2.00	2.03	2.06	2.10	2.13	2.16	70
80	2.20	2.23	2.27	2.31	2.35	2.38	2.42	2.46	2.50	2.54	80
90	2.58	2.62	2.66	2.70	2.74	2.78	2.82	2.87	2.91	2.95	90
100	3.00	3.06	3.12	3.18	3.24	3.31	3.37	3.44	3.50	3.57	100
110	3.63	3.70	3.76	3.83	3.90	3.97	4.04	4.11	4.18	4.25	110
120	4.32	4.39	4.46	4.54	4.61	4.68	4.76	4.84	4.92	4.99	120
130	5.07	5.15	5.23	5.31	5.39	5.47	5.55	5.63	5.71	5.80	130
140	5.88	5.96	6.05	6.13	6.22	6.31	6.39	6.48	6.57	6.66	140
150	6.75	6.84	6.93	7.02	7.11	7.21	7.30	7.39	7.49	7.58	150
160	7.68	7.78	7.87	7.97	8.07	8.17	8.27	8.37	8.47	8.57	160
170	8.67	8.77	8.88	8.98	9.08	9.19	9.29	9.40	9.51	9.61	170
180	9.72	9.83	9.94	10.05	10.16	10.27	10.38	10.49	10.60	10.72	180
190	10.83	10.94	11.06	11.17	11.29	11.41	11.52	11.64	11.76	11.88	190
200	12.00	12.12	12.24	12.36	12.48	12.61	12.73	12.85	12.98	13.10	200
210	13.23	13.36	13.48	13.61	13.74	13.87	14.00	14.13	14.26	14.39	210
220	14.52	14.65	14.79	14.92	15.05	15.19	15.32	15.46	15.60	15.73	220
230	15.87	16.01	16.15	16.29	16.43	16.57	16.71	16.85	16.99	17.14	230
240	17.28	17.42	17.57	17.71	17.86	18.01	18.15	18.30	18.45	18.60	240
250	18.75	—	—	—	—	—	—	—	—	—	250

l_a = slenderness ratio

l_B = length of buckling

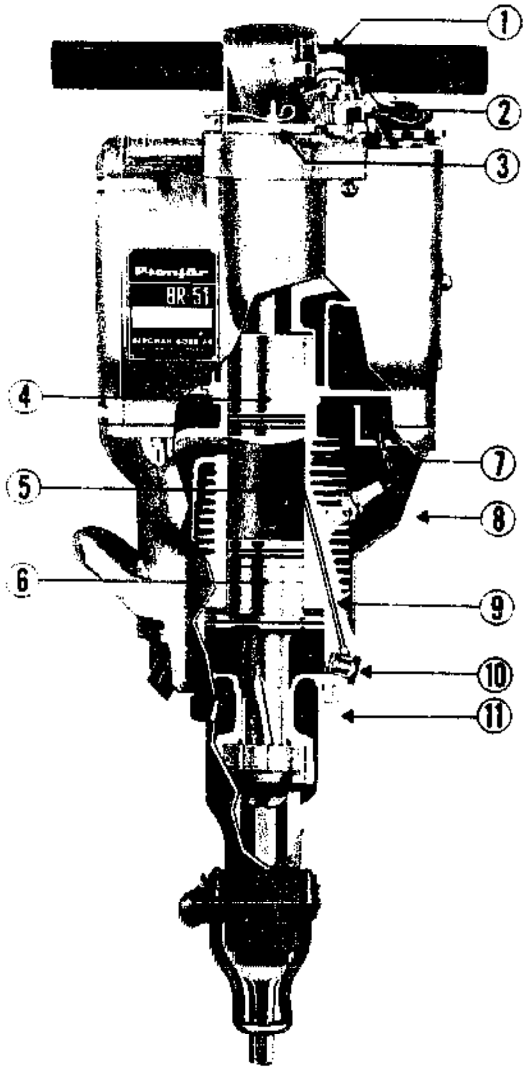
r = radius of gyration

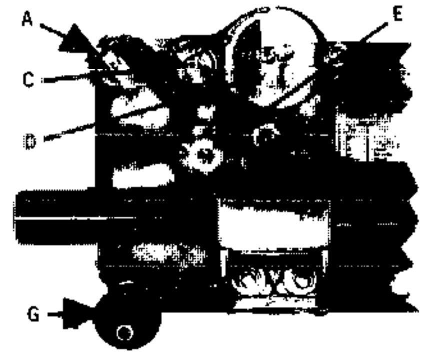
$$l_a = \frac{l_b}{r}$$



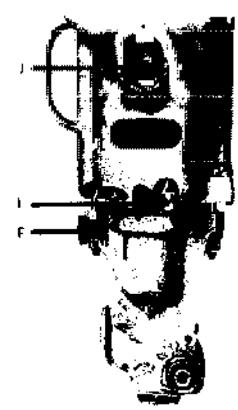
6. MACHINES AND TOOLS

MACHINES AND TOOLS Rock drilling machine, General description	No.: 6.1o1 Date: 13.7.75 Sig.: [signature]



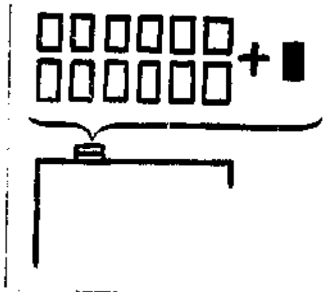


A Cover of fuel tank
C Fuel valve
D Cover of air filter
E Slow run control
F Control lever
G Starter wire
J Short-circuit switch
L Gas duct valve

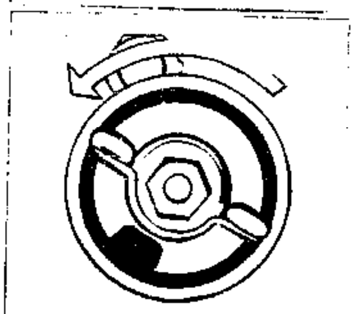


1 Slow run control
2 Fuel valve, speed regulator
3 Cover of air filter, choke
4 Engine piston
5 Gas chamber
6 Hammer piston
7 Cylinder
8 Short-circuit switch
9 Gas duct with permanent cleaning pin
1o Gas duct valve
11 Drill shank housing

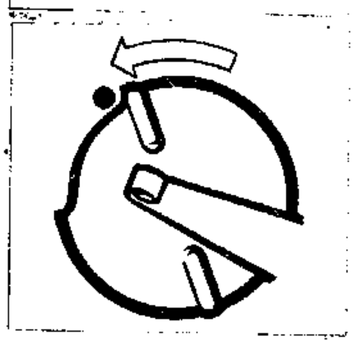
MACHINES AND TOOLS		No.: 6.1o2
Rock drilling machine,	Operation and Maintenance	Date: 13.7.75
		Sig.:



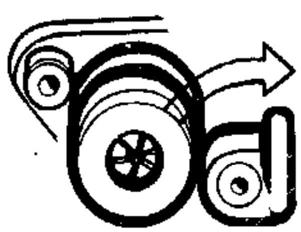
1 Before starting
Mix fuel 1 to 12, i.e. 8%. Use ordinary 2-stroke oil-mixture. Shake well. Fill the tank. The right fuel-mixture is vital!



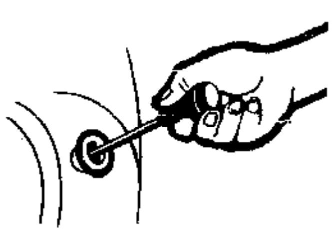
2 Open the fuel needle valve When the engine is warm the normal setting is half a turn



3 Close the choke fully (turn counter-clockwise)

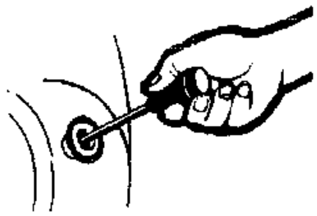


4 Check that the throttle is open — idling latch turned aside



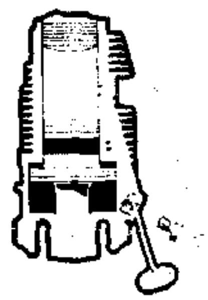
5 Starting and stopping
Pull the starter wire until fuel reaches the engine and it fires

6 Open the choke fully.

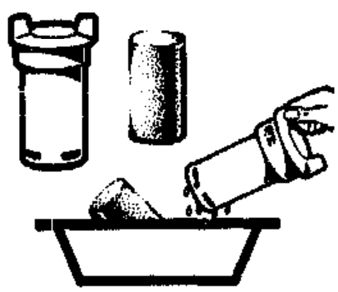


7 Pull the starter wire sharply. When the engine has started run it until warm and then adjust the fuel supply for even running

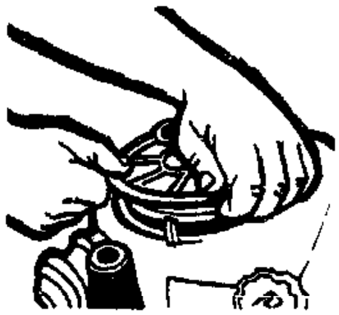
8 For brief stops press the short-circuit leaf. For longer stops — close the fuel valve.



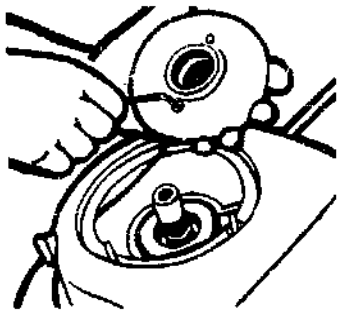
9 **Maintenance**
Clean the gas duct, permanent cleaning pin and gas duct valve — preferably every week. Clean the full length of the duct with the cleaning needle. Check the valve.



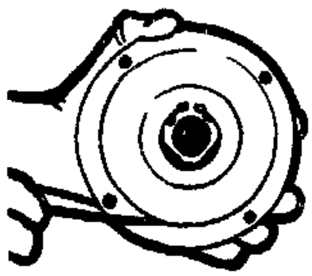
10 Clean the air filter every day in oil-mixed fuel. If pure gasoline is used — moisten the filter element with oil before re-assembly.



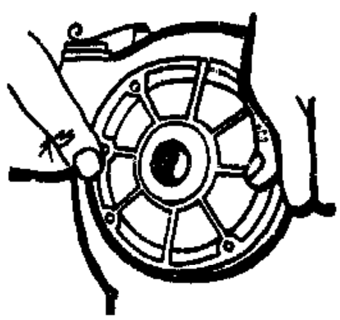
11 Replacing of starter wire
Remove nuts and washers from the cover plate. Lift up the cover together with the starter pulley. Hold the spring against the cover while departing cover and pulley



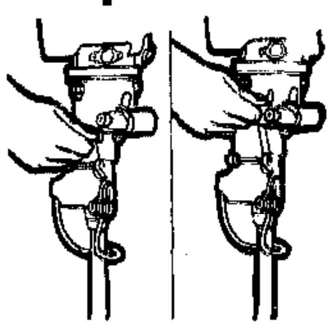
12 Release the starter wire screw and remove the wire



13 Insert the new wire through the bushing in the tank and fix it to the pulley. Re-assemble pulley and cover (with spring). Coil up the wire on the pulley in the direction shown by the arrow on the cover



14 Hold the assembled cover over the studs. Turn ½—¾ of a turn clockwise (to tension the spring) and press it down on the studs. Pull at the same time slightly on the starter wire. Refit washers and nuts.



15 Changing from drilling to impact work (BR-80)
Lever down: drilling
Lever up: impact work

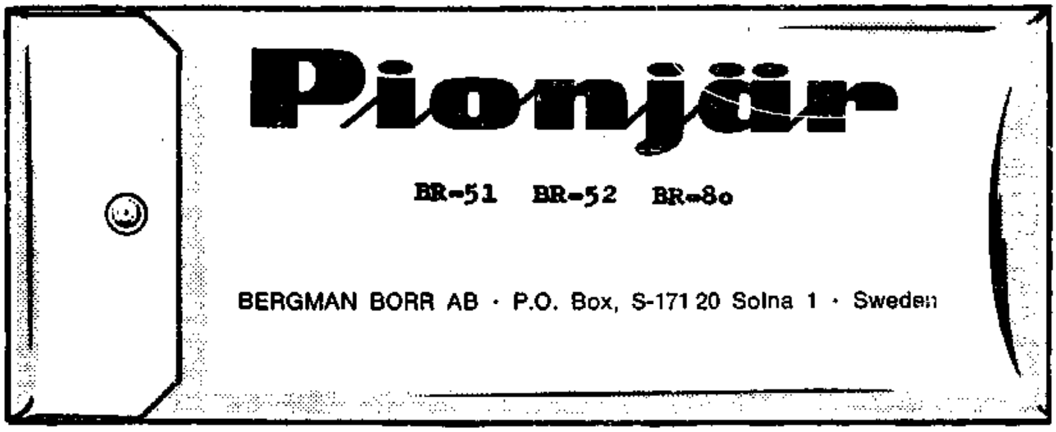
MACHINES AND TOOLS

Rock drilling machine, Toolbag for maintenance

No.: 6.105

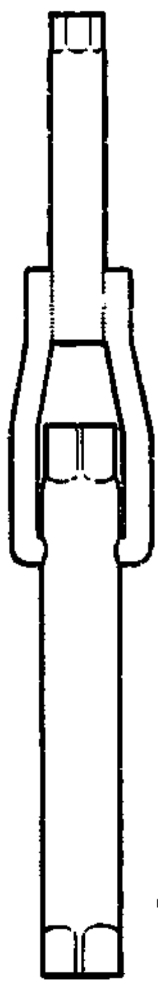
Date: 13.7.75

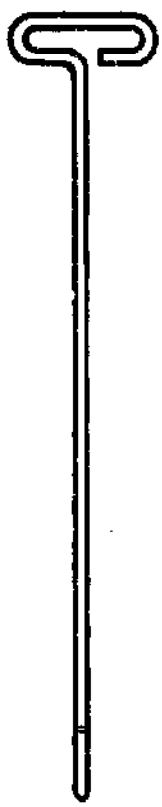
Sig.: [signature]



Tool bag

Spark plug wrench

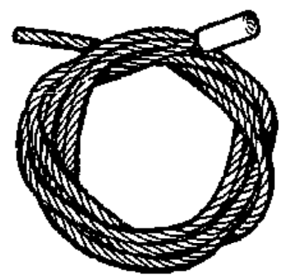




Cleaning needle for gas duct

Hexagonal key (allen wrench)

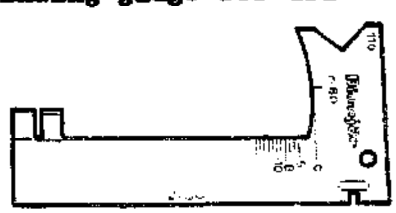
Starter wire



Gauge for drill chuck

Spark plug

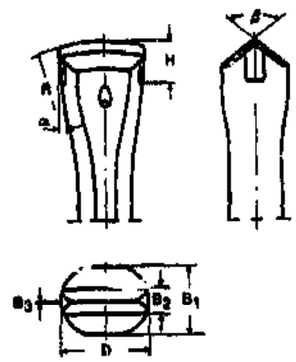
Grinding gauge for drill bit



MACHINES AND TOOLS Rock drilling machine,	7/8" integral drill steels	No.: 6.106 Date: 13.7.75 Sig.: [signature]

Nomenclature

1. Striking surface
2. Shank
3. Collar
4. Rod
5. Flushing hole
6. Carbide insert
7. Cutting edge
8. Wing
9. Bit



B_1 Bit thickness
B_2 Insert width
B_3 Width of cutting edge
D Bit diameter
H Insert height
L Effective drill-steel length
L_1 Shank length
R Cutting edge radius
α Clearance angle
β Cutting edge angle

7/8" integral drill steels

MANUFAC-TURERS

Sandvik Coromant INDIA

SALES AND SERVICE

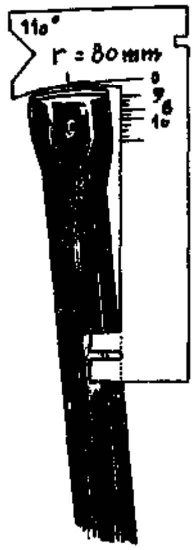
Atlas Copco (India) Pvt. Ltd.

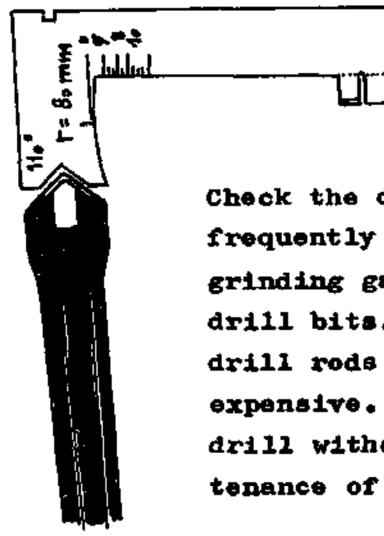
Head Office:
Mahatma Gandhi Memorial Building,

Netaji Subhas Road, Bombay-2.

Series	Effective length mm	ft. in.	Bit diameter mm	in.	Catalogue No.
11	800	2' 7"	34	1 11/32	714—0834
	1600	5' 3"	33	1 19/64	714—1633
	2400	7'10"	32	1 1/4	714—2432
	3200	10' 6"	31	1 7/32	714—3231
	4000	13' 1"	30	1 3/16	714—4030
	4800	15' 9"	29	1 9/64	714—4829
12	800	2' 7"	40	1 37/64	714—0840
	1600	5' 3"	39	1 17/32	714—1639
	2400	7'10"	38	1 1/2	714—2438
	3200	10' 6"	37	1 29/64	714—3237
	4000	13' 1"	36	1 27/64	714—4036
	4800	15' 8"	35	1 3/8	714—4835
	5600	18' 4"	34	1 11/32	714—5634
	6400	21'	33	1 19/64	714—6433
13	400	1' 4"	34	1 11/32	714—0434
	800	2' 7"	33	1 19/64	714—0833
	1200	3'11"	32	1 1/4	714—1232
	1600	5' 3"	31	1 7/32	714—1631
	2000	6' 6"	30	1 3/16	714—2030
16	600	2'	35	1 3/8	714—0636
	1200	3'11"	34	1 11/32	714—1234
	1800	5'11"	33	1 19/64	714—1833
	2400	7'10"	32	1 1/4	714—2432
17	600	2'	41	1 5/8	714—0641
	1200	3'11"	40	1 37/64	714—1240
	1800	5'11"	39	1 17/32	714—1839
	2400	7'10"	38	1 1/2	714—2438
Boulder steel	500	1' 8"	32	1 1/4	714—0532

MACHINES AND TOOLS	No.: 6.1o7
Rock drilling machine, Grinding of drill bits	Date: 17.7.75
	Sig.: Aschwanden





Check the drill bits frequently with the grinding gauge for drill bits. Quality drill rods are very expensive. Do not drill without maintenance of the bits.

The maintenance of drill bits can be done on ordinary grinding machines in any mechanical workshop. It is not possible to sharpen the drill bits with files, because the drill bit consists of very hard tungsten carbide steel.

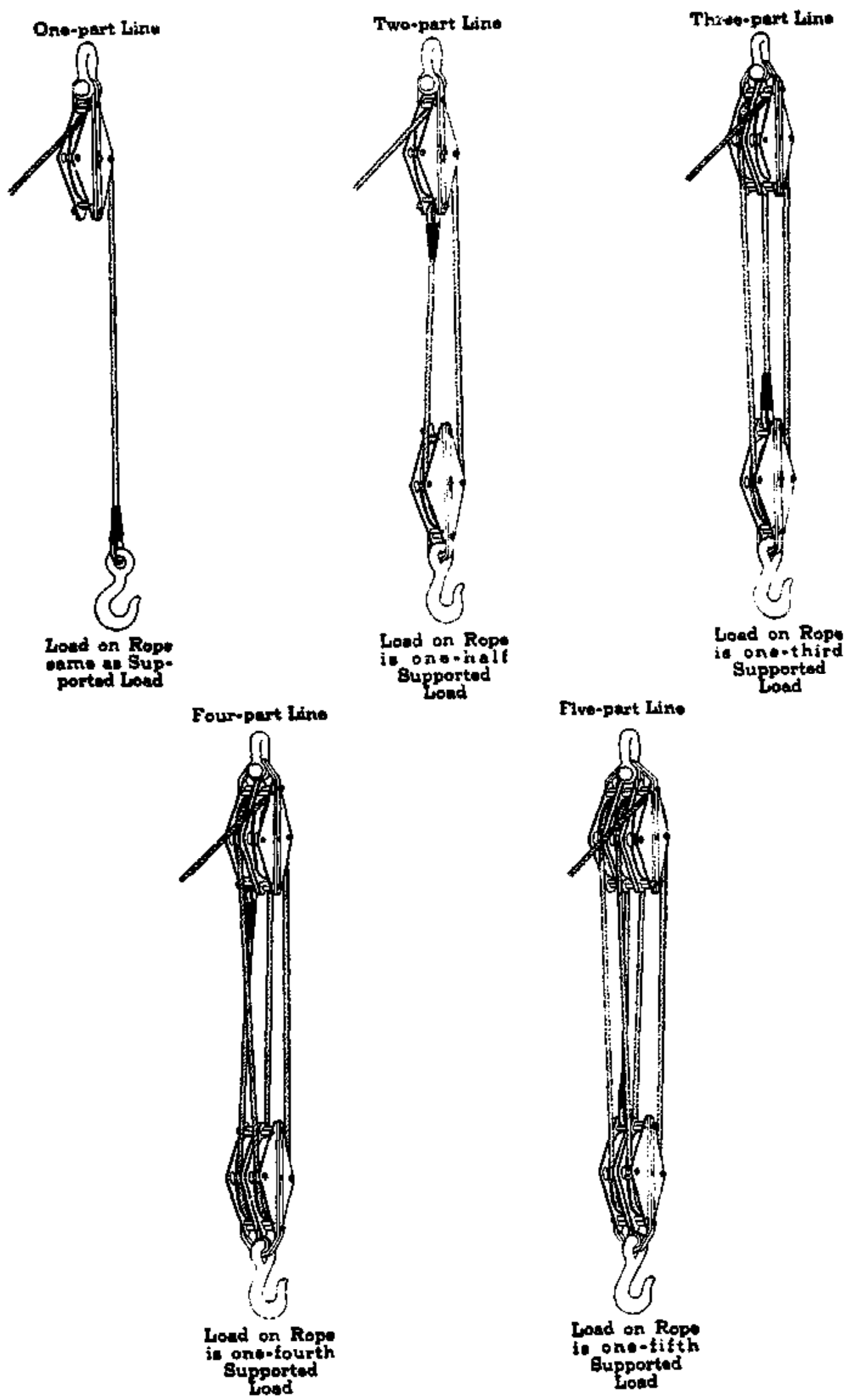
Under field conditions you can use, if available, a special Pionjär grinding machine, driven by the drilling mashine itself.

Fix the drill bit a few millimetres distance from the grinding wheel. In any case use protective glasses for the grinding work.

MACHINES AND TOOLS

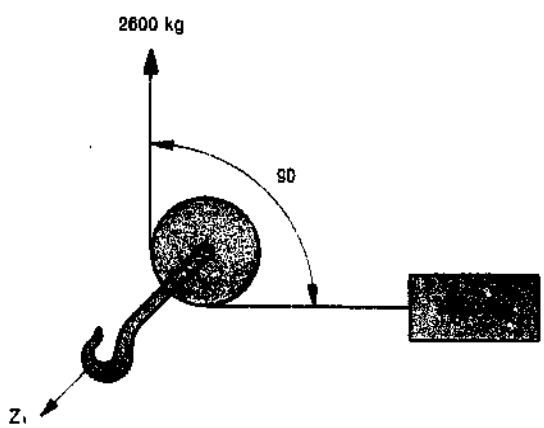
Pulley systems, Different combinations

No.:	6.2o1
Date:	15.9.75
Sig.:	[signature]

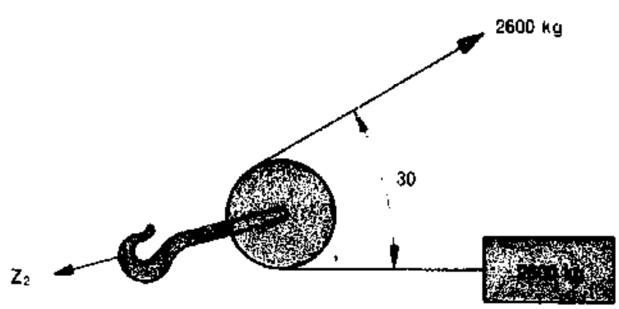


MACHINES AND TOOLS Pulley systems, Load calculation	No.: 6.2o2 Date: 15.9.75 Sig.: [signature]

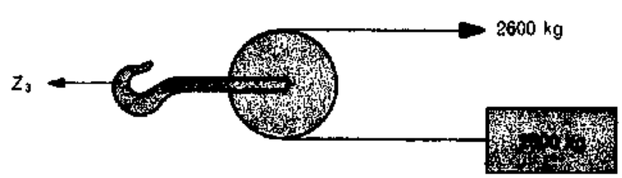
$Z_1 = 1{,}4 \times 2600 = 3700$ kg



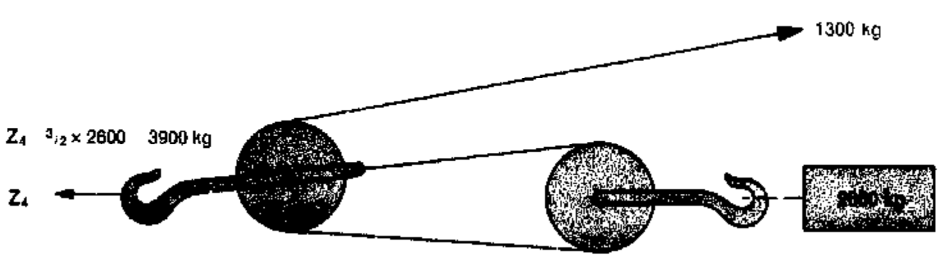
$Z_2 = 1{,}9 \times 2600 = 5000$ kg



$Z_3 = 2 \times 2600 = 5200$ kg



$Z_4 = {}^{3}/_{2} \times 2600 = 3900$ kg



There are two models in use

- Model T 13 Nominal capacity 2.5 tons (pulling)
- Model T 35 Nominal capacity 5.2 tons (pulling)

1. General Remarks

T 13 and T 35 are hand operated pulling and lifting units with an unlimited rope travel. They work by direct pull on the rope, the pull being applied by means of two pairs of self energizing smooth jaws which exert a grip on the rope in proportion to the load actually being lifted or pulled.

The two levers that actuate the jaws provide a forward or backward motion to the rope, depending on whichever lever is used.

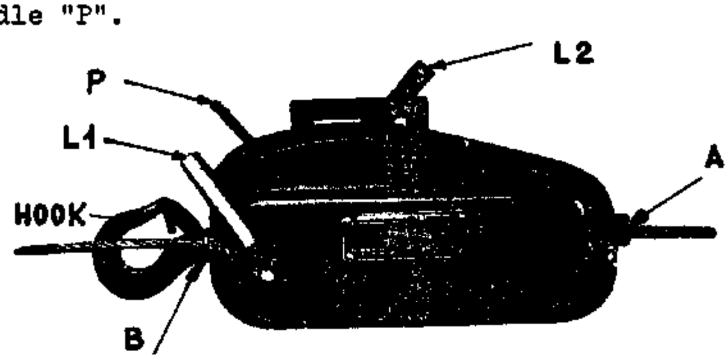
2. Operation

Preparation: (compare sketches below)

- Uncoil the special rope in a straight line to prevent loops which might untwist the strands or form kinks when under tension.
- Pull release handle "P" towards the hook (towards the anchor pin for T 35) into notched position. This opens the jaws.
- Insert the fused end of the rope at "A" the machine lying on the ground; this is the best position for feeding the rope between the jaws. Push the rope into the machine until it emerges at "B".
- Anchor the machine and the cable hook with correct slings.
- Pull the wire rope until it is tight on the load.
- Push back release handle "P".

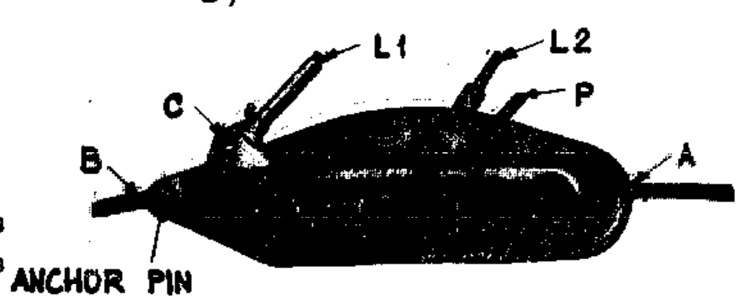
Sketch of T 13

Pulling 2.5 tons
Lifting 1.5 tons



Sketch of T 35

Pulling 5.2 tons
Lifting 3.2 tons



Pulling or lifting:

- Fix and lock the telescopic operating handle on stub "L 1".
- Move the lever to and fro to move the rope through the machine.
- As the machines do not have ratchets, the operating handle needs not be used through its full stroke. If space is confined, short strokes can be made. The load is moved on both forward and backward strokes of the handle, and the handle can be left in any position of its stroke with out danger of "flying".

Slacking the wire-rope or lowering:

- Fix the telescope operating handle on stub "L 2".
- For T 35 only: Place "L 1" on fast speed.
- Move to and fro as above.

For T 35 to change speed:

- Fast speed: for approach, lift button on top of "L 1" and give pin "C" a half-turn.
- Slow speed: for high load, reverse above operation.

Note:
- Make sure that the effort to be exerted is within the rated capacity of the machine.
- Never operate forward and reverse at the same time.
- Levers "P" and "L 2" must move freely at all times.

Releasing or disengaging the wire-rope:

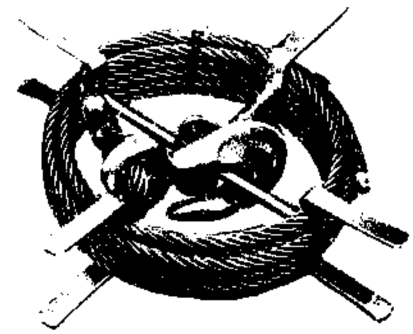
It is impossible to operate rope-release-handle "P" when there is any load on the machine, as the jaws are locked on the rope by the tension in the rope.
Operate rope-reverse-lever "L 2" to take load off the machine, then pull "P" into the notch and remove the cable.

3. Lubrication

- Lubrication should be carried out at regular intervals to ensure that all the rope gripping mechanisms are working freely. Before putting a machine into service lubricate generously and, if convenient, lubricate before each application.
- A symptom of lack of lubrication is jerkiness when lowering a load.
- To lubricate either pour heavy gear oil into the machine through the slot on the top of the machine, shake the machine and allow to drain, or squirt plenty of oil with an oil gun into the machine.
- Exess lubrication cannot cause the wire-rope to slip. Wire-rope should also be lubricated to keep it free from rust and in good condition.

Remark: These are the instructions from the manufacturer.
On the Chirkotar-bridge erection the cable started to slip out of the machine after it had got in touch with coal-tar-paint.
Therefor pay attention while working on the bridge-deck.

HABEGGER GRIPHOIST T 35



Special wire rope

The special wire rope is designed to meet the requirements of the machine. Ordinary wire ropes deform under the pressure of the jaws, causing malfunction of the machine.

- The wire rope should be reeled and unreeled in a straight line to prevent kinking.
- To avoid unspinning of the strands, never allow a loaded cable to rotate.
- Kinked wire rope will not work in the machines. Never use the cable for a sling, instead a seperate wire rope or a chain sling should be used.
- Never subject the wire rope to abrasion by rubbing over sharp edges.

Operation

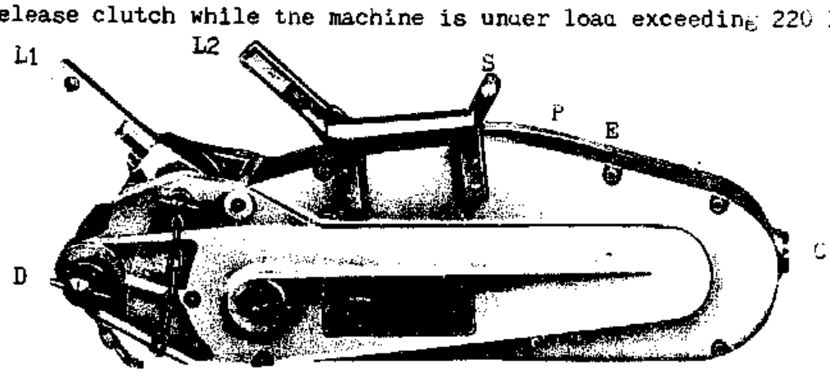
1 Push clutch actuating lever "P" firmly towards position "S", this opens boths pairs of jaws.

2 Introduce tapered end of wire rope through guide bushing "C" towards "D".

3 Pull wire rope coming out of the anchor pin side by hand and tighten to load. The push clutch actuating lever "P" back into position "E".

4 Place telescopic handle on power stroke lever "L1". Engage notch in locking pin and fix lever by turning it round. Pulling or lifting are carried out by a steady backward and forward movement on power stroke lever. Jerking motion should be avoided to ensure a smooth operation. The load can be lowered or released by operating release lever "L2" in the same way. Never operate both levers at the same time.

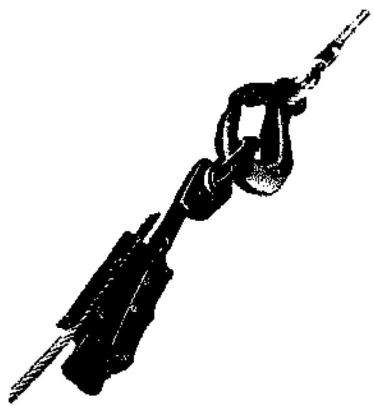
5 On completion of operation slacken the wire rope completely by operating re-
1 lease lever, pull clutch actuating lever and remove wire rope. Bring clutch actuating lever back into closed position. It is impossible with human effort to release clutch while the machine is under load exceeding 220 lbs.



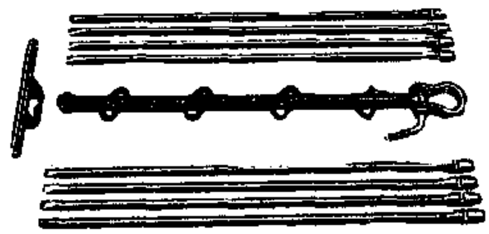
Cable brake

for cable ø 10-14mm

capacity: 2.0 tons



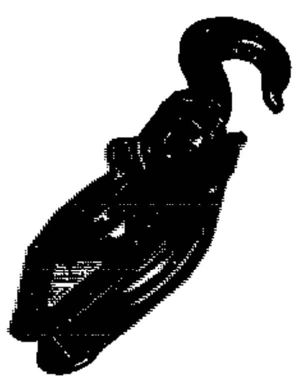
Field anchors "Titan"



Hoist block

one reel

capacity: 5.0 tons

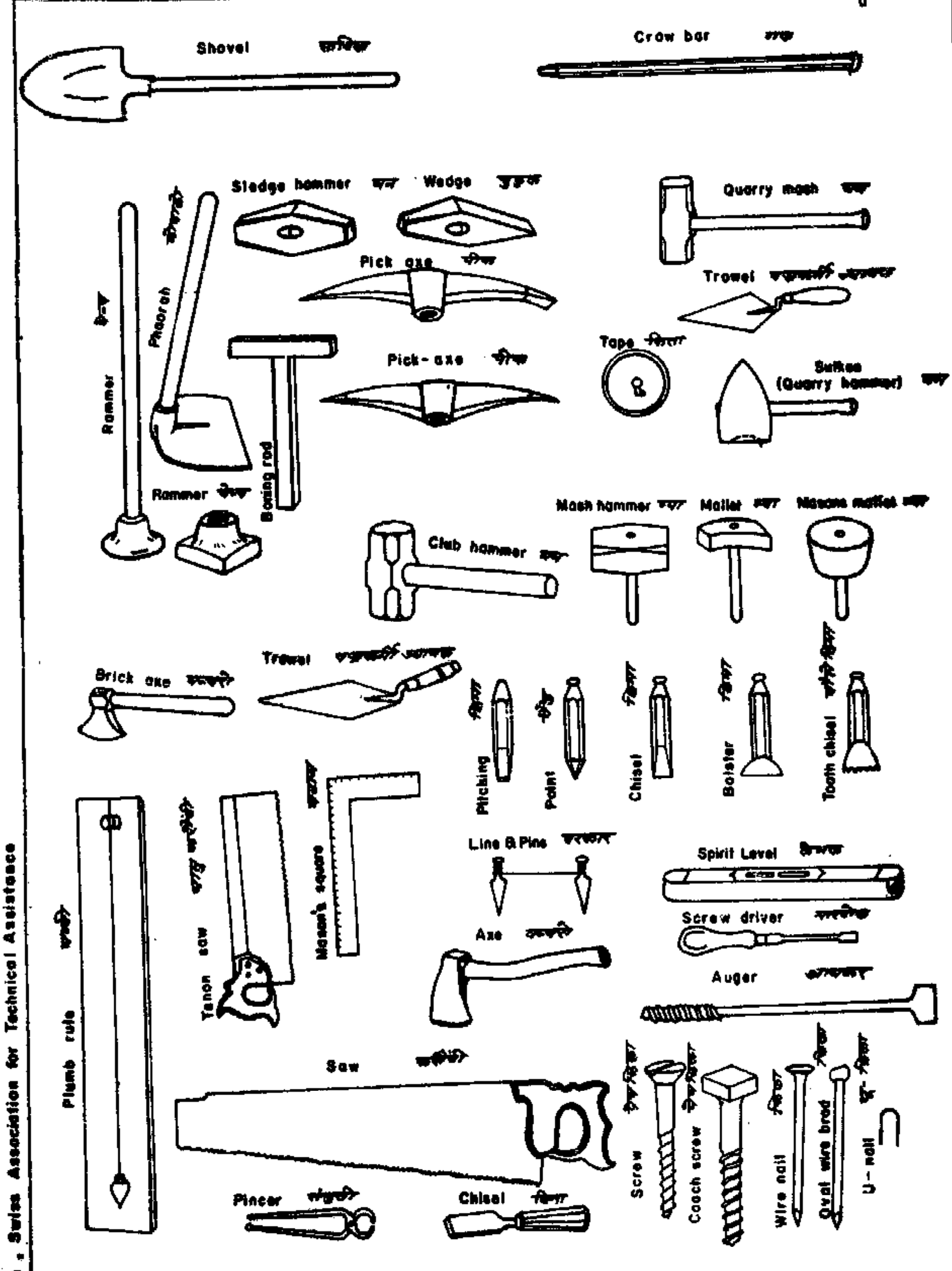


Hoist block

two reels

capacity: 5.0 tons

MACHINES AND TOOLS	No. : 6.401
Different Tools	Date : 2.1.77
	Sig : R. Gröli



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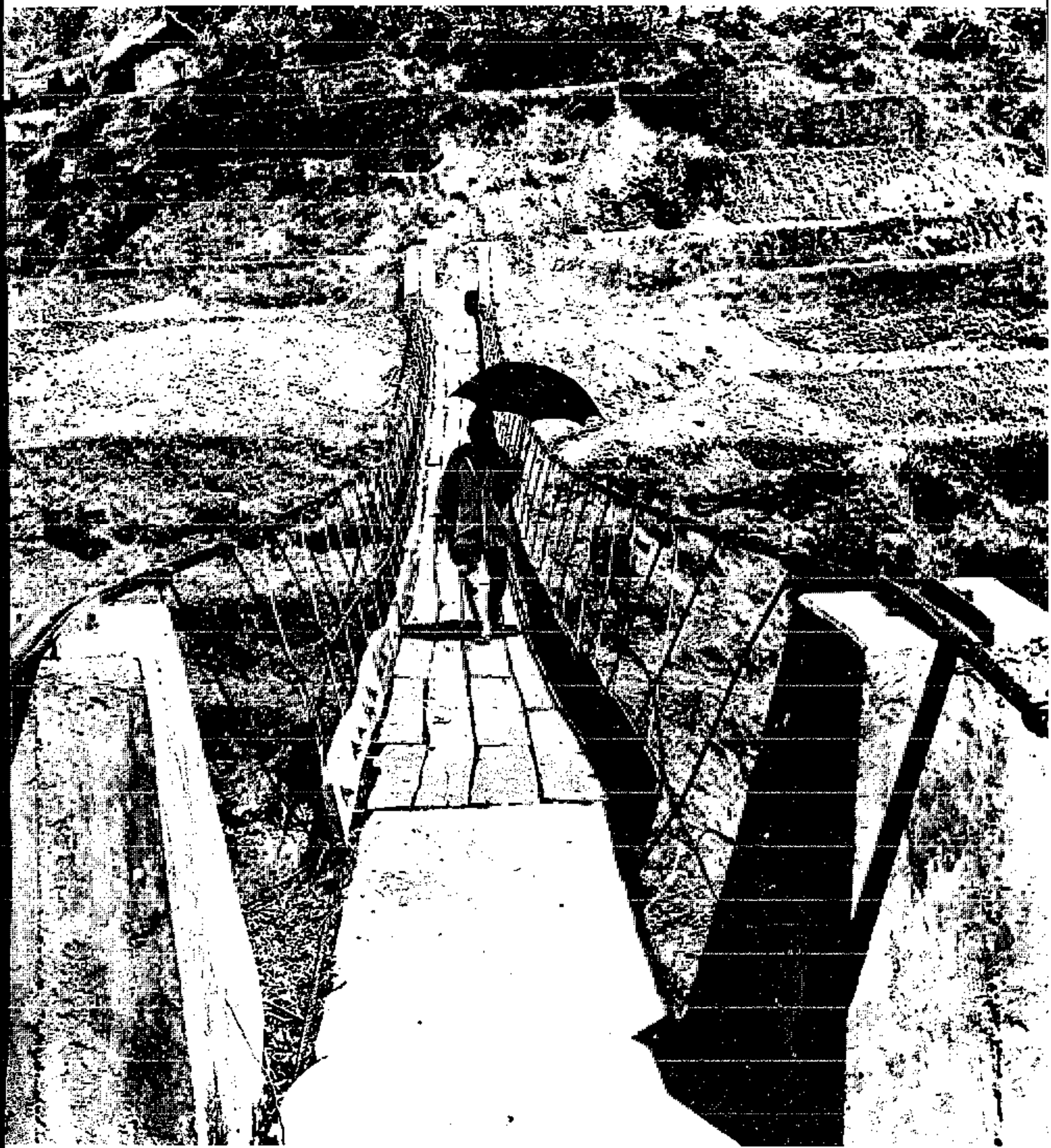
H.M.G. OF NEPAL, MINISTRY OF WORKS AND TRANSPORT, ROADS DEPARTMENT

SATA, SWISS ASSOCIATION FOR TECHNICAL ASSISTANCE

PART B



EXECUTION AND MAINTENANCE OF

STANDARD TRAIL SUSPENDED AND SUSPENSION BRIDGES

PREFACE to the second enlarged edition

The manual for construction of suspension bridges will be quite helpful to the engineers who will construct suspension bridges in Nepal. It contains the details of methods of surveying, calculations and design procedures. Previously we did not have any such manual having so much in detail. I have no doubt that this manual will help all the engineers who will construct suspended and suspension bridges, specially those who will be newcomers and work for construction of trail suspension bridges.
At the same time I must appreciate the commendable work done by Mr. H. Pfaffen, civil engineer with SATA.

C. B. Pradhanang
Superintending Engineer

Kathmandu, March 1977

The manual for Trail Suspension Bridges which first appeared in autumn 1975 has now been reedited for this second enlarged edition. The contents were increased at the wish of many for an extensive treatment of the deliberation and analysis necessary to plan, design, estimate and construct standardized bridges.
The suspended bridge (bridge without pylons) was completely accepted as an equally valid solution to the suspension bridge, its standardized design has also been taken into full consideration.
We have not attempted to cover the entire field of the bridge construction work, but rather to select some of the most important sections for unstiffened suspension bridges and their foundation constructions with a special reference to a practical and economical engineering work. It has been assumed that our readers already have a basic knowledge of engineering work and we hope that they will find this book both instructive and covering the matters for execution of trail bridges.
For further assistance we recommend the standardized designs of steelwork for suspended and suspension bridges of HMG' Roads Department compiled with SATA, Swiss Association for Technical Assistance. The quantity of work has, however, been such, that the 330 plans for the unit - construction bridge systems could not be included in this manual. These drawings have been worked out and are available from the Suspension Bridge Division.
This edition was financed by SATA. At the same time I would like to thank all at the Suspension Bridge Division for their helpful comments, especially the SATA engineers Leo Condrau and Robert Groeli for their unvaluable help to complete this manual.

Hans Pfaffen
SATA

Kathmandu, March 1977

PREFACE to the first edition

The descriptions given in this book will be quite helpful specially to those who will be working for suspension bridge projects for the first time. The tables and formulas given will enable the surveyors to work out the calculations on site itself. The instructions to be followed during the construction period will help all the bridge builders to avoid the mistakes that may even lead to the failure of bridges.

C. B. Pradhanang

Superintending Engineer
Suspension Bridge
Division

Kathmandu, September 1975

The Suspension Bridge Division should construct more than 50 foot - trail suspension bridges throughout the country during the 5th Plan (1975 - 1980) period. Past experience has shown that little technical training was provided for newcomers in the field of suspension bridge design and construction work. The Manual as presented now, is in a preliminary phase and should give a basis for future technical training. In advance I would like to thank those who will give critical suggestions, and help for adding new pages.

H. Aschmann
SATA

Kathmandu, September 1975

PART A

1. TYPES OF TRAIL SUSPENSION OR SUSPENDED BRIDGES
2. BRIDGE DESIGN
3. STRUCTURAL ANALYSIS
4. SURVEY OF BRIDGE SITES
5. CONSTRUCTION WORK
6. MACHINES AND TOOLS

PART B

7. COST ESTIMATE
8. LAY OUT
9. CONSTRUCTION WORK
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13. PHOTOS OF STANDARD STEEL PARTS

PART B

EXECUTION AND MAINTENANCE

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3.6 Anchor Blocks for Suspension and Suspended Bridges, Gravity Block Typ No. 1, Gravity/Earth Block Typ No. 2, Gravity/Rock Block Typ No. 3, Rock Anchor Typ No. 4

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3.9 Double Eccentric Loading, Coefficient for Calculation the max. Soil Bearing of Bi-Axial and Eccentric compressed Foundations, Calculation Example for a Pylon Foundation, Calculation Example for an Anchor Block used as Wind Guy and Side Stay Cable Anchorage, Dimensioning in Reinforced Concrete Construction taking the Axial Compression Force into Account, Bending Moments, Shearing Forces and Deflection, Trigonometry,General Conversion Tables, Mensuration of Areas and Volumes, Colour Indication of Temperature of Steel, Calculation of Anchor Rods and Hooks

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6.2 Pulley System (Hoist Block), Different Combination, Load Calculation by using of Pulley

6.3 Pulling Machines, Tirfor, Habegger, Accessories

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7.1 Planning and Execution Chart for Construction Work on Suspended and Suspension Bridges

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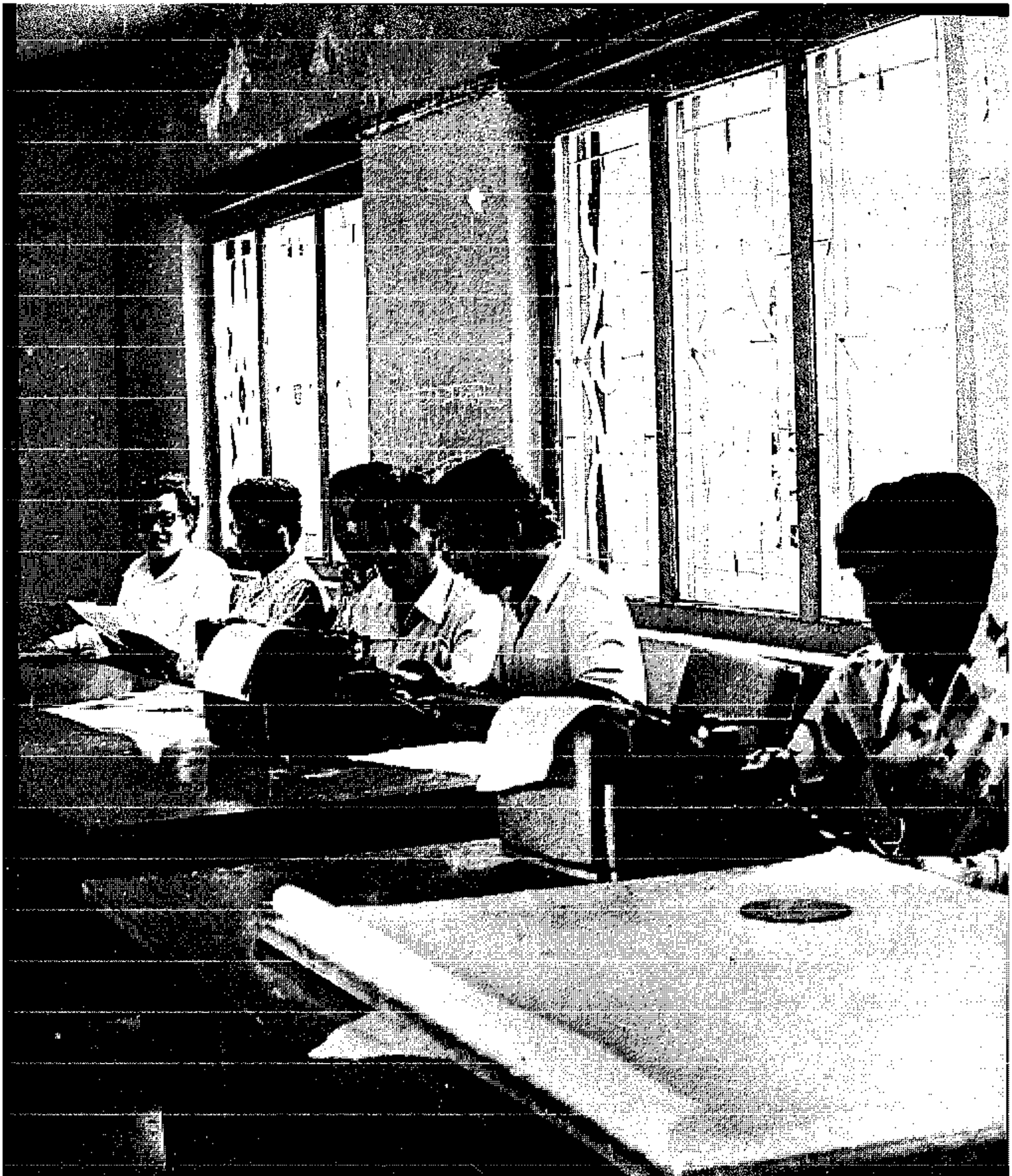

7. COST ESTIMATE

COST ESTIMATE

Planning and execution chart for construction work

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Date : 26th Febr. 77

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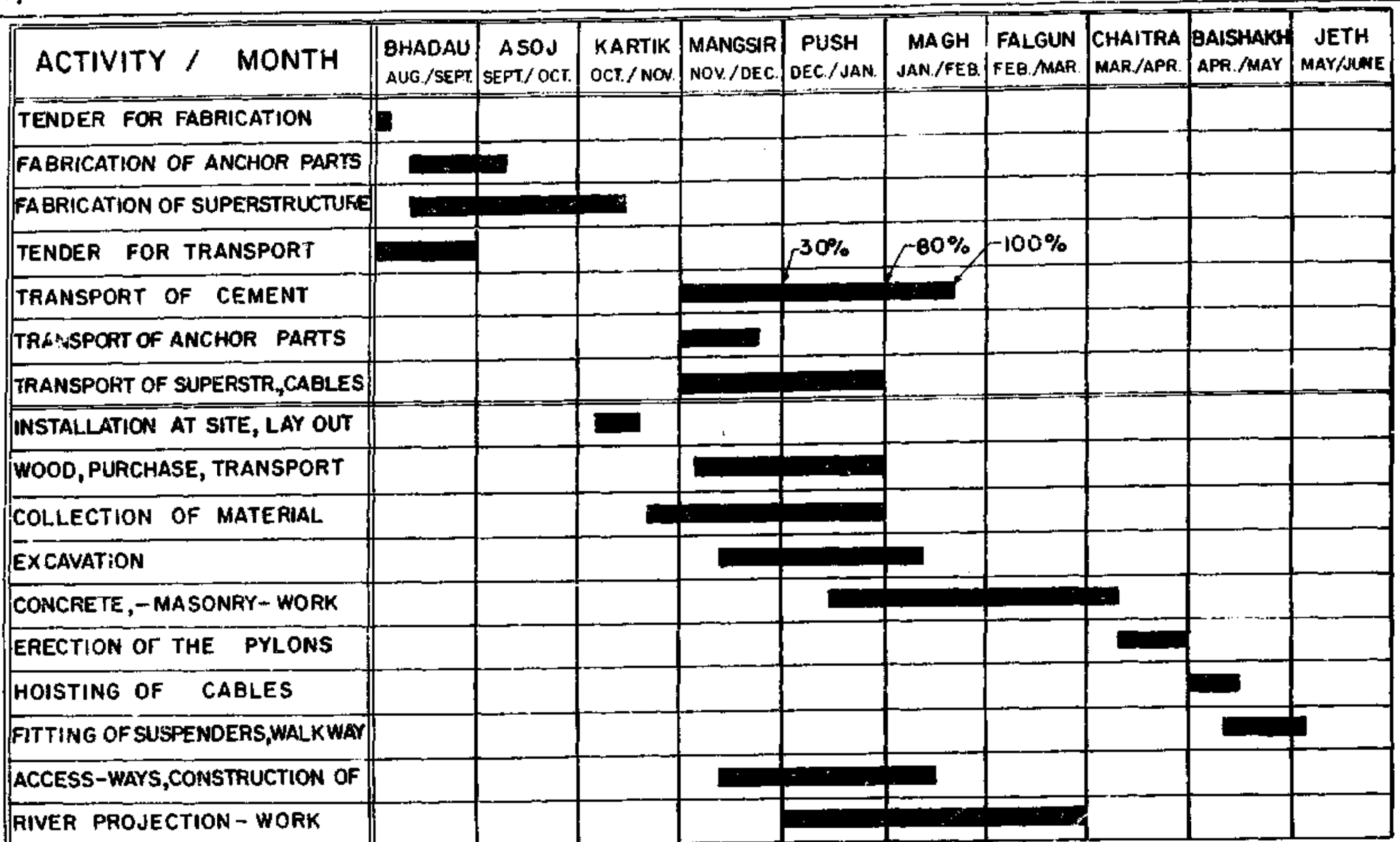

This is a rough schedule and will only give some hints for the preparation of such a program. For the whole project it should be worked out in more detail, e.g. the site-work divided in left-bank and right-bank, pylon foundation, main anchorage and windguy anchorage, preparation of deck-planks etc.....

Such a diagram shows activities which can be done simultaneously and also the influence of a delay in one activity (e.g. transport) on the whole construction-progress.

COST ESTIMATE FOR SUSPENSION BRIDGES Item 1. Transportation to item 1.5.3 weight of camp equipment	No. : 7.201 Date : 22nd Dec. 76 Sig :

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The herewith given rate analysis is based on the "NORMS" for analysis of rate by HMG, Department of Roads (Quantity surveying branch) and on rates sanctioned in the Suspension Bridge Division. The following analysis should be used only while the general arrangement and the detail drawing of a certain project of a suspension bridge are be taken into consideration. It must be said, that the following rates are taking care to the way of design work done by HMG Suspension Bridge Division. At the same moment it is important to mention, that the influence resulting from the HMG'standard has been considered.

1. TRANSPORTATION ESTIMATE CRITERIAS

1.1 Transportation by plane
The rates for this kind of transportation can be get from the Royal Nepal Airlines Corporation.

1.2 Transportation by truck
- Black top road : 0,00130 Rs. per kg per km
- Gravel and mud road : 0,00195 Rs. per kg per km
- River bank road : 0,00320 Rs. per kg per km

1.3 Transportation on porters back
- a porter walks 8 miles (13km) a day
- a porter carries 40kg easily steel parts and wooden planks
- a porter carries 50kg easily steelparts if the overall measurements are limited (1.25m in length)
- a porter carries 30kg of difficult parts -i.e. parts beyond 50kg and 1.25 m in length.
- a porter carries 20kg of cables
- wind-tie cables of ø ¼" (6,3mm) are estimated as easy steel parts
- cement bags of 50kg in weight are estimated as easy parts too.
- How many parts are to be estimated either as easy or difficult parts can be taken from the list in the general arrangement.

1.4 Loading and unloading
This amount varies on the conditions of the transportation for a certain bridge. The following assumption may be taken :

1.4.1 Transportation by plain : 35 Rs. per m span
1.4.2 Transportation by truck : 12 Rs. per m span
1.4.3 Transportation by porter : 3 Rs. per m span

1.5 Assumed weights of camp equipment etc.
This item varies on the different kind of work needed. The following weights may be taken as an average :

1.5.1 Spans 66 to 114m :
Store to bridge site : 1'600 kg
and back to store : 1'400 kg

1.5.2 Spans 115 to 174m:
Store to bridge site : 2'000 kg
and back to store : 1'700 kg

1.5.3 Spans 175 to m:
Store to bridge site : 3'100 kg
back to store (SBD) : 2'700 kg

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Suspension Bridge Division

1.6 Assumed weights of equipment for campe maintenance
and small materials for work execution .
7 kg per m span

1.7 Additional weight of equipment for rock drilling work
(Rock drilling machine, griding machine for drill bits, drill bits, fuel container, helmet, vice, water pipe, repairing and maintenance tools etc.)
Assumption: 150 kg store to site
120 kg back to store of SBD (Roads Department)

2. CAMP ESTABLISHMENT

Area needed for a project :
- 66 to 114 m span = 300 m2 (2 cement stores)
- 115 to 174 m span = 360 m2 (2 cement stores)
- 175 to 222 m span = 420 m2 (2 cement stores)
- 223 to ... m span = 500 m2 (3 cement stores)

Coolies Manday 6 Nos. per m2

3. CAMP MAINTENANCE

Material : Kerosene - oil .... : 54 Litres per month
First aid, different goods, batteries, latern glasses,
small materials etc. : 200 Rs. per month

Labour : Supervisor............ : 1 Nos. (exept during rainy season)
Store keeper.......... : 1 Nos.
Watchmen............. : 4 Nos.

4. PURCHASE OF GOODS FOR CAMP MAINTENANCE AND EXECUTION OF THE WORK

The amount of this item has not to be added to the estimated cost for a bridge site. The equipment can be used at more then one bridge site only. To purchase goods which is not available in the store of HMG Roads Department (Suspension Bridge Division) the amount of the 5 % contingencies is including these costs. The equipment must be brought back to the stores (refer also to rate analysis item 1.5) after completion of the work. Befor taking the goods the drawings of HMG'standard design should be read, because many items are put into the steelpartlists etc.

Description	Unit	spans in metres 66 - 114	115 - 174	175 - ...
Tent, double corner	pc.	2	2	2
Camp cot, durable type	pc.	4	5	5
Tarpaulin of different sizes	sq.ft.	750	900	1100
Petromax with spare parts	pc.	2	2	2
Lanterns	pc.	4	6	6
Torches	pc.	4	5	6
Camp tables	pc.	3	3	4
Camp chairs	pc.	8	8	10
Water filters	pc.	2	2	3
Hand bags	pc.	2	2	2
Cash boxes	pc.	1	1	1
Survey umbrella	pc.	-	-	1
Umbrellas	pc.	4	5	5

COST ESTIMATE FOR SUSPENSION BRIDGES

4. Purchase of goods (continuation)

No. : 7.203

Date : 22nd. Dec. 76

Sig :

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Suspension B.idge Division

4. Purchase of goods and equipment for execution work, continuation

Description	Unit	66 - 114	115 - 174	175 - ...
Kitchen utensils	set	1	1	1
Sleeping bags	pc.	1	1	1
Slide rule calculator	pc.	1	1	1
Theodolite (incl. stand)	pc.	1	1	1
Level (incl. staff)	pc.	1	1	1
Levelling staff	pc.	(1)	(1)	(1)
Tape, about 3m length	pc.	2	2	3
Tape, 20 to 30 m length	pc.	1	2	2
Spring balance, 50 kg capacity	pc.	1	2	1
Spring balance, 100 kg capacity	pc.	1	1	2
Weighing balance, 100 kg capacity	pc.	1	1	2
Shovels	pc.	15	20	30
Crow - bar ø 1¼"	pc.	5	8	15
Chisels, medium size	pc.	5	6	7
Hammer, small (0,5 kg)	pc.	30	40	50
Hammer, medium (5,0 kg)	pc.	6	8	10
Hammer, big (6,5 kg)	pc.	3	4	5
Mason's squares	pc.	2	2	3
Carpenter's level (spirit-level)	pc.	2	2	2
Plumb bob (plummet)	pc.	3	3	4
Screw jack (6" size)	pc.	1	1	1
Paint for marking (0,5 Litre)	tin	2	2	3
Buckets (20 Litres)	pc.	12	24	36
Fixation hook for pylon erection cable	pc.	4	6	8
Hack saw frame	pc.	2	2	3
Hack saw blades, best quality	doz.	1	1	2
Wood saws of different sizes	pc.	4	6	8
Auger ø ½" and 3/4"	doz.	1½	2	2
Lay out frame of wooden planks	pc.	1	1	1
Files of different sizes (halfround, triangular, flat, full round)	set.	1	1	1
Die sets (¼,½,3/4,5/8,7/8,1" threads)	set.	1	1	1
Tongs	pair.	3	3	4
Nippers (pliers)	pc.	2	3	3
Pincers	pair	2	2	2
Screw drivers of different sizes	set	1	1	1
Nylondori ø 1"	m	200	400	600
Manila rope ø 1"	m	140	240	340
Extra steel wire cable for front and backstay during pylon erection ø ½"	m	200	320	350
Bulldog grips (½,3/4,5/8,1,1¼,1½")	pc.	24	24	24
Cable brakes for ø 1"	pc.	2	2	2
Cable brakes for ø 1¼"	pc.	2	2	2
Cable brakes for ø 1½"	pc.	2	2	3
Pulleys (double for cable ø 1")	pc.	4	4	4
Chain pulleys, 2 tons capacity	pc.	1	1	2

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4. Purchase of goods and equipment for execution work, 2nd. continuation

Description	Unit	66 - 114	115 - 174	175 - ...
Tirfor machine (complete) 2,5 tons	set	3	-	-
Tirfor machine (complete) 5,2 tons	set	-	3	3
Rock anchorage for tirfor(Habegger)	set	(1)	(1)	(1)
Wrenches for nut and bolts ø 3/8"	pc.	6	8	10
Wrenches for nut and bolts ø 1/2"	pc.	5	7	9
Wrenches for nut and bolts ø 3/4"	pc.	3	10	16
Wrenches for nut and bolts ø 5/8"	pc.	14	24	24
Wrenches for nut and bolts ø 7/8"	pc.	2	6	16
Wrenches for nut and bolts ø 1"	pc.	2	2	2
Wrenches for nut and bolts ø 1 1/4"	pc.	2	2	2
Wrenches for nut and bolts ø 1 1/2"	pc.	2	2	2
Wrenches for nut and bolts ø 40mm	pc.	2	2	2
Wrenches of different other sizes	set.	1	1	1
C - Clamp	pc.	2	2	3
Blowers for black smith	pc.	1	1	2

Special equipment only if really required

Blaster's pincers
Rock drilling machine, griding machine for drill bits, drill bits of different length, fuel container, helmet, vice,
Water pump with flexible pipes
Water pipes etc.
Cable car for temporary crossing

The total amount of the above items should not be added to the estimated cost of a proposed bridge. Most of the equipment can be taken from the SBD store and must be returned after completion of the bridge. The goods which cannot be taken from the SBD store will be purchased within the amount of 5% contingencies. The above list is a guideline for the preparation and should show the kind of goods and their approximative amount.

5. TEMPORARY CROSSING

5.1 Hire a boat per month
5.2 Boat Manday 4 Nos. in dry season (for large river only)
5.3 Temporary 'bridge': The span of a temporary crossing (i.e. length) is to take from the general arrangement. The length of a temporary bridge is never as long as for the proposed bridge.
Labour : Unskilled 5 Manday per m span of temporary bridge
Material : Take an assumption of about 25 Rs. per m length

6. SITE CLEARANCE

6.1 Clearance before starting of the execution work : L.S. about 300 to 800 Rs.
6.2 Clearance after completion, including collection of materials for preparation of auction (but without backfilling) : L.S. about 500 to 1400 Rs.

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Suspension Bridge Division

7. WOOD WORK FOR 1 m3

7.1 Sal wood for decking for 1 m3

Assuming 40 % wastage, total wood required 1.67 m3 (58.8928 cubic feet). The wastage remains at the wooden location - i.e. only one m3 must be transported to the bridge site. A porter carries 40 kg and walks 8 miles (13 km) a day. One m3 is about 900 kg in weight (sal wwod). The planks must be sawed according to the standard drawings of HMG'Standard bridge design. The lay out frame, supplied by SBD, must be used at the wooden location and the provided holes are to drill at the wooden location too.

Material : 1.67 m3 (58.8928 cubic feet) Royality
Labour : 10 Manday Coolies for felling and dressing
35 Manday Coolies for helping etc.
9 Coolies for helping etc.
½ Manday Carpenter to drill holes etc.
22 ½ Nos. of porters for transportation
T. & P. Lumpsum : 1/15th of the above labour

7.2 Salla wood for shuttering for 1 m3

Assuming 40 % wastage, total wood required = 1.67 m3 for 1 m3 sawed wood. The wastage remains at the wooden location. Only one m3 of salla wood must be carried to the bridge site. One m3 of salla wood is assumed with 800 kg per m3.

Material : 1.67 m3 (58.8928 cubic feet)
Labour : 10 Manday Coolies for felling and dressing
35 Manday Saw men to make planks and beams
9 Manday Coolies for helping etc.
20 Nos. of porters for transportation
T. & P. Lumpsum : 1/15th of the above labour

8. LONGITUDINAL FIBRE GLASS PLANKS FOR THE WALK - WAY

8.1 Longitudinal fibre glass planks can provide a usefull alternativ solution for longitudinal planks. The rates may be got from the Balaju Yantra Shala, BYS, at the Industrial Estate Balaju (Kathmandu). This alternative kind of fibre glass planks are cheaper then wooden planks if the wooden location is creating a long and costly transportation. By comparing the different kind of planks, the coalter painting and fixation cost have also to be taken into account.

9. PAINTING OF WOOD USED AT THE WALK - WAY

9.1 Painting of wooden longitudinal planks per m span. Refer to standard walk - way drawing.

Material : 1.176 Litre Coaltar paint
0.300 Litre Fuel
Labour : 0.3 Manday Painter
T. & P. LumPsum : 1/20th of the above

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Suspension Bridge Division

10. EXCAVATION WORK
(Based on 'Norms' of rate analysis by HMG, Roads Department)

10.1 Excavation of top soil and carrying away from the foundation areas (thickness 15 - 2o cm) per SQ.M. (m2)

Labour : Manday 0.40 (Unskilled)

10.2 Excavation of common material, haulage distance 10 metres and disposal per CU.M. (m3)
If the above item (10.1) has been taken the volume of the excavation must be calculated in such a way, that the item 10.1 is taken into account.

Labour : Manday 0.80 (Unskilled)

10.3 Excavation of soft rock material, requiring use of crowbar, haulage distance 1o m and disposal (take reference to item 10.1) per CU.M. (m3)

Labour : Manday 2.00 (Unskilled)

10.4 Excavation - drilling & blasting - hard rock material, haulage distance 10 m and disposal per Cu.M. (m3)

Material	:	Gelatine	0.25 kg	
		Detonator	2.00 pc.	
		Fuse wire	2.00 m	
Labour	:	Manday	3.59	(Unskilled)
		Manday	0.05	(Blaster)

10.5 Foundation excavation in dry common material - vertical lift 1 m, horizontal haulage distance 10 m and disposal per CU.M. (m3)
If you have used the item 10.1 please take the redution due to that position into reference by estimating the volumes.

Labour : Manday 1.34 (Unskilled)

Vertical lift : for each additional lift per CU.M. (m3) per 1 m height

Labour : Manday 0.30 (Unskilled)

10.6 Foundation excavation in dry soft rock material, vertical lift 1 m, horizontal haulage distance 10 m and disposal per CU.M. (m3)

Labour : Manday 2.50 (Unskilled)

Vertical lift : for each additional lift per CU.M. (m3) per 1 m height

Labour : Manday 0.40 (Unskilled)

10.7 Foundation Excavation in dry hard rock, material, drilling and blasting, vertival lift 1 m, horizontal haulage distance 10 m and disposal per CU.M. (m3)

Material	:	Gelatine	0.25 kg
		Detonator	2.00 pc.
		Fuse wire	2.00 m

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10.7 Continuation

Labour : Manday 4.76 (Unskilled)
Manday 0.05 (Blaster)

Vertical lift : for each additional lift per CU.M. (m3) per m hight

Labour : Manday 0.40 (Unskilled)

10.8 Foundation excavation in shallow water, common material, vertical lift 1 m, horizontal haulage distance 10 m and disposal per CU.M. (m3)
This position may be used on the middle piers for multiple span suspension bridges etc. .

Labour : Manday 2.25 (Unskilled)

Vertical lift : for each additional lift per CU.M. (m3) per m hight

10.9 Bottom trimming of rock foundation pit and clearance per SQ.M. (m2)
(refer to detail drawings carefully)

Labour : Manday 0.61 (Unskilled)

11. FABRICATION OF GABION (Based on NORMS by HMG, Roads Department)

11.1 Fabrication of gabion including rolling, cutting and weaving complete.
Mesh size : 80 x 100 mm
Mesh wire : 9 SWG
Selvedge wire: 6 SWG

11.1.1 Box size 2 m x 1 m x 1 m

Material : G.I. Wire 36.00 kg
Selvedge wire 3.75 kg

Labour : Manday 2.42 (Skilled)
Manday 1.21 (Unskilled)

11.1.2 Box size 3 m x 1 m x 1 m

Material : G.I. Wire 52.35 kg
Selvedge wire 4.85 kg

Labour : Manday 3.52 (Skilled)
Manday 1.76 (Unskilled)

11.1.3 Box size 2 m x 1 m x 0.5 m

Material : G.I. Wire 24.55 kg
Sevedge wire 3.00 kg

Labour : Manday 1.650 (Skilled)
Manday 0.825 (Unskilled)

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11.1.4 Boxe size 3 m x 1 m x 0.5 m

Material : G.I. Wire 36.00 kg
Selvedge wire 3.90 kg

Labour : Manday 2.42 (Skilled)
Manday 1.21 (Unskilled)

11.2 Assemble gabion, place in position including streching, wiring the gabion together and tying down lids. Analys per box (piece)
Binding wire : 11 S.W.G.

11.2.1 Box size 2 m x 1 m x 1 m

Material : Binding wire 1.15 kg

Labour : Manday 0.40 (Unskilled)

11.2.2 Box size 3 m x 1 m x 1 m

Material : Binding wire 1.60 kg

Labour : Manday 0.60 (Unskilled)

11.2.3 Boxe size 2 m x 1 m x 0.5 m

Material : Binding wire 0.90 kg

Labour : Manday 0.20 (Unskilled)

11.2.4 Boxe size 3 m x 1 m x 0.5 m

Material : Binding wire 1.20 kg

Labour : Manday 0.30 (Unskilled)

12. FILLING OF STONES IN GABION CRATES PER CU.M. (m3) based on 'NORMS' by HMG R.D.

Collection of rubble of required size, haulage distance 10 m, partly stacking, filling in gabion crates per CU.M. (m3)

Collection of rubble, stones etc.

Labour : Manday 0.70 (Unskilled)

Filling in gabion crates

Labour : Manday 0.80 (Unskilled)

Additional cost for additional haulage for every 10 m more:

Labour : Manday 0.16 (Unskilled)

13. FILLING OF SAND, STONES, BOULDERS, ROCK PIECES ETC. IN CELL - TYPE FOUNDATION INCLUDING COMPACTING PER CU. M. (m3)

The excavation material which lies around the foundation should be used.

Labour : Manday 0.60 (Unskilled)

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14. COLLECTION OF MATERIALS
Based on NORMS by HMG Department of Roads

14.1 Collection of rubble of required size, haulige distance 10 m and stacking

What are rubbles ? bits of brocken stones, rock or brickwork, stones from a river bed, coarse gravel (30 to 55 mm) e.g. build a road with a foundation of rubble

Collection of rubble of required size per CU.M. (m3)

Labour : Manday 0.70 (Unskilled)

Additional work for extra haulage per 10 m per one cubicmetre

Labour : Manday 0.16 (Unskilled)

14.2 Collection of stones, gravel including selection, screening and stacking within 10 m haulage distance per CU.M. (m3)

14.2.1 Size 40 to 70 mm
Collection of stones and gravel etc. per m3
Labour : Manday 5.00 (Unskilled)

Additional work for extra haulage per 10 m per one cubicmetre
Labour : Manday 0.16 (Unskilled)

14.2.2 Size 70 to 100 mm
Collection of stones and gravel etc. per m3
Labour : Manday 4.00 (Unskilled)

Additional work for extra haulage per 10 m per one cubicmetre
Labour : Manday 0.16 (Unskilled)

14.3 Collection and sieving gravel including stacking within 10 m haulage per CU.M.

14.3.1 Size 5 to 70 mm
Collection, sieving and stacking per one cubicmetre
Labour : Manday 2.5 (Unskilled)

Additional work for extra haulage per 10m per one cubicmetre
Labour : Manday 0.16 (Unskilled)

14.3.2 Size 5 to 40 mm
Collection, sieving and stacking per CU.M. (m3)
Labour : Manday 4.0 (Unskilled)

Additional work for extra haulage per 10 m per one cubicmetre
Labour : Manday 0.16 (Unskilled)

14.3.3 Size 5 to 20 mm
Collection, sieving ans stacking per CU.M. (m3)
Labour : Manday 5.88 (Unskilled)

Additional work for extra haulage per 10 m per one cubicmetre
Labour : Manday 0.16 (Unskilled)

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14.3 Continuation

14.3.4 Size 5 to 8 mm
Collection, sieving and stacking per CU.M. (m3)
Labour : Manday 10.00 (Unskilled)

Additional work for extra haulage per 10 m per one cubicmetre
Labour : Manday 0.16 (Unskilled)

14.4 Collection and sieving fine sand within 10 m haulage distance per CU.M. (m3)

14.4.1 Collection and sieving sand in hill areas, haulage distance 1o m per CU.M. (m3)

Labour : Manday 1.49 (Unskilled)

Additional work for extra haulage per 10 m per one cubicmetre
Labour : Manday 0.12 (Unskilled)

14.5 Breacking stones including collection, sieving and stacking within 10 m haulage per CU.M. (m3)

14.5.1 Size 40 to 70 mm
Collection, breacking,sieving etc.
Labour : Manday 8.00 (Unskilled)

Additional work for extra haulage per 10 m per one cubicmetre
Labour : Manday 0.12 (Unskilled)

14.5.2 Size 20 to 40 mm
Collection, breacking, sieving etc.
Labour : Manday 12.00 (Unskilled)

Additional work for extra haulage per 10 m per one cubicmetre
Labour : Manday 0.12 (Unskilled)

14.5.3 Size 10 to 20 mm
Collection, breacking, sieving etc.
Labour : Manday 18.00 (Unskilled)

Additional work for extra haulage per 10 m per one cubicmetre
Labour : Manday 0.12 (Unskilled)

14.5.4 Making sand by crushing of stones per CU.M. (m3)
If the sand location is quite far from the site, the crushing of stones to get sand might be the cheaper way. A carefull comparison should be made. This rate is sanctioned by the Suspension Bridge Division.

Crushing of stones to get sand including collection, sieving and stacking within 10 m haulage distance per CU.M.

Labour : Manday 35.00 (Unskilled)

Additional work for extra haulage per 10 m per one cubicmetre
Labour : Manday 0.12 (Unskilled)

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15. DRY RUBBLE MASONARY PER CU.M.
(Based on 'NORMS' by HMG Roads Department)

15.1 Providing and lying dry rubble masonry of hard block stones, height of masoned body up to five metres and haulage distance within 30 metres per CU.M. (m3)

Collection of rubble refer to item 14.1

Material	:	rubble	1.10	m3
Labour	:	Manday	3.50	(Unskilled)

16. R.R. MASONRY IN CEMENT MORTAR PER CU.M.
(Based on rates sanctioned in SBD)

16.1 R.R. Masonry in cement mortar 1 : 4 per CU.M.

This item should only be used below the known high flood level at the pylon and pier foundation for single and multiple span suspension bridges. This kind of masonary work is not allowed for wind guy blocks and main anchor blocks. The detail drawings and general arrangement have to be taken into consideration.

Material	:	Rubble	1.25	m3
		Sand	0.34	m3
		Cement	2.55	bags of 50 kg in weight
Labour	:	Manday	0.10	(Head Mason)
		Manday	2.00	(Mason)
		Manday	3.20	(Unskilled)
		Manday	0.20	(Waterman)
Scaffolding	:		1/30th	of the above labour

T. & P. Lumpsum : 1/20th of the above labour only

16.2 R.R. Masonry in cement mortar 1 : 6 per CU.M.

Material	:	Rubble	1.25	m3
		Sand	0.42	m3
		Cement	2.10	bags of 50 kg in weight
Labour	:	Manday	0.10	(Head Mason)
		Manday	2.00	(Mason)
		Manday	3.20	(Unskilled)
		Manday	0.20	(Waterman)
Scaffolding	:		1/30th	of the above labour

T. & P. Lumpsum : 1/20th of the above labour only

16.3 Stone Dressing per CU.M.
This position is actually not necessary for suspension and suspended bridge project by the design section of SBD of HMG Roads Department.

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17. CONCRETE WORK PER CU.M. (Based on rates sanctioned in SBD)

17.1 Lean concrete 1 : 4 : 8 per CU.M. (m3)
Only used as granular sub grade about 5 to 7 cm thick.

Material :	Aggregate	0.90	m3	
	Sand	0.45	m3	
	Cement	3.30	bags of 50 kg in weight	
Labour :	Manday	0.10	Head Mason	
	Manday	0.70	Mason	
	Manday	1.20	Waterman	
	Manday	7.20	Unskilled	

T. & P. Lumpsum : 1/20th of the above labour only

17.2 Plum concrete consits of 60 % mass concrete and 40 % boulders and rubbles or hard rock pieces per CU.M. (m3)

Material :	Aggregate	0.528	m3
	Rubble,etc.	0.5oo	m3
	Sand	0.264	m3
	Cement	~~0.250~~ 2.58	bags of 50 kg in weight
Labour :	Manday	o.60	Head Mason
	Manday	0.40	Mason
	Manday	0.70	Waterman
	Manday	4.30	Unskilled
	Manday	0.25	Unskilled (Washing rubble, based on 'NORMS')
	Manday	1.75	Unskilled (Providing and laying rubble within a haulage distance up to 30 m)

T. & P. Lumpsum : 1/20th of the above labour only

17.3 Mass concrete 1 : 3 : 6 per CU.M. (m3)

Material :	Aggregate	0.88	m3
	Sand	0.44	m3
	Cement	4.30	bags og 50 kg in weight
Labour :	Manday	0.10	Head Mason
	Manday	0.70	Mason
	Manday	1.20	Waterman
	Manday	7.20	Unskilled

T. & P. Lumpsum : 1/20th of the above labour

17.4 Mass concrete 1 : 2 : 4 per CU.M. (m3)
Refer to detail drawings because this kind of concrete is only used in small quantities at the top of the pylon foundation.

Material :	Aggregate	0.88	m3
	Sand	o.44	m3
	Cement	6.60	bags of 50 kg in weigth

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17.4 Mass concrete 1 : 2 : 4 per CU.M. (continuation)

Labour	:	Manday	0.10	Head Mason
		Manday	0.70	Mason
		Manday	1.20	Waterman
		Manday	7.20	Unskilled

T. & P. Lumpsum : 1/20th of the above labour only

18. SHUTTERING PER ONE SQ.M. (m2) (Based on rates sanctioned in SBD)
For the foundation used at suspension and suspended bridges is no need of centering work. The shuttering faces are always vertical and plain. Please refer to the general arrangement and detail drawing of the Suspension Bridge Division of HMG Roads Department. For the cost of the needed wood refer to cost item 7.2 (Salla wood for Shuttering). But for the shuttering work of foundation designed for suspended and suspension bridges the longitudinal wooden planks of the walk - way can be used for the wooden form work without wastage the planks too.

Material	:	Nails	0.03	kg
Labour	:	Manday	0.10	Carpenter
		Manday	0.10	Unskilled

T. & P. Lumpsum : 1/15th of the above labour only

19. 'PLACING OF REINFORCEMENT IN CEMENT CONCRETE WORK PER 100 KG (kg)
The reinforcement steel for suspension and suspended bridges is rather simple and a easy design. There are easy bending form (only streight with hooks at their ends) or U-forms for starter bars.

Material : Reinforcement 100 kg (it may supplied by SBD/SATA)
Binding wire 0.50 kg

Labour	:	Manday	3	Black smith
		Manday	4	Unskilled

T. & P. Lumpsum : 1/20th of the above labour only

20. CEMENT PLASTER WORK 12 mm thick per SQ.M. (m2) (Based on SBD rates)
Cement plaster is normaly not used at suspension and suspended bridges. The general arrangement and the detail drawings should be taken into reference.

Material	:	Sand	0.016 m3
		Cement	0.12 bags og 50 kg in weight
Labour	:	Manday	0.250 Mason
		Manday	0.333 Unskilled

T. & P. Lumpsum 1/20th of above labour only

21. BACKFILLING WORK PER CU.M. (Based on rates sanctioned in SBD)
The backfilling work should be done at each foundation to protect the blocks against erosion and sliding. The passive earth pressure is also taken into account by the calculated safety factors of the foundation. The excavation material laying around the foundation must be used and the backfilling should be done proper and compacted as much as possible.

Labour : Manday 0.50 Unskilled

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21. PLACING OF ANCHORAGE PARTS FOR SUSPENSION BRIDGES PER UNIT AT ONE SIDE

(Based on rates sanctioned by the Suspension Bridge Division of HMG Roads Department)

21.1 Main cable anchorage for one anchorage block at one river side

If a multiple span has to be etimated the lenth of the middle span should be taken into reference.

Span in metres	66 - 78	90 - 150	162 - 222 m
Fitter (Manday)	2	3	4
Unskilled (Manday)	6	9	12

21.2 Pylon and walk - way anchorage for one foundation at one river side

If a multiple span bridge has to be estimated the span in the middle should be taken.

Span in metres	66 - 78	90 - 150	162 - 222 m
Fitter (Manday)	1.8	2.2	3.4
Unskilled (Manday)	6.0	7.0	11.0

21.3 Placing of standard wind - guy anchorage per anchor block - i.e. cable end. Please refer to standard lay out drawing, general arrangement and detail drawings of the wind guy blocks etc.

Cable ∅ in inch (")	∅ 1"(25mm)	∅ 1¼"(32mm)	∅ 1½"(38mm)
Fitter (Manday)	0.30	0.60	0.80
Unskilled (Manday)	0.30	0.90	1.40

21.4 Placing of standard side stay cable anchorage hook per unit - i.e. cable end. Up to the span 150 metres there are <u>no</u> side stay cable provided. If there will be a special case the rate for spans from 162 to 198 m may be taken. For multiple spans take the middle span.

Spans in metres	162 to 198	210 - 222 m
Fitter (Manday)	0.50	0.60
Unskilled (Manday)	0.50	0.70

21.5 Placing of anchorage hook for front and back stay cable including turn-buckle to take up the pre-tension. For the back stay cable the hook at the main anchor block (hoisting hook) should be used. The rate is estimated for one river side. For multiple span take the middle span.

Spans in metres	66 - 114	126 - 174	210 - 222 m
Fitter (Manday)	1.20	1.80	2.40
Unskilled (Manday)	1.20	1.80	2.40

21.6 Placing of anchorage parts in rock anchor foundation types, tunnel or drilled holes in a hard and sound rock per anchorage unit.
Take four times the above rates (items 21.1 to 21.5) which are confirmed to the span or cable ∅.

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22. PYLON ERECTION AND SCAFFOLDING PER M HIGHT OF ONE PYLON

(Based on rates sanctioned by the suspension bridge division of HMG Roads Department)

Some usefull information :

Span in metre (or middle span)	Height of the pylons in metres
66 m	11.00 m
78 m	12.80 m
90 m	14.70 m
102 m	16.50 m
114 m	18.30 m
126 m	18.30 m
138 m	21.90 m
150 m	21.90 m
162 m	25.50 m
174 m	25.50 m
186 m	29.10 m
198 m	29.10 m
210 m	32.70 m
222 m	32.70 m

22.1 Scaffolding of pylon for each 4 metres height

Material :	Bamboo	50 Nos.	(1st Pylon)....	15 Nos. (2nd Pylon)
	Nariwal dori	12 kg	....	12 kg
Labour :	Manday	2	Carpenter	2 Carpenter
	Manday	12	Unskilled	12 Unskilled

Transportation : Up to 2 miles : coolies per bamboo = 0.25
Up to 4 miles : coolies per bamboo = 0.50
Up to 8 miles : coolies per bamboo = 1.00

The costs of the scaffolding for the second pylon will be cheaper, because most of the bamboos can be used twice. Take an assumption that 70 % of the bamboos can be used ones again for the second pylon. Therefore only 15 bamboos must be brought to the bridge site for the second pylon for each four metres height.

22.2 Pylon erection and lifting arrangement per m pylon height including fixation of front and back stay cables during assembling work.

Labour :	Manday	1.50	Fitter
	Manday	8.00	Unskilled

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23. CABLE HOISTING FOR SUSPENSION BRIDGES

(Based on rates sanctioned in SBD)

23.1 Hoisting of side stay cables per m length. (m1)

Please refer to general arrangement and detail drawings. For bridge spans up and including 150 m there are no side stay cables provided. For multiple spans take the middle span.

Span in metres		162 - 198 m	210 - 222 m
Fitter	(Manday)	0.08	0.09
Unskilled	(Manday)	0.40	0.50

In the above figures the labour to take up the pre-tension (2 tons rsp. 2.5 tons) is inluded.

23.2 Hoisting of main cable per m span (m1/span) for one main cable only

The diametres are according to HMG'Standard design. Refer also to chapter 2.5 (Standard design for suspension bridges).

Spans in metres	Fitter (Manday)	Unskilled (Manday)
66 m	0.15	0.90
78 m	0.15	0.90
90 m	0.10	0.60
102 m	0.10	0.60
114 m	0.15	0.90
126 m	0.15	0.90
138 m	0.15	0.90
150 m	0.15	0.90
162 m	0.10	0.60
174 m	0.15	0.90
186 m	0.15	0.90
198 m	0.15	0.90
210 m	0.15	0.90
222 m	0.15	0.90

For multiple span bridges take the rate per m span from the span of the stanadard middle span.

Noteworth : Fitter (Manday) and Unskilled (Manday) are given per m span for one cable only. Hoisting sag refer to general arrangement and chapter 2.5 (Standard design)

23.3 Hoisting of spanning cable per m span for one cable only

In the following rates the work to take up the pre-tension is included. There are turn - buckles provided for each cable end separately and they should be opened before hoisting the spanning cables. The cable ø are according to HMG'Standard Design.

Spans in metres	Fitter (Manday)	Unskilled (Manday)
66 to 102 m (3t)	0.07	0.45
114 to 150 m (4t)	0.08	0.55
126 to 186 m (5t)	0.08	0.60
198 to 222 m (6t)	0.12	0.72

For multiple span take the rate for the middle standard span.

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23.4 Hoisting of the wind - guy cables per m span of the wind-guy cable

The span of the wind - guy cable is often not the same as the span of the bridge. Please take the correct span from the general arrangement. The distance between the wind tie cables (ø ¼") is 3.60 m according to HMG'Standardization. In the general arrangement the real distances between the wind - tie clamps schould be given. To mark e.g. with paint where the wind tie clamps should be placed is also included in the following rates. The wind guy cables should be pretensioned. To take up this force on each cable end turn buckles etc. are provided. Befor starting the hoisting work those turn-buckles must be wide opened.

ø of wind-guy cable	Fitter (Manday)	Unskilled (Manday)
ø 1 " (25 mm)	0.10	0.60
ø 1¼ " (32 mm)	0.12	0.75
ø 1½ " (38 mm)	0.15	0.90

23.5 Hoisting and fixation of the wind ties ø 1/4" per piece.
The numbers of wind ties can be taken from the general arrangement. The wind - ties are provided every 3.60 m according to the standard design. Sometimes the wind anchor blocks are placed either in front or back the pylon foundation center line - i.e. the number of wind ties varies.

Labour per wind tie (piece) : Fitter 0.15 (Manday)
Unskilled 0.15 (Manday)

The above labour includes the time needed for the fixation on the cross beam of the walk - way (Gangway)

23.6 Fitting of fixation and hand rail cables per m span of the bridge.

This work can be estimated per m length of the bridge, because the Standard design of the suspension bridges shows two hand rail and two fixation cable for each bridge. The hoisting for these four cables is very easy because this work will be done after erection of the walk way.

Labour : Manday 0.08 Fitter
Manday 0.12 Unskilled

24. ERECTION OF THE WALK - WAY PER M SPAN (LENGTH)
(Based on rates sanctioned in SBD)

24.1 Erection of the suspenders, cross beams, wind bracing flats etc. per m length of the bridge.
The standard design of HMG Roads Department (Suspension Bridge Division) shows for all suspension bridges the same walk - way. Because of that the assembling work can be standardized.

Labour : Manday 1.50 Fitter
Manday 2.25 Unskilled

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24.2 Fitting of longitudinal planks to the cross beams of the walk-way per m length of the bridge.

In this connection refer also to the item 7.1 (Sal wood for longitudinal wooden planks) and item 8.1 (Fibre glass longitudinal planks). The coalter painting of the wooden planks is included in the item 9.1 (Painting of wooden longitudinal planks).

24.2.1 Fitting of <u>wooden</u> longitudinal planks per m length of the bridge (Bolts and nuts are supplied by the workshop)

Labour	:	Manday	0.30	Fitter
		Manday	0.40	Unskilled

24.2.2 Fitting of fibre-glass longitudinal planks per m length of the bridge (Bolts and nuts are supplied by the workshop)

Labour	:	Manday	0.20	Fitter
		Manday	0.10	Unskilled

24.3 Fitting of wire-mesh netting per m length of the bridge

Material	:	Bending wire	0.05	kg
Labour	:	Manday	0.05	Fitter
		Manday	0.25	Unskilled

24.4 Loading and unloading of the bridge
This work should be done at each bridge to take up the pretension in the spanning cable. The Standard design provides for each cable end one turn-buckle. The turn-buckles are to open before hoisting the spanning cables (refer also to item 23.3 Hoisting of spanning cable).

Span of the bridge (or length)	Labour (Manday) Unskilled
66 - 126 m	5
127 - 222 m	10
223 - ... m	13

25. FINISHING WORK

25.1 Painting of the steel construction per m pylon height.
The workshop will deliver the steelpart two times painted. Due to transportation some re-painting work may be necessary. This work is only to do at the pylons. Take care to the kind of paint used

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25.1 Painting work (continuation)

by the workshop. It is assumed that 0.50 m2 per m pylon height must be repainted.

Material	:	Paint	0.05 Litre per m pylon height
Labour	:	Manday	0.07 Painter per m pylon height
		Manday	0.05 Unskilled labour per m pylon height

25.2 Maintain of the threads of the anchor bars for the main and wind guy cable per cable end.

Labour	:	Manday	0.15 Fitter per cable end

25.3 Retightening of the cable clamps, bulldog grips, take up bolts and lock nuts of the turn buckles etc.

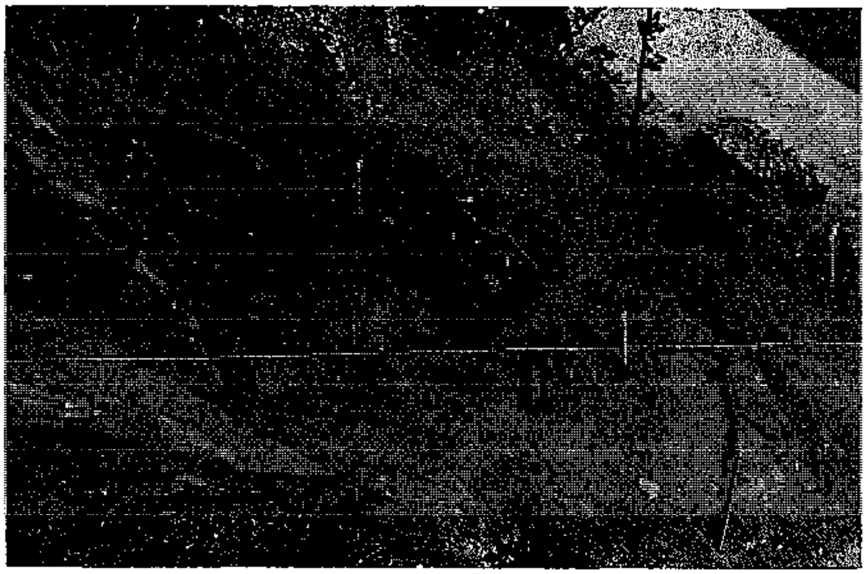
Span or length of the bridge	Fitter (Manday)
66 - 126 m	4
127 - 222 m	6
223 - ... m	8

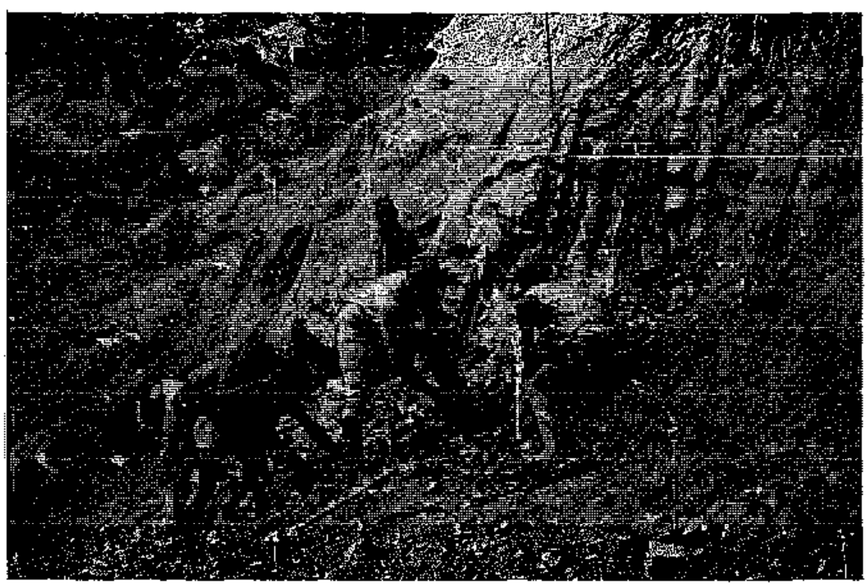
For the estimate work of a suspended bridge (bridge without pylons) please refer to chapter 7.2 Cost estimate for a suspended bridge.

Noteworth : There are different kind of material etc. needed for many of the items of this rate analysis for the cost estimates of standard suspension bridges. The site in charg should work out a list of the goods to be purchased but he should note, that the costs are already included in the rate analysis.
As a guide line at the following items are materials included :
(Exept items 1.6, 1.7, 2., 3. and 4.)

9.1 : Coalter paint and fuel	10.4 : Gelatine, detonator, fuse wire
10.7: Gelatine, Detonator, fuse wire	11. G.I. wire, selvedge wire
16. : Cement bags	17. : Cement bags
18. : Nails	19. : Reinforcement rods,binding wire
20. : Cement	22.1 : Narival dori
24.3: Bending wire	25.1 : Paint for pylon (repainting)

COST ESTIMATE FOR SUSPENION AND SUSPENDED BRIDGES	No : 7.220
Photos shown the work execution	Date : 1st March 77
	Sig : [signature]





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The herewith given rate analysis is based on the "NORMS" for analysis of rate by HMG, Department of Roads (Quantity surveying branch) and on rates sanctioned in the Suspension Bridge Division. The following analysis should be used only while the general arrangement and the detail drawing of a certain project of a suspended bridge are be taken into consideration. It must be said, that the following rates are taking care to the way of design work done by HMG Suspension Bridge Division. At the same moment it is important to mention, that the influence resulting from the HMG'standard has been considered.

1. TRANSPORTATION ESTIMATE CRITERIAS

1.1 Transportation by plane
The rates for this kind of transportation can be got from the Royal Nepal Airlines Corporation.

1.2 Transportation by truck
- Black top road : 0,00130 Rs. per kg per km
- Gravel and mud road : 0,00195 Rs. per kg per km
- River bank road : 0,00320 Rs. per kg per km

1.3 Transportation on porters back
- a porter walks 8 miles (13km) a day
- a porter carries 40kg easily steel parts and wooden planks
- a porter carries 50kg easily steelparts if the overall measurements are limited (1.25m in length)
- a porter carries 30kg of difficult parts -i.e. parts beyond 50kg and 1.25 m in length.
- a porter carries 20kg of cables
- wind-tie cables of ø $\frac{1}{4}$" (6,3mm) are estimated as easy steel parts
- cement bags of 50kg in weight are estimated as easy parts too.
- How many parts are to be estimated either as easy or difficult parts can be taken from the list in the general arrangement.

1.4 Loading and unloading
This amount varies on the conditions of the transportation for a certain bridge. The following assumption may be taken :

1.4.1 Transportation by plain : 30 Rs. per m span
1.4.2 Transportation by truck : 10 Rs. per m span
1.4.3 Transportation by porter : 2 Rs. per m span

1.5 Assumed weights of camp equipment etc.
This item varies on the different kind of work needed. The following weights may be taken as an average :

1.5.1 Spans 39 to 60m :
Store to bridge site : 1'000 kg
and back to store : 850 kg

1.5.2 Spans 63 to 87m :
Store to bridge site : 1'150 kg
and back to store : 950 kg

1.5.3 Spans 90 to 126m :
Store to bridge site : 1'500 kg
and back to store : 1'300 kg

1.5.4 Spans beyond 126m :
Store to bridge site : 1'600 kg
and back to store : 1'400 kg

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1.6 Assumed weights of equipment for campe maintenance and small materials for work execution.
6 kg per m span

1.7 Additional weight of equipment for rock drilling work
(Rock drilling machine, griding machine for drill bits, drill bits, fuel container, helmet, vice, water pipe, repairing and maintenance tools etc.)
Assumption: 150 kg store to site
120 kg back to store of SBD (Roads Department)

2. CAMP ESTABLISHMENT

Area needed for a project :
- 39 to 60 m span = 170 m2 (1 cement store)
- 63 to 87 m span = 250 m2 (2 cement stores)
- 90 to 126 m span = 320 m2 (2 cement stores)
- 127 to ... m span = 390 m2 (2 cement stores)

Coolies: Manday 6 Nos. per m2

3. CAMP MAINTENANCE

Material : Kerosene - oil .... : 54 Litres per month
First aid, different goods, batteries, latern glasses, small materials etc. : 200 Rs. per month

Labour : Supervisor............ : 1 Nos. (exept during rainy season)
Store keeper.......... : 1 Nos.
Watchmen.............. : 4 Nos.

4. PURCHASE OF GOODS FOR CAMP MAINTENANCE AND EXECUTION OF THE WORK

The amount of this item has not to be added to the estimated cost for a bridge site. The equipment can be used at more then one bridge site only. To purchase goods which is not available in the store of HMG Roads Department (Suspension Bridge Division) the amount of the 5 % contingencies is including these costs. The equipment must be brought back to the stores (refer also to rate analysis item 1.5) after completion of the work. Befor taking the goods the drawings of HMG'standard design should be read, because many items are put into the steelpartlists etc.

Description	Unit	spans in metres 39 - 60	63 - 87	90 - ...
Tent, double corner	pc.	1	2	2
Camp cot, durable type	pc.	3	4	4
Tarpaulin of different sizes	sq.ft.	450	680	1000
Petromax with spare parts	pc.	2	2	2
Lanterns	pc.	3	4	4
Torches	pc.	4	4	5
Camp tables	pc.	3	3	3
Camp chairs	pc.	8	8	8
Water filters	pc.	2	2	2
Hand bags	pc.	2	2	2
Cash boxes	pc.	1	1	1
Survey umbrella	pc.	-	-	1
Umbrellas	pc.	3	3	4

COST ESTIMATE FOR SUSPENDED BRIDGES	No. : 7.223
4. Purchase of goods (continuation)	Date : 18th Jan. 77
	Sig : [signature]

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4. Purchase of goods and equipment for execution work, continuation

Description	Unit	39 - 60	63 - 87	90 - ...
Kitchen utensils	set	1	1	1
Sleeping bags	pc.	1	1	1
Slide rule calculator	pc.	1	1	1
Theodolite (incl. stand)	pc.	1	1	1
Level (incl. staff)	pc.	1	1	1
Levelling staff	pc.	(1)	(1)	(1)
Tape, about 3m length	pc.	2	2	2
Tape, 20 to 30 m length	pc.	1	1	1
Spring balance, 50 kg capacity	pc.	1	1	1
Spring balance, 100 kg capacity	pc.	1	1	2
Weighing balance, 100 kg capacity	pc.	1	1	2
Shovels	pc.	15	20	25
Crow - bar ϕ 1¼"	pc.	4	6	10
Chisels, medium size	pc.	5	6	7
Hammer, small (0,5 kg)	pc.	15	25	35
Hammer, medium (5,0 kg)	pc.	4	6	8
Hammer, big (6,5 kg)	pc.	2	2	3
Mason's squares	pc.	2	2	2
Carpenter's level (spirit-level)	pc.	2	2	2
Plumb bob (plummet)	pc.	3	3	4
Screw jack (6" size)	pc.	1	1	1
Paint for marking (0,5 Litre)	tin	2	2	2
Buckets (20 Litres)	pc.	12	16	24
Blowers for black smith	pc.	1	1	2
Hack saw frame	pc.	2	2	2
Hack saw blades, best quality	doz.	1	1	2
Wood saws of different sizes	pc.	3	4	5
Auger ϕ ½" and 3/4"	doz.	½	1	1
Lay out frame of wooden planks	pc.	1	1	1
Files of different sizes (halfround, triangular, flat, full round)	set.	1	1	1
Die sets (¼,½,3/4,5/8,7/8,1" threads)	set.	1	1	1
Tongs	pair.	2	2	3
Nippers (pliers)	pc.	2	2	2
Pincers	pair	2	2	2
Screw drivers of different sizes	set	1	1	1
Nylondori ϕ 1"	m	20	70	120
Manila rope ϕ 1"	m	90	120	180
Bulldog grips for cables ϕ ¼ "	pc.	10	15	20
Bulldog grips for cables ϕ ½ "	pc.	4	6	6
Bulldog grips for cables ϕ 1 "	pc.	-	4	4
Bulldog grips for cables ϕ 1¼"	pc.	2	2	2
Bulldog grips for cables ϕ 1½"	pc.	4	6	8
Cable brakes for ϕ 1 "	pc.	-	2	2
Cable brakes for ϕ 1½"	pc.	2	4	4

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4. Purchase of goods and equipment for execution work, 2nd. continuation

Description		39 – 60	63 – 87	90 – ...
chain pulley, 2 tons capacity	pc.	1	1	2
Tirfor machine (complete) 2,5 tons	set.	1	2	–
Tirfor machine (complete) 5,2 tons	set.	–	–	2
Rock anchorage for tirfor (Habegger)	set.	(1)	(1)	(1)
Wrenches for nut and bolt ø ¼ "	pc.	4	6	8
Wrenches for nut and bolt ø ½ "	pc.	5	6	6
Socket wrenches for nuts ø ¾ "	pc.	3	3	3
Wrenches for nut and bolt ø 1 "	pc.	2	2	2
Wrenches for nut and bolt ø 1¼"	pc.	2	2	2
Wrenches for nut and bolt ø 1½ "	pc.	–	–	2
Wrenches of different other sizes	set.	1	1	1
C – Clamp	pc.	1	1	2

Special equipment only if really required

Blaster's pincers
Rock drilling machine, griding machine for drill bits, drill bits of different length, fuel container, helmet, vice,
Water pump with flexible pipes
Water pipes etc.
Cable car for temporary crossing

The total amount of the above items should not be added to the estimated cost of a proposed bridge. Most of the equipment can be taken from the SBD store and must be returned after completion of the bridge. The goods which cannot be taken from the SBD store will be purchased within the amount of 5% contingencies. The above list is a guideline for the preparation and should show the kind of goods and their approximative amount.

5. TEMPORARY CROSSING

5.1 Hire a boat per month
5.2 Boat Manday 4 Nos. in dry season (for large river only)
5.3 Temporary 'bridge': The span of a temporary crossing (i.e. length) is to take from the general arrangement. The length of a temporary bridge is never as long as for the proposed bridge.
Labour : Unskilled 5 Manday per m span of temporary bridge
Material : Take an assumption of about 25 Rs. per m length

6. SITE CLEARANCE

6.1 Clearance before starting of the execution work : L.S. about 300 to 700 Rs.
6.2 Clearance after completion, including collection of materials for preparation of auction (but without backfilling) : L.S. about 500 to 1200 Rs.

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7. WOOD WORK FOR 1 m3

7.1 Sal wood for decking for 1 m3

Assuming 40 % wastage, total wood required 1.67 m3 (58.8928 cubic feet). The wastage remains at the wooden location - i.e. only one m3 must be transported to the bridge site. A porter carries 4o kg and walks 8 miles (13 km) a day. One m3 is about 9oo kg in weight (sal wwod). The planks must be sawed according to the standard drawings of HMG'Standard bridge design. The lay out frame, supplied by SBD, must be used at the wooden location and the provided holes are to drill at the wooden location too.

Material : 1.67 m3 (58.8928 cubic feet) Royality
Labour : 10 Manday Coolies for felling and dressing
35 Manday Coolies for helping etc.
9 Coolies for helping etc.
½ Manday Carpenter to drill holes etc.
22 ½ Nos. of porters for transportation
T. & P. Lumpsum : 1/15th of the above labour

7.2 Salla wood for shuttering for 1 m3

Assuming 40 % wastage, total wood required = 1.67 m3 for 1 m3 sawed wood. The wastage remains at the wooden location. Only one m3 of salla wood must be carried to the bridge site. One m3 of salla wood is assumed with 8oo kg per m3.

Material : 1.67 m3 (58.8928 cubic feet)
Labour : 10 Manday Coolies for felling and dressing
35 Manday Saw men to make planks and beams
9 Manday Coolies for helping etc.
20 Nos. of porters for transportation
T. & P. Lumpsum : 1/15th of the above labour

8. LONGITUDINAL FIBRE GLASS PLANKS FOR THE WALK - WAY

8.1 Longitudinal fibre glass planks can provide a usefull alternativ solution for longitudinal planks. The rates may be got from the Balaju Yantra Shala, EJS, at the Industrial Estate Balaju (Kathmandu). This alternative kind of fibre glass planks are cheaper then wooden planks if the wooden location is creating a long and costly transportation. By comparing the different kind of planks, the coalter painting and fixation cost havealso to be taken into account.

9. PAINTING OF WOOD USED AT THE WALK - WAY

9.1 Painting of wooden longitudinal planks per m span. Refer to standard walk - way drawing.

Material : 1.176 Litre Coaltar paint
0.300 Litre Fuel
Labour : 0.3 Manday Painter
T. & P. Lumpsum : 1/20th of the above

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10. EXCAVATION WORK
(Based on 'Norms' of rate analysis by HMG, Roads Department)

10.1 Excavation of top soil and carrying away from the foundation areas (thickness 15 - 2o cm) per SQ.M. (m2)

Labour : Manday 0.40 (Unskilled)

10.2 Excavation of common material, haulage distance 10 metres and disposal per CU.M. (m3)
If the above item (10.1) has been taken the volume of the excavation must be calculated in such a way, that the item 10.1 is taken into account.

Labour : Manday 0.80 (Unskilled)

10.3 Excavation of soft rock material, requiring use of crowbar, haulage distance 1o m and disposal (take reference to item 10.1) per CU.M. (m3)

Labour : Manday 2.00 (Unskilled)

10.4 Excavation - drilling & blasting - hard rock material, haulage distance 10 m and disposal per Cu.M. (m3)

Material :	Gelatine	0.25 kg	
	Detonator	2.00 pc.	
	Fuse wire	2.00 m	
Labour :	Manday	3.59	(Unskilled)
	Manday	0.05	(Blaster)

10.5 Foundation excavation in dry common material - vertical lift 1 m, horizontal haulage distance 10 m and disposal per CU.M. (m3)
If you have used the item 10.1 please take the redution due to that position into reference by estimating the volumes.

Labour : Manday 1.34 (Unskilled)

Vertical lift : for each additional lift per CU.M. (m3) per 1 m height

Labour : Manday 0.30 (Unskilled)

10.6 Foundation excavation in dry soft rock material, vertical lift 1 m, horizontal haulage distance 10 m and disposal per CU.M. (m3)

Labour : Manday 2.50 (Unskilled)

Vertical lift : for each additional lift per CU.M. (m3) per 1 m height

Labour : Manday 0.40 (Unskilled)

10.7 Foundation Excavation in dry hard rock, material, drilling and blasting, vertival lift 1 m, horizontal haulage distance 10 m and disposal per CU.M. (m3)

Material :	Gelatine	0.25 kg
	Detonator	2.00 pc.
	Fuse wire	2.00 m

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10.7 Continuation

Labour : Manday 4.76 (Unskilled)
Manday 0.05 (Blaster)

Vertical lift : for each additional lift per CU.M. (m3) per m hight

Labour : Manday 0.40 (Unskilled)

10.8 Foundation excavation in shallow water, common material, vertical lift 1 m, horizontal haulage distance 10 m and disposal per CU.M. (m3)
This position may be used on the middle piers for multiple span suspension bridges etc. .

Labour : Manday 2.25 (Unskilled)

Vertical lift : for each additional lift per CU.M. (m3) per m hight

10.9 Bottom trimming of rock foundation pit and clearance per SQ.M. (m2)
(refer to detail drawings carefully)

Labour : Manday 0.61 (Unskilled)

11. FABRICATION OF GABION (Based on NORMS by HMG, Roads Department)

11.1 Fabrication of gabion including rolling, cutting and weaving complete.
Mesh size : 80 x 100 mm
Mesh wire : 9 SWG
Selvedge wire: 6 SWG

11.1.1 Box size 2 m x 1 m x 1 m

Material : G.I. Wire 36.00 kg
Selvedge wire 3.75 kg

Labour : Manday 2.42 (Skilled)
Manday 1.21 (Unskilled)

11.1.2 Box size 3 m x 1 m x 1 m

Material : G.I. Wire 52.35 kg
Selvedge wire 4.85 kg

Labour : Manday 3.52 (Skilled)
Manday 1.76 (Unskilled)

11.1.3 Box size 2 m x 1 m x 0.5 m

Material : G.I. Wire 24.55 kg
Sevedge wire 3.00 kg

Labour : Manday 1.650 (Skilled)
Manday 0.825 (Unskilled)

COST ESTIMATE FOR SUSPENDED BRIDGES 11.1.4 Gabion box of size 3 x 1 x 0.5 m to 13. Filling of sand, stones, boulders etc. in cell-type foundation	No. : 7.226 Date : 18th Jan. 77 Sig :

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11.1.4 Boxe size 3 m x 1 m x 0.5 m

Material : G.I. Wire 36.00 kg
Selvedge wire 3.90 kg

Labour : Manday 2.42 (Skilled)
Manday 1.21 (Unskilled)

11.2 Assemble gabion, place in position including streching, wiring the gabion together and tying down lids. Analys per box (piece)
Binding wire : 11 S.W.G.

11.2.1 Box size 2 m x 1 m x 1 m

Material : Binding wire 1.15 kg

Labour : Manday 0.40 (Unskilled)

11.2.2 Box size 3 m x 1 m x 1 m

Material : Binding wire 1.60 kg

Labour : Manday 0.60 (Unskilled)

11.2.3 Boxe size 2 m x 1 m x 0.5 m

Material : Binding wire 0.90 kg

Labour : Manday 0.20 (Unskilled)

11.2.4 Boxe size 3 m x 1 m x 0.5 m

Material : Binding wire 1.20 kg

Labour : Manday 0.30 (Unskilled)

12. FILLING OF STONES IN GABION CRATES PER CU.M. (m3) based on 'NORMS' by HMG R.D.

Collection of rubble of required size, haulage distance 10 m, partly stacking, filling in gabion crates per CU.M. (m3)

Collection of rubble, stones etc.

Labour : Manday 0.70 (Unskilled)

Filling in gabion crates

Labour : Manday 0.80 (Unskilled)

Additional cost for additional haulage for every 10 m more:

Labour : Manday 0.16 (Unskilled)

13. FILLING OF SAND, STONES, BOULDERS, ROCK PIECES ETC. IN CELL - TYPE FOUNDATION INCLUDING COMPACTING PER CU. M. (m3)

The excavation material which lies around the foundation should be used.

Labour : Manday 0.60 (Unskilled)

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14. COLLECTION OF MATERIALS
Based on NORMS by HMG Department of Roads

14.1 Collection of rubble of required size, haulige distance 10 m and stacking

What are rubbles ? bits of brocken stones, rock or brickwork, stones from a river bed, coarse gravel (30 to 55 mm) e.g. build a road with a foundation of rubble

Collection of rubble of required size per CU.M. (m3)

Labour : Manday 0.70 (Unskilled)

Additional work for extra haulage per 10 m per one cubicmetre

Labour : Manday 0.16 (Unskilled)

14.2 Collection of stones, gravel including selection, screening and stacking within 10 m haulage distance per CU.M. (m3)

14.2.1 Size 40 to 70 mm
Collection of stones and gravel etc. per m3
Labour : Manday 5.00 (Unskilled)

Additional work for extra haulage per 10 m per one cubicmetre
Labour : Manday 0.16 (Unskilled)

14.2.2 Size 70 to 100 mm
Collection of stones and gravel etc. per m3
Labour : Manday 4.00 (Unskilled)

Additional work for extra haulage per 10 m per one cubicmetre
Labour : Manday 0.16 (Unskilled)

14.3 Collection and sieving gravel including stacking within 10 m haulage per CU.M.

14.3.1 Size 5 to 70 mm
Collection, sieving and stacking per one cubicmetre
Labour : Manday 2.5 (Unskilled)

Additional work for extra haulage per 10m per one cubicmetre
Labour : Manday 0.16 (Unskilled)

14.3.2 Size 5 to 40 mm
Collection, sieving and stacking per CU.M. (m3)
Labour : Manday 4.0 (Unskilled)

Additional work for extra haulage per 10 m per one cubicmetre
Labour : Manday 0.16 (Unskilled)

14.3.3 Size 5 to 20 mm
Collection, sieving ans stacking per CU.M. (m3)
Labour : Manday 5.88 (Unskilled)

Additional work for extra haulage per 10 m per one cubicmetre
Labour : Manday 0.16 (Unskilled)

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14.3 Continuation

14.3.4 Size 5 to 8 mm
Collection, sieving and stacking per CU.M. (m3)
Labour : Manday 10.00 (Unskilled)

Additional work for extra haulage per 10 m per one cubicmetre
Labour : Manday 0.16 (Unskilled)

14.4 Collection and sieving fine sand within 10 m haulage distance per CU.M. (m3)

14.4.1 Collection and sieving sand in hill areas, haulage distance 10 m per CU.M. (m3)
Labour : Manday 1.49 (Unskilled)

Additional work for extra haulage per 10 m per one cubicmetre
Labour : Manday 0.12 (Unskilled)

14.5 Breacking stones including collection, sieving and stacking within 10 m haulage per CU.M. (m3)

14.5.1 Size 40 to 70 mm
Collection, breacking,sieving etc.
Labour : Manday 8.00 (Unskilled)

Additional work for extra haulage per 10 m per one cubicmetre
Labour : Manday 0.12 (Unskilled)

14.5.2 Size 20 to 40 mm
Collection, breacking, sieving etc.
Labour : Manday 12.00 (Unskilled)

Additional work for extra haulage per 10 m per one cubicmetre
Labour : Manday 0.12 (Unskilled)

14.5.3 Size 10 to 20 mm
Collection, breacking, sieving etc.
Labour : Manday 18.00 (Unskilled)

Additional work for extra haulage per 10 m per one cubicmetre
Labour : Manday 0.12 (Unskilled)

14.5.4 Making sand by crushing of stones per CU.M. (m3)
If the sand location is quite far from the site, the crushing of stones to get sand might be the cheaper way. A carefull comparison should be made. This rate is sanctioned by the Suspension Bridge Division.

Crushing of stones to get sand including collection, sieving and stacking within 10 m haulage distance per CU.M.

Labour : Manday 35.00 (Unskilled)

Additional work for extra haulage per 10 m per one cubicmetre
Labour : Manday 0.12 (Unskilled)

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15. DRY RUBBLE MASONARY PER CU.M.
(Based on 'NORMS' by HMG Roads Department)

15.1 Providing and lying dry rubble masorry of hard block stones, height of masoned body up to five metres and haulage distance within 30 metres per CU.M. (m3)

Collection of rubble refer to item 14,1

Material :	rubble	1.10	m3
Labour :	Manday	3.50	(Unskilled)

16. R.R. MASONRY IN CEMENT MORTAR PER CU.M.
(Based on rates sanctioned in SBD)

16.1 R.R. Masonry in cement mortar 1 : 4 per CU.M.

This item should only be used below the known high flood level at the pylon and pier foundation for single and multiple span suspension bridges. This kind of masonary work is not allowed for wind guy blocks and main anchor blocks. The detail drawings and general arrangement have to be taken into consideration.

Material :	Rubble	1.25	m3
	Sand	0.34	m3
	Cement	2.55	bags of 50 kg in weight
Labour :	Manday	0.10	(Head Mason)
	Manday	2.00	(Mason)
	Manday	3.20	(Unskilled)
	Manday	0.20	(Waterman)
Scaffolding :		1/30th	of the above labour

T. & P. Lumpsum : 1/20th of the above labour only

16.2 R.R. Masonry in cement mortar 1 : 6 per CU.M.

Material :	Rubble	1.25	m3
	Sand	0.42	m3
	Cement	2.10	bags of 50 kg in weight
Labour :	Manday	0.10	(Head Mason)
	Manday	2.00	(Mason)
	Manday	3.20	(Unskilled)
	Manday	0.20	(Waterman)
Scaffolding :		1/30th	of the above labour

T. & P. Lumpsum : 1/20th of the above labour only

16.3 Stone Dressing per CU.M.
This position is actually not necessary for suspension and suspended bridge project by the design section of SBD of HMG Roads Department.

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17. CONCRETE WORK PER CU.M. (Based on rates sanctioned in SBD)

17.1 Lean concrete 1 : 4 : 8 per CU.M. (m3)
Only used as granular sub grade about 5 to 7 cm thick.

Material	:	Aggregate	0.90	m3
		Sand	0.45	m3
		Cement	3.30	bags of 50 kg in weight
Labour	:	Manday	0.10	Head Mason
		Manday	0.70	Mason
		Manday	1.20	Waterman
		Manday	7.20	Unskilled

T. & P. Lumpsum : 1/20th of the above labour only

17.2 Plum concrete consits of 60 % mass concrete and 40 % boulders and rubbles or hard rock pieces per CU.M. (m3) (Mass concrete 1 : 3 : 6 + 40 % boulders)

Material	:	Aggregate	0.528	m3
		Rubble,etc.	0.500	m3
		Sand	0.264	m3
		Cement	2.58 ~~0.258~~	bags of 50 kg in weight
Labour	:	Manday	0.60	Head Mason
		Manday	0.40	Mason
		Manday	0.70	Waterman
		Manday	4.30	Unskilled
		Manday	0.25	Unskilled (Washing rubble, based on 'NORMS')
		Manday	1.75	Unskilled (Providing and laying rubble within a haulage distance up to 30 m)

T. & P. Lumpsum : 1/20th of the above labour only

17.3 Mass concrete 1 : 3 : 6 per CU.M. (m3)

Material	:	Aggregate	0.88	m3
		Sand	0.44	m3
		Cement	4.30	bags og 50 kg in weight
Labour	:	Manday	0.10	Head Mason
		Manday	0.70	Mason
		Manday	1.20	Waterman
		Manday	7.20	Unskilled

T. & P. Lumpsum : 1/20th of the above labour

17.4 Mass concrete 1 : 2 : 4 per CU.M. (m3)
Refer to detail drawings because this kind of concrete is only used in small quantities at the top of the main anchor block

Material	:	Aggregate	0.88	m3
		Sand	0.44	m3
		Cement	6.60	bags of 50 kg in weigth

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17.4 Mass Concrete 1 : 2 : 4 per CU. M. (continuation)

Labour :	Manday	0.10	Head Mason
	Manday	0.70	Mason
	Manday	1.20	Waterman
	Manday	7.20	Unskilled

T. & P. Lumpsum : 1/20 of the above Labour only

18. SHUTTERING PER ONE SQ.M. (m2) (Based on rates sanctioned in SBD)
For the foundation used at suspended bridges is not much need of centering work. The shuttering faces are always vertical and plain. Please refer to general arrangement and detail drawings of the Suspension Bridge Division of HMG Roads' Department. For the cost of the needed wood refer to cost item 7.2 (Salla wood for shuttering) but, take into account that for shuttering work at Suspension and Suspended Bridges the longitudinal wooden planks can be used for the wooden form work without wastage the planks.

Material : Nails 0.03 kg

Labour :	Manday	0.10	Carpenter
	Manday	0.10	Unskilled

T. & P. Lumpsum : 1/15th of the above labour only

19. PLACING OF REINFORCEMENT IN CEMENT CONCRETE WORK PER 100 KG (kg)
The reinforcement steel used at suspension and suspended bridges is rather simple and of easy design. There are easy bending forms (only streight with hooks at its ends) or U-forms for starter bars etc.

19.1 Reinforcement steel cutted and bended at the bridge site

Material : Reinforcement 100 kg (it might be supplied by SBD/SATA etc)
Binding wire o.50 kg

Labour :	Manday	3	Blacksmith
	Manday	4	Unskilled

T. & P. Lumpsum : 1/20th of the above labour only

19.2 Reinforcement 'ready made' by the workshop according to the list of HMG Suspension Bridge Division

Material : Reinforcement 100 kg (Cost included in the manufacturing costs of the steel construction by the workshop)

Bending wire 0.50 kg

Labour :	Manday	0.20	Blacksmith
	Manday	2	Unskilled

T. & P. Lumpsum : 1/20th of the above labour only

20. BACKFILLING WORK PER CU.M. (m3) (Based on rates sanctioned in SBD)
The backfilling work must be done at each foundation to protect the blocks against erosion and sliding. The passive earth pressure is also often be taken into account by calculating the foundation blocks. Thus the backfilling must be made proper and compacted in layers of 20 cm as much as possible.

Labour : Manday 0.50 Unskilled

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21. PLACING OF ANCHORAGE PARTS FOR SUSPENDED BRIDGES PER UNIT AT ONE SITE

(Based on rates sanctioned by the Suspension Bridge Division of HMG Roads Department)

21.1 Main cable anchorage for one anchore block at one river side

21.1.1 Suspended Bridges from 39 to 60 m span
The analysis includes all work which is needed to place the anchor parts for the main and hand-rail cables. Because the steelparts are standardized, the required work is the same for all bridges within the spans from 39 to 60 m

Fitter	(Manday)	1
Unskilled	(Manday)	2

21.1.2 Suspended Bridges from 63 to 87 m span

Fitter	(Manday)	1,3
Unskilled	(Manday)	2,6

21.1.3 Suspended Bridges from 90 to 126 m span

Fitter	(Manday)	2,0
Unskilled	(Manday)	4,0

21.1.4 Suspended Bridges from 127 to .... m span

Fitter	(Manday)	3,0
Unskilled	(Manday)	6,0

21.2 Placing of standard wind cable anchorage per anchor block - i.e. cable end. Please refer to standard lay out drawings, general arrangement and detail drawings of the wind guy blocks etc.

Cable ø in inch (")		ø ½"(tie cable only)	ø 1"	ø 1¼"	ø 1½"
Fitter	(Manday)	0,20 For short spans	0,30	0,60	0,80
Unskilled	(Manday)	0,20 only used	0,30	0,90	1,40

At short span bridges (up to 54 m) the wind bracing cables might not be proposed. Please read the general arrangement carefully.

21.3 Placing of anchorage parts in rock anchor foundation types, 'tunnel' or drilled holes in hard or sound rock per anchorage unit (cable end)

Take four (4) times the above rates (item 21.2) which are confirmed to the cable ø.

22. CABLE HOISTING FOR SUSPENDED BRIDGES
(Based on rates sanctioned in SBD)

22.1 Hoisting of main cable per m span (m1/span) for one main cable only. The diametres are according to HMG'Standard design. Refer also to chapter 2.4 (Standard design for suspended bridges) e.g.page 2.403. The cables must be at least three (3) times wrepped on the drum anchorage - i.e. the cable ends have to be turned 3 times around the drum anchorage. These work is also included in the following rates. The standard of the suspended bridges shows, that only cables of ø 1½" (breaking load 77 tons) are used.

Fitter	(Manday)	0,15
Unskilled	(Manday)	0,90

Note : Fitter (Manday) and unskilled Labour (Manday) are given per m span of the bridge for one cable only. Hoisting sags and numbers of cables refer to page 2.403 and general arrangement.

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22.2 Hoisting of the wind - guy cables per m span of the wind-guy cable

The span of the wind - guy cable is often not the same as the span of the bridge. Please take the correct span from the general arrangement. The distance between the wind tie cables (ø ¼") is 4.80 m according to HMG'Standardization. In the general arrangement the real distances between the wind - tie clamps should be given. To mark e.g. with paint where the wind tie clamps should be placed is also included in the following rates. The wind guy cables should be pretensioned. To take up this force on each cable end turn buckles etc. are provided. Before starting the hoisting work those turn-buckles must be wide opened.

ø of wind cablec	Fitter (Manday)	Unskilled (manday)
ø ½ "(12,7mm)	0.07	0.50
ø 1 "(25,4mm)	0.10	0.60
ø 1¼ "(31,8mm)	0.12	0.75
ø 1½ "(38,1mm)	0.15	0.90

22.3 Hoisting and fixation of the wind ties ø 1/4" per piece.
The numbers of wind ties can be taken from the general arrangement. The wind - ties are provided every 4.80 m according to the standard design. Sometimes the wind anchor blocks are placed either in front or back the pylon foundation center line - i.e. the number of wind ties varies.

Labour per wind tie (piece) : Fitter 0.15 (Manday)
Unskilled 0.15 (Manday)

The above labour includes the time needed for the fixation on the cross beam of the walk - way (Gangway)

22.4 Fitting of fixation and hand rail cables per m span of the bridge.

This work can be estimated per m length of the bridge, because the Standard design of the suspension bridges shows two hand rail and partly two fixation cable for each bridge. The hoisting for these four cables is very easy because this work will be done after erection of the walk way.

		spans from 39 to 60	63 to ... m
Labour :	Manday	0.07 Fitter	0.08 Fitter
	Manday	0.10 Unskilled	0.12 Unskilled

23. ERECTION OF THE WALK - WAY PER M SPAN (LENGTH)
(Based on rates sanctioned in SBD)

23.1 Erection of the hangers (which are members of the cross beam), cross beam, wind bracing flats etc. per m length of the bridge.
The standard design of HMG Roads Department shows foe all bridges the same way system. Because of that the assembling work can be standardized.

Labour : Manday 1.10 Fitter
Manday 1.90 Unskilled

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23.2 Fitting of wooden deck

23.2.1 Fitting of nailing strips to the cross beams of the walk way per m length of the bridge

The nailing strips should be bolted to the m.s. channel cross beam befor starting the errection work. At the river sides this work goes much quickler than on the swaying cables during the assembling work.

Material	:	Bolts and nuts (washers) supplied by workshop		
Labour	:	Manday	0.01	Carpenter
		Manday	0.01	Fitter
		Manday	0.01	Unskilled

23.2.2 Fitting of the wooden longitudinal planks per m length of the bridge.

The wooden planks are to be nailed to the nailing strips described in the above cost item 23.2.1

Material	:	Nails etc. Supplied by the Workshop		
Labour	:	Manday	0.15	Fitter
		Manday	0.30	Unskilled

23.2.3 Fitting of the fibre glass longitudinal planks

This alternative solution for planking might be sometimes very usefull. By estimating the bridge costs the reference to the proposed kind (either wood or fibre glass) must be taken.

Material	:	Bolts (e.g. wooden screw) and washers Supplied by the Workshop		
		Fibre glass planks Supplied by the Workshop too		
Labour	:	Manday	0.17	Fitter
		Manday	0.10	Unskilled

23.3 Fitting of wire mesh netting per m length of the bridge.

Bending wires, U-nails for short bridges, wire mesh netting etc. will be supplied by the Workshop. The lenth of the bridge must not be taken twice, because the rates include already that on both papapets of the bridge wire mesh must be fixed.

Material	:	Wire mesh, binding wire etc. by the Workshop		
Labour	:	Manday	0.06	Fitter
		Manday	0.30	Unskilled

24. FINISHING WORK

24.1 Maintain of threads of the main clamps, turnbuckles and wind-guy anchorage rodes per cable end.

Labour	:	Manday	0.08	Fitter per cable end

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24.2 Retightening of cable clamps, bulldog grips, turn buckles, lock nuts, etc.

After the completion of the bridge this item is important and must be done carefully

lengthe of the bridge in m	Fitter (Manday)
39 to 54	1
57 to 60	2
36 to 126	3
127 to	4

24.3 Joint sealer (refer to page 5.206 of this book)

Everytime when main cables are fixed by drum-anchorage and the final concrete - after completion of the erection work - work is finished, there is a joint between the main cables and the concrete. In such cases it is most useful to apply an elastic joint sealer to prevent rust in these section. The reference to page 5.205 should also be made.
The quantities given below are including the component A as well as the component B. The primer is used to allow a correct joint (bond) between the concrete, cable and joint sealer.

Spans in m	Thanatar A + B (Joint sealer)	Thana Primer (Primer)	Labour in Manday Unskilled	Skilled
39 - 60	3,2 litres	0,4 litre	0.30	0.30
63 - 87	6,4 litres	0.8 litre	0.50	0.50
87 - 126	9,6 litres	1.2 litres	0.70	0.70

T. & P. Lumpsum : 1/20th of the above labour only

The above rates are for <u>one</u> bridge

24.4 Painting of the steelconstruction

The worshop has to deliver the steelpart two times painted. Due to transportation some re-painting work may be necessary. This work is only to do at the turn-buckles for the windguy and hand-rail cables. Take the same kind and color of paint which has been used by the workshop.

Span in metres	paint required	Painter	Helper (Unskilled)	
39 - 54	0.50 litre	0.80	0.80	(Manday)
57 - 60	1.00 litre	1.50	1.50	(Manday)
63 - 126	1.50 litres	2.20	2.20	(Manday)
127 - ...	2.00 litres	3.00	3.00	(Manday)

T. & P. Lumpsum : 1/20th of the above labour only

Noteworth: There are different kind of material etc. needed for many of the item which are in this rate analysis for the preparation of cost estimates of standard suspended bridges. The site in charge should work out a list of the goods to be purchased, but he has to note, that the costs are already included in the rate analysis.
The used cost items for a particular bridge must be overchecked to be certain, that the goods to be purchased are included.

COST ESTIMATE

Quotation for a Suspended Bridge
(steel construction)

No : 7.301

Date : 22nd Febr. 77

Sig : for [signature]

Quotation for : .... Span : ...... m

Dear Sirs,

Please let us have your best offer for the following items of the above mentioned Suspended Bridge (bridge without pylons) accordung to HMG'Standard Design. Enclosed herewith please find all needed drawings and steelpartlists, which give you all the information. Would you please fill in this list and send it to the Suspension Bridge Division of HMG' Roads' Department. The construction work must be done according to the Indian Standard and the enclosed Standard Drawings. In add. the below mentioned points have also to be kept :

i : The settlement of the final account for construction work will be based on the theoretical weights of the steelparts list of HMG' Standard Drawings.

ii : One test assembly must be made by the workshop and shown to the Suspension Bridge Division of HMG' Roads' Department.

iii : The numbers of the steelparts list must be written on the finished steelparts, units and members.

iv : Threads etc. must be protected with jute etc.

v : The workshop is responsible for seeing that all thimbles can be fitted on the provided pins, steelparts, bolts etc.

vi : The points given in the enclosed "Terms of steelwork" (refer to pages 7.5) must be taken into consideration. The "Terms of steelwork" is an integral part of this quotation form.

Item Nos.	Specification, etc. Steel supplied by whom	Quanity kg	Rate per Rs.	Total Item Rs.
1	Transport of steel which is supplied by the Suspension Bridge Division from the SBD store to the Workshop	......	....	....
2	Cutting and Bending of reinforcement rods according the lists			
	- with steel supplied by SBD	......	....	....
	- with steel supplied by the workshop	......	....	....
3	Fabrication cost of main cable, hand rail cable and wind guy anchorages			
	- with steel supplied by SBD	......	....	....
	- with steel supplied by the workshop	......	....	....
4	Fabrication cost of deck (walkway) incl. hanger rods, wind bracing clamps etc.			
	- with steel supplied by SBD	......	....	....
	- with steel supplied by the workshop	......	....	....
5	Delivery of wire mesh netting, 120 cm wide, 3mm galvanized, one transport unit has to be below 45 kg (prices per m length)			
	- with wire supplied by SBD (manufacturing)	......	....	....
	- with wire supplied by the Workshop	......	....	....
6	Delivery of open thimbles IS 2315-1963, galvanized			
6.1	Thimbles for cable ø ¼ " (price per piece)	......	....	....
6.2	Thimbles for cable ø ½ " (price per piece)	......	....	....
6.3	Thimbles for cable ø 1 " (price per piece)	......	....	....
6.4	Thimbles for cable ø 1¼" (price per piece)	......	....	....
6.5	Thimbles for cable ø 1½" (price per piece)	......	....	....

..../continued

COST ESTIMATE Quotation for a Suspended Bridge (continuation) (steel construction)	No. : 7.302 Date : 22nd Febr.77 Sig : *[signature]*

Item Nos.	Specification, etc. Steel supplied by whom	Quantity kg.	Rate per Rs.	Total Item Rs.
7	Delivery of bulldog grips IS 2361-1970 , galvanized			
7.1	Bulldog grips for cable ø ¼ " (price/piece)	....	....	....
7.2	Bulldog grips for cable ø ½ " (price/piece)	....	....	....
7.3	Bulldog grips for cable ø 1 " (price/piece)	....	....	....
7.4	Bulldog grips for cable ø 1¼" (price/piece)	....	....	....
7.5	Bulldog grips for cable ø 1½" (price/piece)	....	....	....
8	Painting of the whole steel construction according to the drawings and steelparts lists after cleaning of the steelparts.			
8.1	Painting with paint supplied by SBD - first coat (base coat) (price per m2)	....	....	....
	- second coat (finish coat) (price per m2)	....	....	....
8.2	Painting and delivery of paint by the workshop - first coat (base coat) (price per m2)	....	....	....
	- second coat (finish coat) (price per m2)	....	....	....
9.	Delivery of cables 6x19 (12/6/1) according to Indian Standard 2266-1970. The cables are to deliver with steel wire core and galvanized.			
9.1	Delivery of cables ø ¼", Breaking load 2.3 t according to cable list (price per m length)	....	....	....
9.2	Delivery of cables ø ½", breaking load 8.79 t according cable list (price per m length)	....	....	....
9.3	Delivery of cables ø 1", breaking load 35,9 t according cable list (price per m length)	....	....	....
9.4	Delivery of cables ø 1¼",breaking load 54,4 t according cable list (price per m length)	....	....	....
9.5	Delivery of cables ø 1½", breaking load 77 t according to cable list (price per m length)	....	....	....
1-9	Total cost without sale tax		=	....

The sale tax is not to be included in the rates etc.

Term of delivery from the date of receiving the order of the Suspension Bridge Division of HMG Roads' Department :

Item No. 2 .... weeks Item No. 3 .... weeks

Item No. 4 .... weeks

Item No. 5 .... weeks Item No. 6 .... weeks

Item No. 7 .... weeks Item No. 9 .... weeks

The closing date for receipt of quotations will be on ....

Date ....

Signature and stamp of the Workshop ....

COST ESTIMATE **Quotation for a Suspension Bridge** (Steel construction)	No. : 7.401 Date : 28th Febr. 77 Sig : [signature]

Quotation for : .... Span : .... m

Dear Sirs,

Please let us have your best offer for the following items of the above mentioned Suspension Bridge (bridge with pylons) according to HMG'Standard Design. Enclosed herewith please find all needed drawings and steelpartlists, which give you all the information. Would you please fill in this list and send it to the Suspension Bridge Division of HMG' Roads' Department. The construction work must be done according to the Indian Standard and the enclosed Standard Drawings. In addition the below mentioned points have also to be kept :

i : The settlement of the final account for construction work will be based on the theoretical weights of the steelparts list of HMG' Standard Drawings.
ii : One test assembly must be made by the workshop and shown to the Suspension Bridge Division of HMG' Roads' Department.
iii : The numbers of the steelparts list must be written on the finished steelparts, units and members.
iv : Threads etc. must be protected with jute etc.
v : The workshop is responsible for seeing that all thimbles can be fitted on the provided pins, steelparts, bolts etc.
vi : The points given in the enclosed "Terms of steelwork" (refer to pages 7.5) must be taken into consideration. The "Terms of steelwork" is an integral part of this quotation form.

Item Nos.	Specification, etc. Steel supplied by whom	Quantity kg	Rate per Rs.	Total Item Rs.
1	Transport of steel which is supplied by the Suspension Bridge Division from the SBD store to the Workshop	....	....	....
2	Cutting and Bending of reinforcement rods according to the lists			
	- with steel supplied by SBD	....	....	....
	- with steel supplied by the workshop	....	....	....
3	Fabrication cost of main cable, walk-way pylon, side stay and wind guy anchorages			
	- with steel supplied by SBD	....	....	....
	- with steel supplied by the workshop	....	....	....
4	Fabrication of pylon construction			
	- with steel supplied by SBD	....	....	....
	- with steel supplied by the workshop	....	....	....
5	Fabrication of deck (walk-way), Suspenders, stabilizing cable clamps, wind tie clamps, etc.			
	- with steel supplied by SBD	....	....	....
	- with steel supplied by the workshop	....	....	....
6	Delivery of wire mesh netting, 90 cm wide, 3mm galvanized, one transport unit has to be below 45 kg **(price per m length)**			
	- with **wire** supplied by SBD(**manufacturing**)	....	....	....
	- with **wire** supplied by the workshop	....	....	....

...../continued

COST ESTIMATE

Quotation for a Suspension Bridge (continuation)
(steel construction)

No. : 7.402

Date : 28th Febr. 77

Sig : [signature]

Item Nos.	Specification etc. Steel supplied by whom	Quantity	Rate per Rs.	Total Item Rs.
7	Delivery of open thimbles IS 2315-1963, galvanized			
7.1	Thimbles for cable ø ¼ " (price per piece)	......	....	....
7.2	Thimbles for cable ø ½ " (price per piece)	......	....	....
7.3	Thimbles for cable ø 1 " (price per piece)	......	....	....
7.4	Thimbles for cable ø 1¼" (price per piece)	......	....	....
7.5	Thimbles for cable ø 1½" (price per piece)	......	....	....
8	Delivery of bulldog grips IS 2361-1970, galvanized			
8.1	Bulldog grips for cable ø ¼ " (price/piece)	......	....	....
8.2	Bulldog grips for cable ø ½ " (price/piece)	......	....	....
8.3	Bulldog grips for cable ø 1 " (price/piece)	......	....	....
8.4	Bulldog grips for cable ø 1¼" (price/piece)	......	....	....
8.5	Bulldog grips for cable ø 1½" (price/piece)	......	....	....
9	Painting of the whole steel construction according to the drawings and steelparts lists after cleaning of the steel parts.			
9.1	Painting with paint supplied by SBD			
	- first coat (base coat) (price per m2)	......	....	....
	- second coat (finish coat) (price per m2)	......	....	....
9.2	Painting and delivery of paint by the workshop itself			
	- first coat (base coat) (price per m2)	......	....	....
	- second coat (finish coat) (price per m2)	......	....	....
10	Delivery of cables 6x19 (12/6/1) according to Indian Standard 2266-1970. The cables are to deliver with steel wire core and galvanized.			
10.1	Delivery of cables ø ¼", Breaking load 2,3 t according to cable list (price per m length)	......	....	....
10.2	Delivery of cables ø ½", Breaking load 8.79 t according to cable list (price per m length)	......	....	....
10.3	Delivery of cables ø 1", Breaking load 35,90 t according to cable list, (price per m length)	......	....	....
10.4	Delivery of cables ø 1¼", Breaking load 54,4 t according to cable list, (price per m length)	......	....	....
10.5	Delivery of cables ø 1½", Breaking load 77,0 t according to cable list, (price per m length)	......	....	....
1 - 10	Total cost without sale tax		=	....

......./ continued

COST ESTIMATE

Quotation for a Suspension Bridge (continuation)
(steel construction)

No.	: 7.403
Date	: 28th Febr. 77
Sig	: [signature]

The sale tax is not to be included in the rates etc.

Term of delivery from the date of receiving the order of the Suspension Bridge Division of HMG Roads' Department :

Item No. 2 .... weeks
Item No. 3 .... weeks
Item No. 4 .... weeks
Item No. 5 .... weeks
Item No. 6 .... weeks
Item No. 7 .... weeks
Item No. 8 .... weeks
Item No. 10 .... weeks

The closing date for receipt of quotations will be on .... 19....

Date .... 19 ...

Signature and stamp of the Workshop ....

Enclosures : - Standard Drawings
- "Terms of Steelwork"
- Quotation forms (2 x)
- Cable list
- Reinforcement steel list

His Majesty's Government
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ROADS DEPARTMENT

Suspension Bridge Division

1 INTRODUCTION

The here given points etcetera must be taken into consideration by offering and manufacturing of steel construction. In addition the Indian Standards dealing with the steel construction etcetera must also be kept in mind. These "terms of steelwork" of the Suspension bridge Division is an integral part of all orders concerning the construction of any kind of bridges and spare parts etc. These "terms of steelwork" have the first priority, e.g. come before the IS.

2 SAFETY REQUIREMENTS AND HEALTH PROVISIONS

For purpose of safety requirements and health provisions, reference may be made to IS : 818-1968.

3 STRAIGHTENING

All material shall be straight and, if necessary, before being worked shall be straightened and/or flattened by pressure, unless required to be of curvilinear form and shall be free from twists.

4 CLEARANCES

The erection clearance for cleated ends of members connecting steel to steel should preferably be not bigger than 1,0 mm at each end. The erection clearance at ends of beams without web cleats should be not more than 2 mm at each end, but where, for practical reasons, bigger clearance is necessary, suitably designed seatings should be provided. For members under compression load, like column shafts, the connecting steel to steel is usually designed as direct (contact) joints. Refer to 'machining of butts, caps and bases' (Article 10). Where black bolts are used, the holes may be made not more than 2,0 mm bigger than the diameter of the bolts, unless otherwise specified by the engineer. rsp. Standard Drawings of HMG.

5 CUTTING

Cutting may be effected by shearing, cropping or sawing. Gas cutting by mechanically controlled torch may be permitted for mild steel only. Gas cutting of high tensile steel may also be permitted provided special care is taken to leave sufficient metal to be removed by machining so that all metal that has been hardened by flame is removed. Hand flame cutting may be permitted subject to the approval of the Inspector of the Suspension Bridge Division.
Except where the material is subsequently joined by welding, no loads shall be transmitted into metal through a gas cut surfa
Shearing, cropping and gas cutting, shall be clean, reasonably square and free from any distortion and should the Inspector find it necessary, the edges shall be ground afterwards.

6 HOLING

Holes through more than one thickness of material for members shall be drilled, where possible, after the members are assembled and tightly clamped or bolted together in the workshop. Punching may be permitted before test assembly, provided the holes are punched 3 mm less in diametre than the required size and reamed after shop assembly to the full diametre. The thickness of material punched shall not be bigger than 14 mm.
When holes are drilled in one operation through two or more separable parts, these parts, when so specified by the engineer, shall be separated after drilling and the burrs removed.
Holes in connecting angles and plates, other than splices, also in roof members and light framing, may be punched full size through material not over 10 mm thick, except where required for close tolerance or barrel bolts.
Matching holes for rivets and black bolts shall register with each other so that a gauge of 1,5 mm or 2,0 mm (as the case may be, depending on whether the diameter of bolts is less than or more than 25mm) less in diameter than the diameter of the hole will pass freely through the assembled members in the direction at right angle to such members. Finished holes shall be not more than 1.5 mm or 2.0 mm (as the case may be) in diameter larger than the diameter of the black bolt passing through them, unless otherwise specified by the engineer of HMG' Roads' Department.
Holes for turned and fitted bolts shall be drilled to a diameter equal to the nominal diameter of the shank or barrel subject to H8 tolerance specified in IS:919, last edition, "Recommendations for Limits and Fits for Engineering". Preferably, parts t be connected with close tolerance or barrel bolts shall be firmly held together by tacking bolts or clamps and the holes drilled through all the thicknesses in one operation and subsequently reamed to size. All holes not drilled through all thicknesses at one operation shall be drilled to a smaller size and reamed out after assembly. Where this is not practicable, the parts shall be drilled and reamed separately through hard bushed steel jigs.
Holes for rivets or bolts shall not be formed by a gas cutting process.

7 ASSEMBLY

The component parts shall be assembled in such a manner that they are neither twisted nor otherwise damaged and shall be so prepared that the specified cambers, if any, are provided. Refer also to point 15: Shop erection (Test assembly).

8 BOLTING

Where necessary washers shall be tapered or otherwise suitably shaped to give the heads and nuts of bolts a satisfactory bearing.
The threaded portion of each bolt shall project through the nut at least one thread.
In all cases where the full bearing area of the bolt is to be developed, the bolt shall be provided with a washer of sufficier thickness under the nut to avoid any threaded portion of the bolt being within the thickness of the parts bolted together.

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9 WELDING

The welders shall be trained in accordance with IS : 817-1966*. They shall also be subjected to appropriate qualifying specified in IS : 1181-1967.
Welding shall be in accordance with any of the following standards as approbriate:

- IS : 816-1969 Code of practice for use of metal arc welding for general construction in mild steel
- IS : 819-1957 Code of practice for resistance spot welding for light assemblies in mild steel
- IS : 820- Code of practice for use of welding in tubular construction
- IS : 821- Code of practice for use of welding in pipelines
- IS : 822- Code of practice for inspection of welds
- IS : 823-1964 Code of procedure for manual metal arc welding of mild steel
- IS :1024-1968 Code of practice for use of welding in bridges and structures subject to dynamic loading
- IS :1261-1959 Code of practice for seam welding in mild steel
- IS :1323-1959 Code of practice for oxy-acetylene welding for structural work in mild steel

For welding of any particular type of joint, welders shall give evidence acceptable to the purchaser of having satisfactorily completed appropriate tests as described in any of the following standards as relevant:

- †IS : 817-1957 Code of practice for training and testing of metal arc welders
- †IS :1181-1957 Qualifying tests for metal arc welders (engaged in welding structures other than pipes)
- IS :1393-1961 Code of practice for training and testing of oxy-acetylene welders

If there are any new editions of Indian Standard those should be used as references.

10 MACHINING OF BUTTS, CAPS AND BASES

Column splices and butt joints of struts and compression members depending on contact for stress transmission shall be accurately machined and close-butted over the whole section with a clearance not exceeding 0.1 mm locally at any place.
In column caps and bases, the ends of shafts together with the attached gussets, angels, channels, etc. after riveting together, should be accurately machined so that the parts connected butt over the entire surfaces of contact. Care should be taken that those connecting angles or channels are fixed with such accuracy that they are not reduced in thickness by machining by more than 1.0 mm.
Ends of all bearing stiffeners shall be machined or ground to fit tightly at both top and bottom.

11 SLAB BASES AND CAPS

Slab bases and slab caps, except when cut from material with true surfaces, shall be accurately machined over the bearing surfaces and shall be in effective contact with the end of the stanchion. A bearing face which is to be grouted direct to a foundation need not be machined if such face is true and parallel to the upper face.
To facilitate grouting, holes shall be provided where necessary in stanchion bases for the encape of air.

12 SOLID ROUND STEEL COLUMNS

Solid round steel columns with shouldered ends shall be provided with slab caps and bases machined to fit the shoulders, and shall be tightly shrunk on or welded in position.
The tolerance between the reduced end of the shaft and the hole, in the case of slabs welded in position, shall not exceed 0.25 mm.
Where slabs are welded in position, the reduced end of the shaft shall be kept just sufficiently short to accomodate a fillet-weld around the hole without weld-metal being proud of the slab.
All bearing surfaces of slabs intended for metal-to-metal contact shall be machined perpendicular to the shaft.

13 PAINTING

All surfaces which are to be painted, oiled or otherwise treated shall be dry and thoroughly cleaned to remove all loose scale and loose rust.
Surfaces not in contact, but inaccessible after shop assembly, shall receive the full specified protective treatment before assembly. This does not apply to the interior of sealed hollow sections.
In the case of surfaces to be welded, the steel shall not be painted or metal coated within a suitable distance of any edges to be welded if the paint specified or the metal coating would be harmful to welders or impair the quality of the welds.
Welds and adjacent parent metal shall not be painted prior to deslagging, inspection and approval.
Parts to be encased in concrete shall not be painted or oiled. Refer to standard drawings and steelpart lists.

Before painting of steel is commenced, all surfaces to be painted shall be dry and thoroughly cleaned from all loose scale and rust. The specified protective treatment shall be completed after erection. All bolt heads and the welds after deslagging shall be cleaned.
The base coat (primer) and second coat (finish coat) shall be done by the workshop. Where the steel has received a metal coating in the shop, this coating shall be completed in the workshop after the test assembly.

COST ESTIMATE TERMS OF STEELWORK for Suspension and Suspended Bridges (2nd continuation)	No. : 7.503 Date : 1st March 77 Sig : [signature]

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ROADS DEPARTMENT

Suspension Bridge Division

14 MARKING

Each piece of steelwork shall be distinctly marked before delivery, in accordance with a marking diagram, and shall bear such other marks as will facilitate erection. The marking used by the standard drawings must be taken.

15 SHOP ERECTION (TEST ASSEMBLY)

The steelwork shall be temporarily shop erected complete or as arranged with the inspector so that accuracy of fit may be checked before despatch. The parts shall be shop assembled with a sufficient number of parallel drifts to bring and keep the parts in place.
In the case of parts drilled or punched, through steel jigs with bushes resulting in all similar parts being interchangeable, the steelwork may be shop erected in such position as arranged with the inspector.
The workshop is responsible for seeing that all thimbles etc. can be fitted on the provided pins, steelparts, bolts etc.
If there are any differences the engineers of HMG' Roads' Department must be contacted. The test assembly should be shown to the Suspension Bridge Division.

16 PACKING

All projecting plates or bars and all ends of members at joints shall be stiffened, all straight bars and plates shall be bundled, all screwed ends and machined surfaces shall be suitably packed and all rivets, bolts, nuts, washers and small loose parts shall be packed separately in cases so as to prevent damage or distortion during transit. All threads shall be protected with grease and jute.
The transport units (including wire mesh netting) shall not exceed 45 kg in weight.
Take reference to the Standard Drawings.
The packing work shall be done in such a way, that after a rough transportation by truck, aeroplane, helicopter, rope way, boats, beasts of burden as well as porters, the packing will be still in good order. The costs of packing shall be included in the rates. Cable ends are to handle with care and their end must be protected correctly against any accident.

17 INSPECTION AND TESTING

Access to Contractor's Works - The contractor should offer facilities for the inspection of the work at all stages.
Inspection of Fabrication - Unless otherwise agreed this inspection should be carried out at the place of fabrication. The contractor should be responsible for the accuracy of the work and for any error which may be subsequently discovered.
Inspection on Site - To facilitate inspection the contractor should, during all working hours, have a foreman or properly accredited charge hand available on the workshop together with a complete set of contract drawings and any further drawings and instructions which may have been issued from time to time.
The inspector shall have free access at all reasonable times to those parts of the manufacturer's works which are concerned with the fabrication of the steelwork and shall be afforded all reasonable facilities for satisfying himself that the fabrication is being undertaken in accordance with the provisions of the standard drawings and the "terms of steelwork".
Unless specified otherwise inspection shall be made at the place of manufacture prior to despatch and shall be conducted so as not to interfere unnecessarily with the operation of the work.
The manufacturer shall guarantee compliance with the provisions of this standard, if required to do so by the purchaser.
Should any structure or part of a structure be found not to comply with any of the provisions of this standard, it shall be liable to rejection.
No structure or part of the structure, once rejected shall be resubmitted for test, except in cases where the purchaser or his authorized representative considers the defect as rectifiable.
Defects which may appear during fabrication shall be made good with the consent of and according to the procedure laid down by the inspector.
All gauges and templates necessary to satisfy the inspector shall be supplied by the manufacturer. The inspector may at his discretion check the test results obtained at the manufacturer's works by independent tests at the Government Test House or elsewhere, and should the material so tested be found to be unsatisfactory, the costs of such tests shall be borne by the manufacturer, and if satisfactory, the costs shall be borne by the purchaser.

18 STORING AND HANDLING

All structural steel should be so stored and handled to the Suspension Bridge Division that the members are not subject to excessive stresses and damage.

19 FIELD WELDING

All field assembly and welding shall be executed in accordance with the requirements for shop fabrication, excepting such as manifestly apply to shop conditions only. Where the steel has been delivered painted, the paint shall be removed before field welding, for a distance of at least 50 mm on either side of the joints.
This point shall be very unused at suspension and suspended bridges of HMG' Roads' Department and might only be necessary for maintenance and repairing work at existing bridge sites.

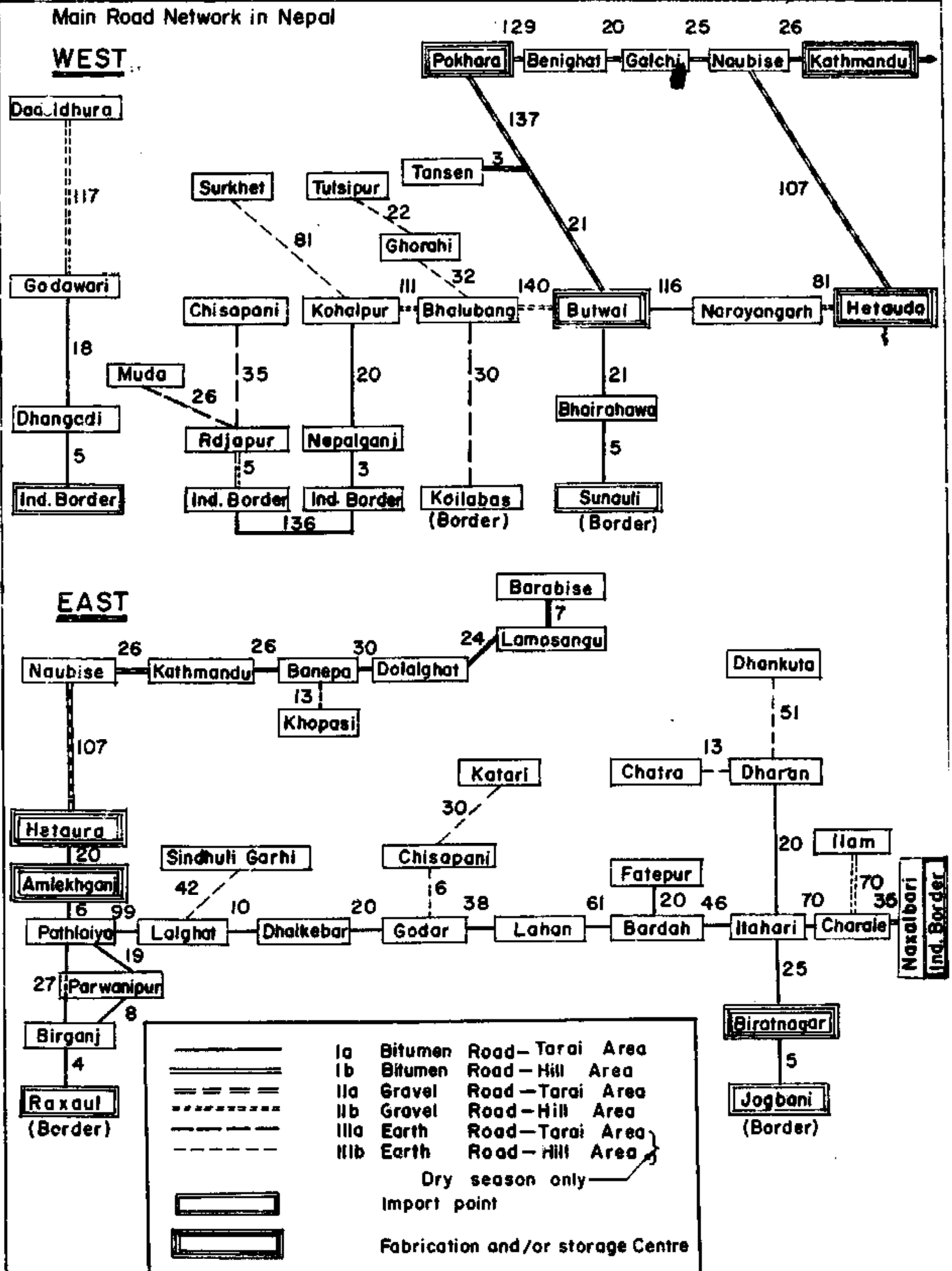
COST ESTIMATE

Network of roads in Nepal, Distances

No :7.601

Date :23rd Febr. 77

Sig :



HMG Nepal Roads Department Suspension Bridge Division

SATA, Swiss Association for Technical Assistance

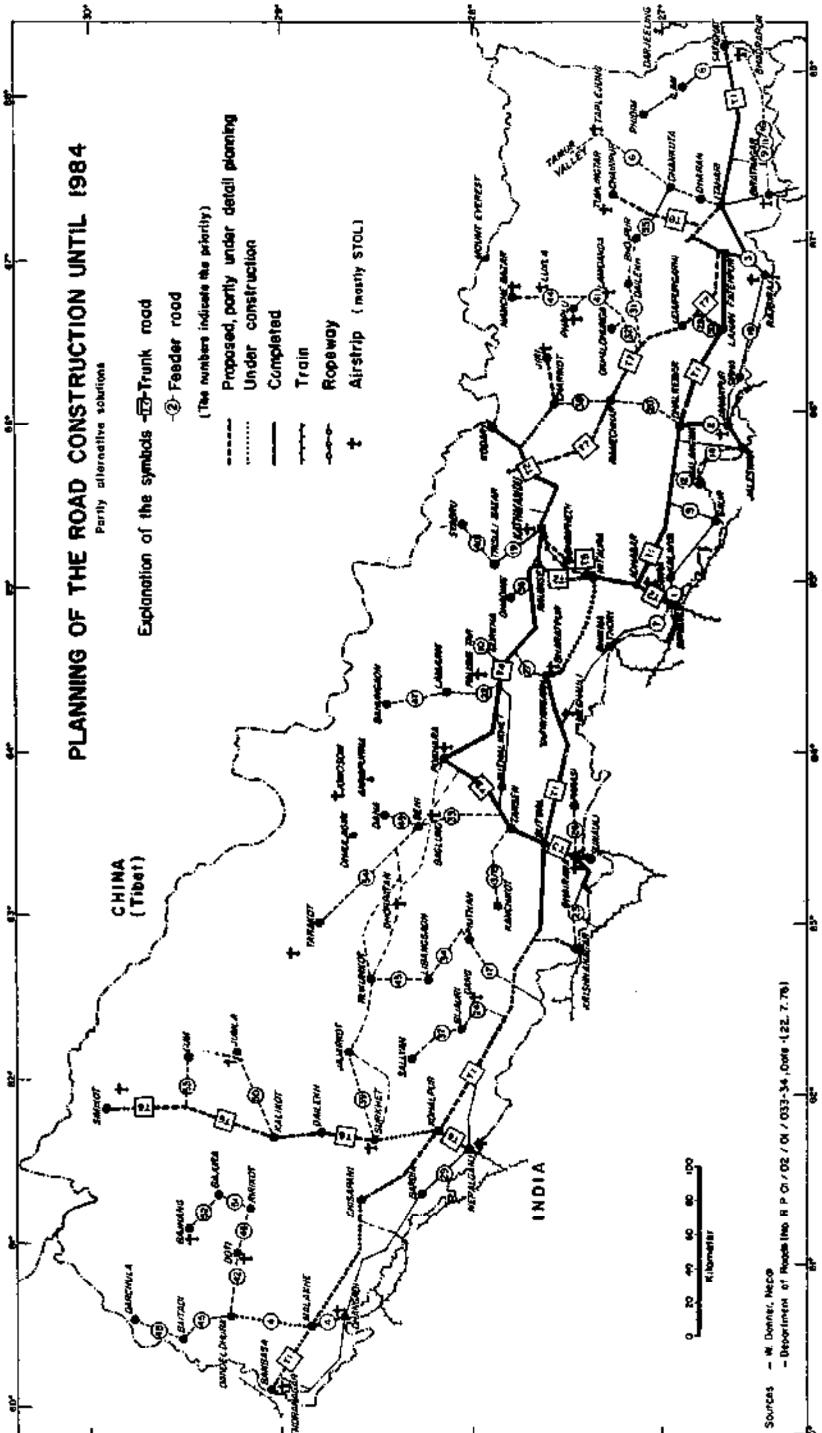
COST ESTIMATE

Planning of the Road Construction until 1984

No. : 7.602

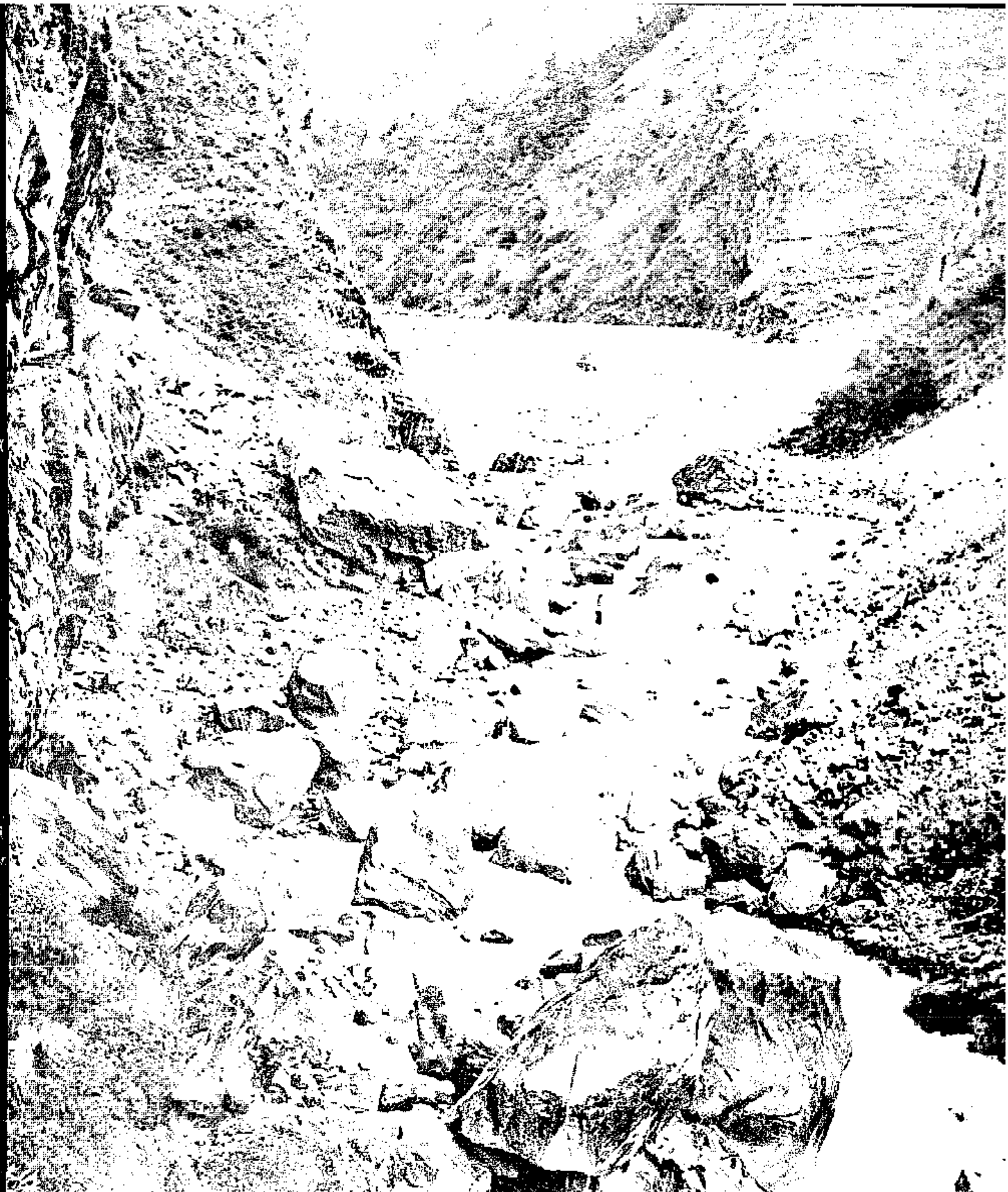
Date : 23rd Febr. 77

Sig : [signature]



SATA, Swiss Association for Technical Assistance

HMG Nepal Roads Department Suspension Bridge Division



8. LAY OUT

LAY OUT OF A SUSPENSION BRIDGE Fixing of the Bridge Position	No. : 8.101 Date : 28.12.76 Sig : Candrian

8.1 General

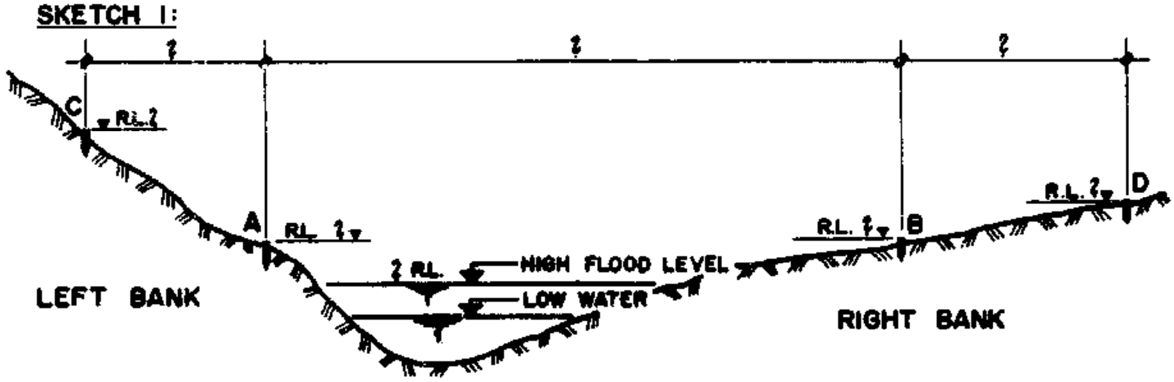
Before starting the lay-out try to find the pegs from the survey done. It may happen that the pegs from the first survey have disappeared. If that happened put new pegs and measure a profile along the new axis. How to do that see chapter 'Site Survey'.

8.2 Fixing of the Bridge Position

All required measurements are given in the general arrangement. The bridge position should be fixed very carefully in order to avoid difficulties in later construction stages. The procedure can be described as follows:

1. Find the existing pegs and bench-marks.
2. Measure the distance between these pegs and check if they are according to the measurements given in the general arrangement.

SKETCH I:



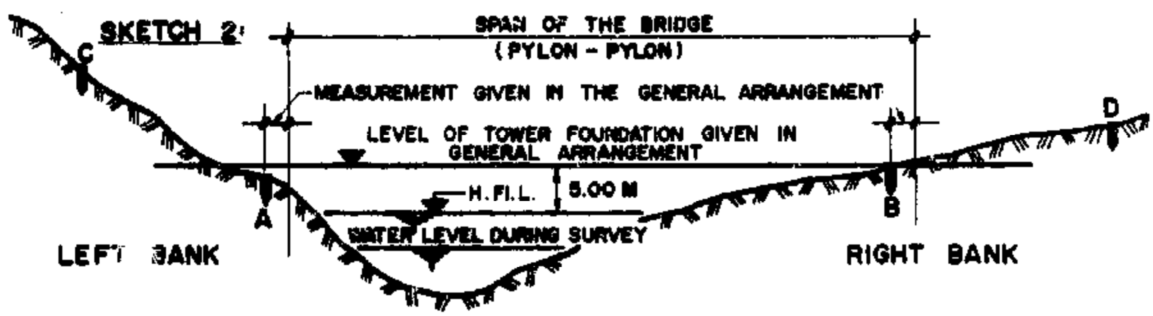
3. Now fix the tower axis on one river bank. From this point measure the span and fix the tower axis on the other bank. (Methods how to do that see chapter 'Site Survey'). Then check the elevation of these pegs and look if they are according to the elevation given in the general arrangement.

LAY OUT OF A SUSPENSION BRIDGE

Fixing of the Bridge Position

No	: 8.102
Date	: 28.12.76
Sig	: Candian

4. If all measurements are correct according to the general arrangement fix the positions of all blocks in the way as shown in the following pages.

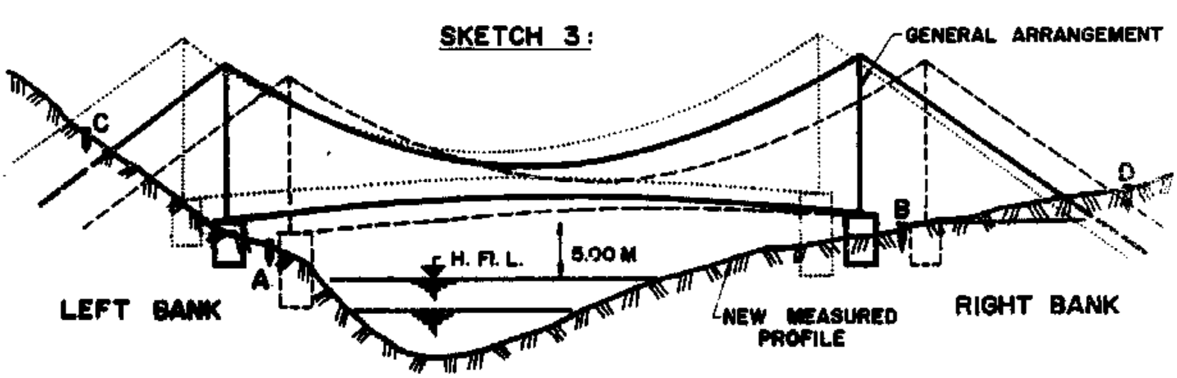


Sometimes it happens that you can't find the old pegs or that the first survey has not been done very exactly or that land slides have occured at the proposed site. In that case you have to measure a new profile. Draw the again measured profile on tracing paper in the same scale as the general arrangement.

Now you can put the general arrangement under this profile and find out the best position of the bridge. It must be kept in mind that the tower-foundations should be placed:

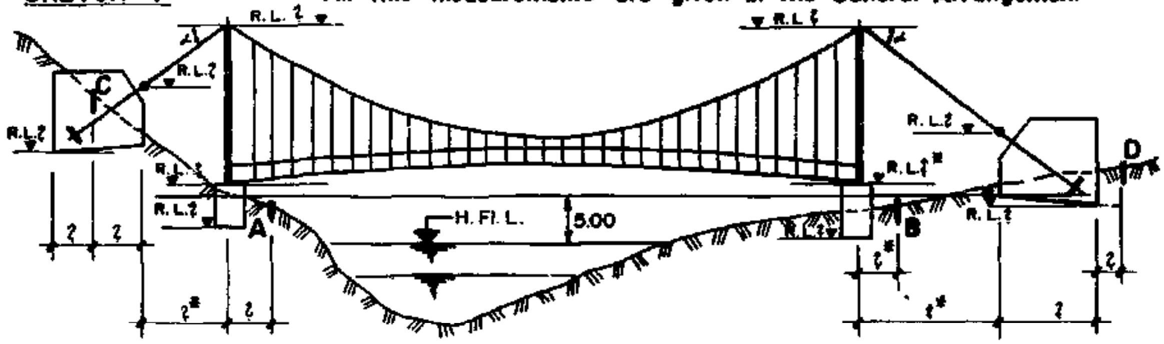
- safe from river-scouring
- in a position that rock-excavations are minimal
- in a position that the volume of excavation and concrete-work remain small.

After finding the best position of the bridge in the drawing you can fix the bridge position at site, too.



LAY OUT OF A SUSPENSION BRIDGE Fixing of the Bridge Position	No. : 8.103 Date : 28.12.76 Sig : Andrau

SKETCH 4: All this measurements are given in the General Arrangement

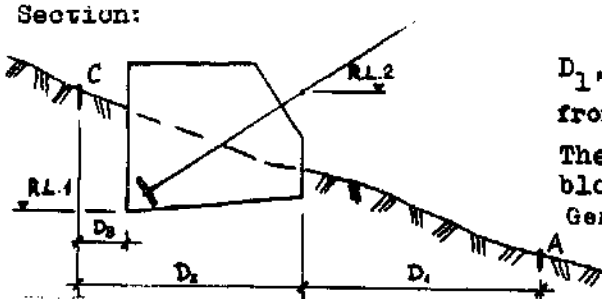


8.3. Lay-out of the blocks

Already at the beginning of the bridge-construction this work should be done carefully and in a detailed way, in order to save time and to facilitate the control of the work for the whole construction-period.

Example for the lay-out of a main-anchorage

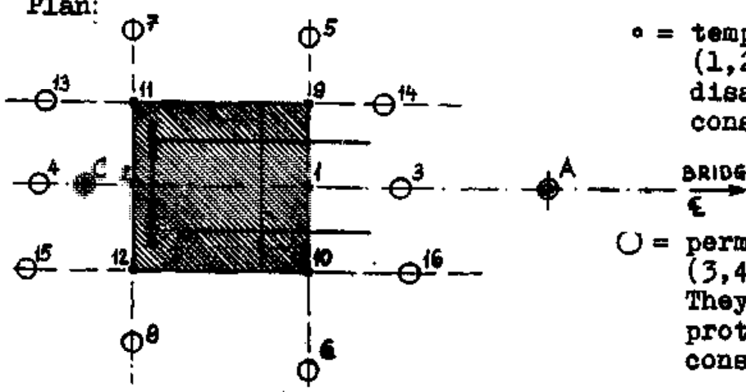
Section:



D_1, D_2, D_3, RL 1 , RL 2 are known from General Arrangement

The dimensions of the anchorage-block are known from the General Arrangement and the Detail Drawings

Plan:



• = temporary pegs. (1,2,9,1o,11,12) They will disappear during the construction-work.

○ = permanent pegs. (3,4,5,6,7,8,13,14,15,16) They should be safe or protected from any construction-obstructions.

- Measure along the bridge center-line the distance from peg "A" to the front edge of the anchorage-block and fix peg "1".
- Measure from peg "1" the length of the anchor-block and put peg "2".
- Check the distance from peg "2" to peg "C".
- Set up two additional pegs of the center-line at places safe from excavation-work (pegs "3" and "4").
- Starting from peg "1" put the pegs 5,9,6 and 1o for the help-line of the front edge. Do the same for the help-line of the back edge; from peg "2" the pegs 7,11,8 and 12 are fixed.
- With the help of the pegs "9" and "11" the help-line of the down-stream edge is determined (pegs 13,14) and with the pegs "1o" and "12" that for the upstream edge (pegs 15,16).

In this way the edges or the center-line can be checked at any time with the aid of a thread or a rope tied to corresponding points.

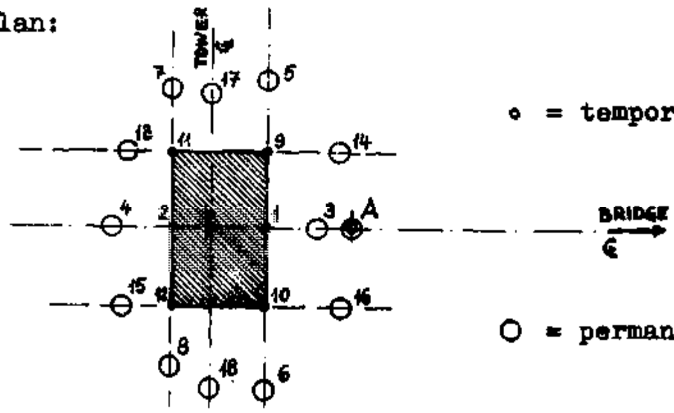
LAY OUT OF A SUSPENSION BRIDGE	No.: 8.105
Tower Foundation, Lay-out along a parallel to the bridge center-line	Date: 8. 9.1975
	Sig.: D. E[illegible]

<u>Example</u> for the lay-out of a tower-foundation

This lay-out is done in a similar way as that for a main-anchorage.

In addition, reference-pegs for the tower center-line should be set up (pegs 17 and 18 in the sketch).

Plan:



∘ = temporary pegs

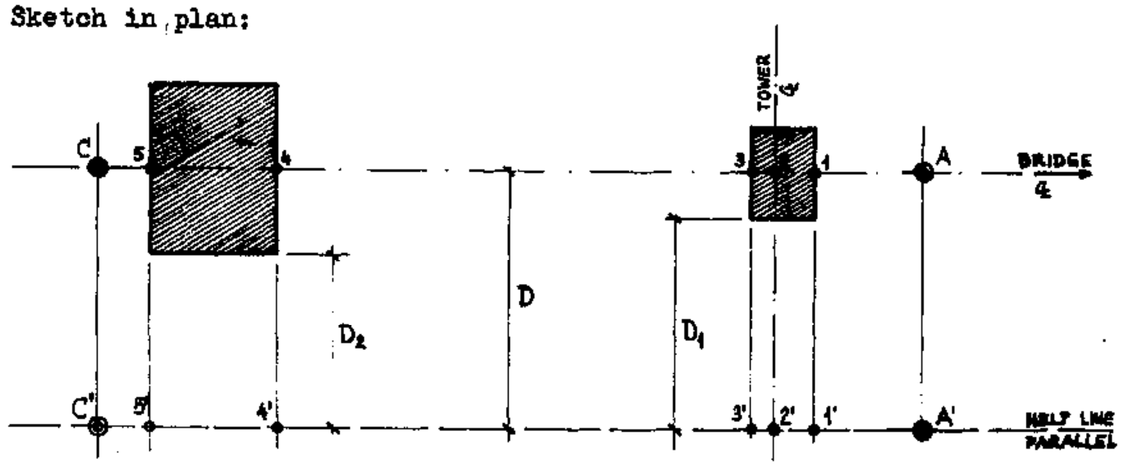
O = permanent pegs

<u>Lay-out with a parallel to the bridge center-line</u>

A <u>parallel-line</u> to the bridge center-line is chosen, safe from all construction-works.
Measure equal distances, perpendicular to the bridge center-line, from peg "A" and peg "B" and fix the pegs "A'" and "B'".

On this help-line all the corresponding points for the positions of main-anchorage and tower-foundation can be placed (1',2',3',...).

Sketch in plan:

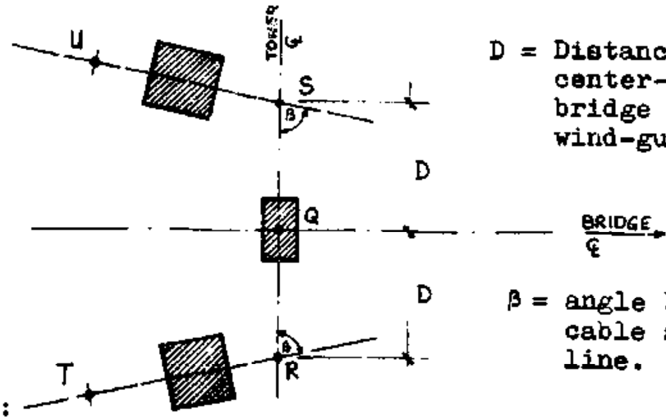


Thus the reference-lines for the front- and back-edges can always be fixed and checked easily with a theodolite.
The reference-lines for the upstream- and downstream-edges may be fixed as proposed under 8.103 or with a theodolite and a measuring-tape (for the distances D_1, D_2).

LAY OUT OF A SUSPENSION BRIDGE	No.: 8.106
Wind - Guy - Anchorage (I)	Date: 13. 9.1975
	Sig.: [signature]

In the bridge-drawings the location of the wind-guy-anchorages is usually given in reference to the tower- and bridge center-line.

Sketch:



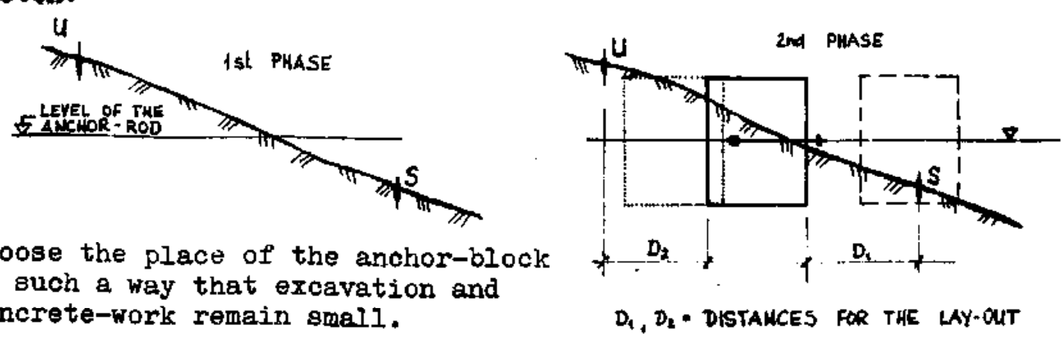
D = Distance along the tower center-line, from the bridge center-line to the wind-guy-cable.

β = angle between wind-guy-cable and tower center-line.

Proceeding:

- Measure from point "Q" along the tower center-line the distance "D" and set up the pegs "R" and "S".
- Measure the angle "β" in "R" (take as reference if possible the peg "R+" on the other bank) and fix point "T". Do the same from peg "S" and fix point "U". The lines "SU" and "RT" are the center-line of the wind-guy-anchorage.
- Fix the position of the anchor-block. Use a profile-drawing. The elevation of the anchor-rod is usually the same as the top of the tower-foundation. (see next sketch).

Sketch:



Choose the place of the anchor-block in such a way that excavation and concrete-work remain small.

Note: For the lay-out of a new line, in any angle to an already given line, the reference-point on this given line should be chosen as far away as possible, for example on the other river bank.

Near every foundation and anchorage, bench marks should be levelled as reference for the elevations.
For this and for the measurement of horizontal distances on slopes please refer to the chapter "Survey Methods"

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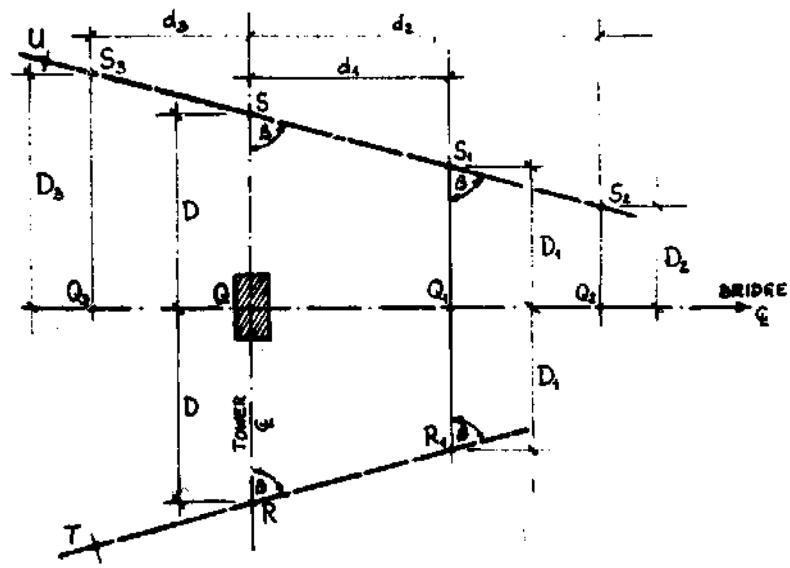
LAY OUT OF A SUSPENSION BRIDGE	No.: 8.107
Wind - Guy - Anchorage (II)	Date: 14. 9.1975
	Sig.: D.S.

If it is not possible to measure along the tower center-line due to obstacles (rock, trees..), the lay-out can also start from any other point of the bridge center-line (from Q_1, Q_2, Q_3....).

Sketch in plan:



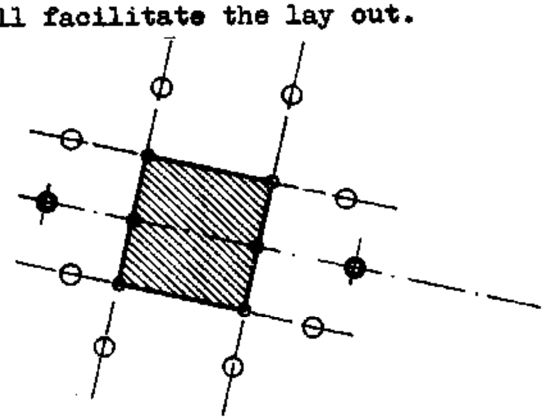
Example: For "Q_1"

- Calculate the distance "D_1" from "Q_1" to "R_1" and "S_1".
  $D_1 = D - d_1 \times \cot\beta$ (D_3 would be : $D + d_3 \times \cot\beta$) .
- Fix the pegs "R_1" and "S_1".
- Measure on these points the angle β and set up the pegs "R","S", "T" and "U". (Distance "R_1R" $= \frac{d_1}{\sin\beta}$)
- Fix the location of the anchorage-block (see 8.105).

Remark:
The point "Q_1" can also be in the river-bed if for one reason or the other it will facilitate the lay out.

For the wind-guy-anchorage, help-lines and reference-points are fixed similarly to the main-anchorage. (see 8.103).

A bench mark should be set up for the check of the elevation.

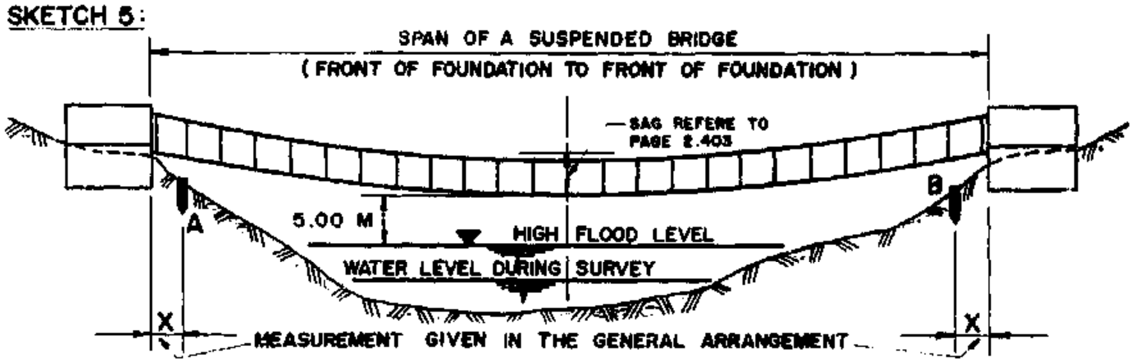


See also chapter "Survey Methods",

LAY OUT OF A SUSPENDED BRIDGE	No : 8.201
	Date : [illegible].12.[illegible]
	Sig : [signature]

The lay out of a suspended bridge can be made in a similar way as the lay out of a suspension bridge. There are only some differences in the given measurements. So the given span is not measured from tower to tower (there are no towers) or from drum to drum. The span is measured from the front of the foundation on the left bank to the front of the foundation on the right bank.

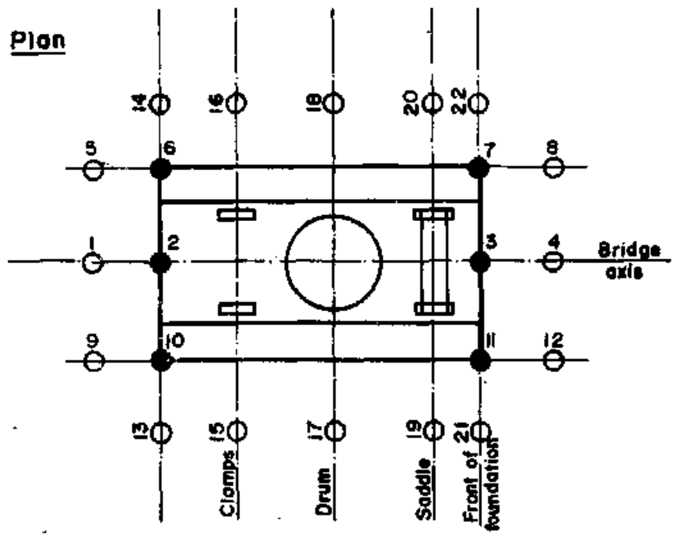
SKETCH 5:



The fitting of the position of the windguy-anchorage can be done in the same way as shown under Suspension bridge.

Example for the lay out of the main anchor block

Example for the lay — out of a main anchor block



○ **Permanent pegs**
They should be safe or protected from any construction — obstruction

● **Temporary pegs**
They will disappear during the construction work

— The dimensions of the anchor block are known from the detail drawings

— The positions of the steelparts are known from the LAY-OUT drawings

- Fix on the center-line the front of the foundation (peg 3).
- Measure from peg 3 the length of the foundation and put peg 2.
- set up two additional pegs of the center-line at places safe from excavation work (pegs 1 and 4).
- starting from peg 3 put the pegs 21, 7, 11, 20 for the help-line of the front edge. Do some for the help-line of the back edge; from peg 2 the pegs 14, 6, 10 and 13 are fixed.
- with the help of the pegs 6 and 7 the help-line at the down stream edge is determinated (pegs 5 and 8) and with the pegs 10 and 11 that for the upstream edge (pegs 9 and 12).
- fix the axis lines of the clamps, the drum and the saddle (pegs 15, 16 and 17,18 and 19, 20).

In this way the edges or the center-line can be checked at any time with the aid of a thread or a rope tied to corresponding paints.

9. CONSTRUCTION WORK

General

Included in this chapter will be all works required at site after finishing the lay-out up to the erection of the bridge. One of the most important points which must be remarked, is the erosion. We should try to prevent erosion during construction work and also afterwards. The best way to prevent erosion is to open the excavation only for a short time. So excavation, concreting and refilling is one working process. The refilling is one of the most important works. Some methods, how to do it, are shown in this chapter.

9.1. Collection of Materials

The quantities of all materials are given in the Cost Estimate or can be calculated out of the quantities given in the detail drawings. Store the collected materials near the places where they will be used afterwards. So you do not have to carry them too far during the construction period. Also do not collect too high quantities of each item.

Required Materials

Rubbles: Rubbles are bits of broken stones, rock or brickwork. Stones from a riverbed, coarse gravel (30 - 55 mm) e. g. You can also get them out of rock excavation materials.

Stones: The size of the stones should be from 40 to 100 mm. If you have rock excavation, you can often use broken stones out of this excavation. Stones shall be hard, sound, durable and clean. All stones should be free of sand, dust, salt, lime, clay or other deleterious matter.

Gravel: The gravel can be found in the riverbeds or can be made by breaking stones. Also they should be clean and free of earth. The required size can be obtained by sieving. The smallest size of gravel is about 5 mm.

Sand: The sand can usually be found in the riverbeds. To get the right size and to clean it we have to sieve it.
If the sand location is quite far away from the site, the crushing of stones to get sand might be the cheaper way. A careful comparison should be made.

Sand shall be evenly graded from fine to coarse particles to maximum 3/16" (5 mm) of which

10 - 30 % should pass through a sive of 52 meshes per sq.inch.

and not more than
10% should pass through a sive of 100 meshes per sq.inch.

Sand should be gritty, hard particles, free from dust, clay, animal, vegetable or other organic matter.

A list about which kinds of materials are useful for construction work is given in the chapter "Soil investigation" on page 4.307

Excavation, normal Excavation and Trench Excavation

There are different types of Excavation required for the work on Suspension and Suspended Bridges, as the normal excavation, the trench excavation and the rock excavation. On the General Arrangement and on the detail drawing there is remarked what kind of excavation you need. The instructions given on these drawings must be followed very strictly, because in the calculation of the blocks these points are included. So if you do not make the excavation according to the drawings, the designed blocks might be too small (due to lack of earth resistance) and the safety factor too little.

The main thing you have to make sure is that you do not make too big excavations in order to save work and not to disturb too much the soil in place and to prevent erosion.

Normal Excavation

If there is no special mention in the General Arrangement as well as in detail drawings, we have a normal excavation according to the block and the conditions at site. The most important point to remark is that sometimes we have blocks with a bottom which is not horizontal but in shape. We call this type "inclined bottom". So also the foundation has to be made with an inclined bottom. Do not make a horizontal excavation and refill it afterwards. In this way we do not get the required effect with this shape. With this shape in the excavation we can increase the factor of friction between the block and the earth and so save concrete. (See factor of friction for inclined bottom on page 3.708)

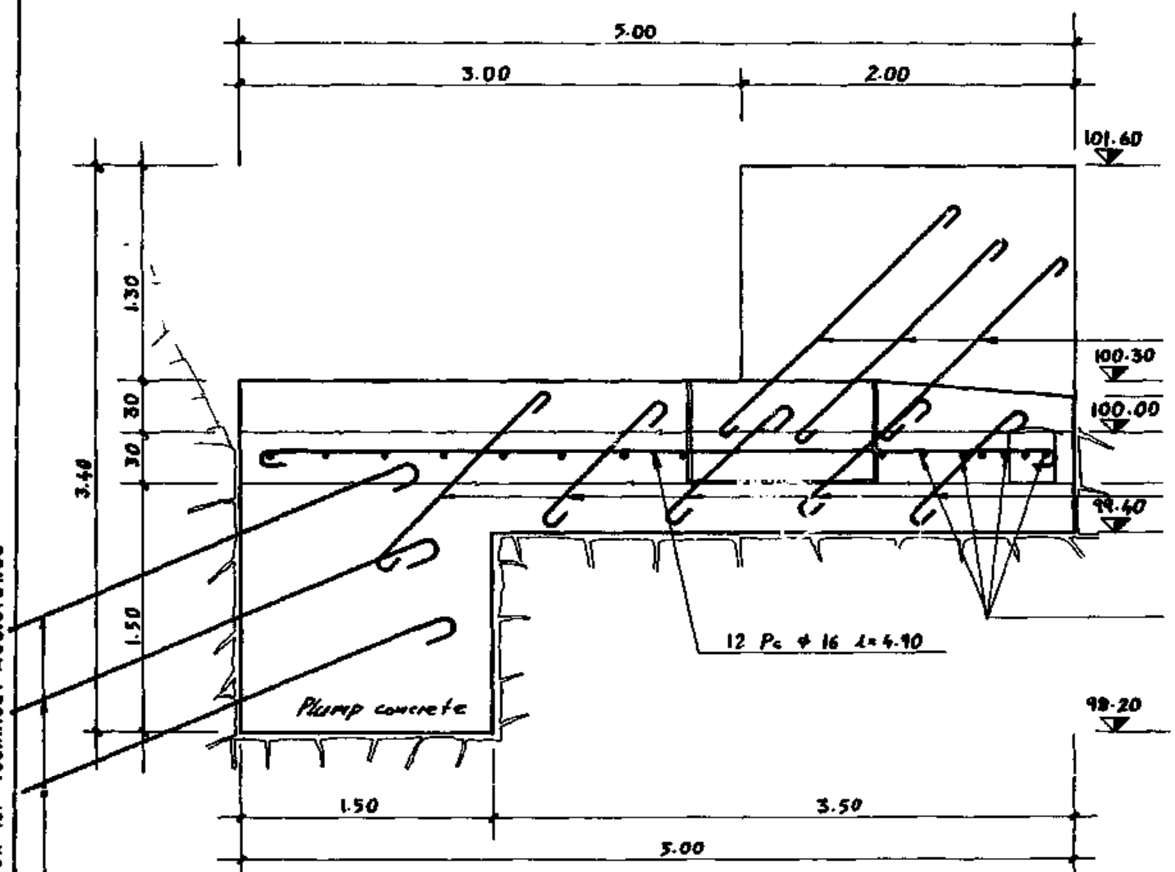
Trench excavation

A trench excavation is an excavation with vertical faces. The foundation must be exactly the siye of the block. If we need this kind of foundation this is mentioned in the General Arrangement or detail drawings. Sometimes this is not possible to make due to the soil conditions. So the refilling has to be made in layers of 20 cm thickness and these layers have to be compacted very well so that the refilling keeps the passive earth pressure(earth resistance) resulting as re-action from the block. These refillings have also to be covered by picking so that erosion should not damage the ground surface.

Very often we have to make rock excavation for our foundations. In soft rock we can go on with the excavation in the same way as in the earth. In hard rock this is not possible. Often excavation by manpower is not possible. So we have to make the excavation by blasting. If the rock is hard we do not have to make much excavation.Then we can connect the concrete block with the rock with some rock anchors. Sometimes also the anchor parts are fixed directly on rock anchors.

Depending on the kind of rock we also design special types of foundations. In this way we can often save a lot of concrete. Some types of rock anchorage utilizing rock resistance in an excavated hole and utilizing drilled rock holes are shown on page 3.605

Please take reference to page 3.201.



CONSTRUCTION WORK

Rock anchor, Purpose, description, material list, fitting and test

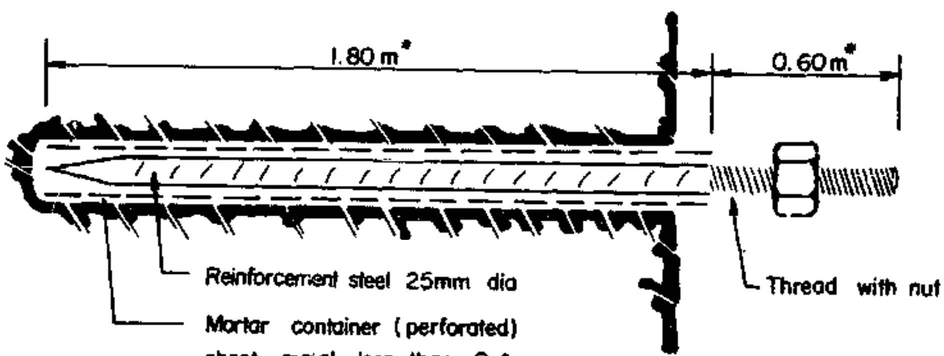
No.: 9.203
Date: 7.11.75
Sig.: [signature]

1. Purpose by using rock anchors

   Instead of anchoring cables on concrete blocks, reliable hard rock found at site can be used as an anchorage medium with the help of rock anchors. This will considerably reduce costs and help to speed up the work.

Rock anchors used for main cable anchorage
Tatopani (Budhi Gandaki), 1974

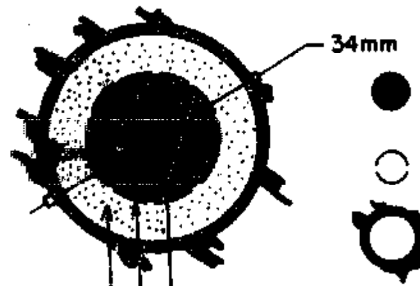
2. Short description of a rock anchor system



* Length as used in ordinary cases

CONSTRUCTION WORK Rock anchor, Purpose,description,material list fitting and test	No : 9.204 Date : 27.2.77 Sig : Caudrau

Section of anchor



Example : Calculation of mortar quantity

item	dia (mm)	area (cm^2)
anchor rod	25	4,9
mortar container (quantity of mortar)	23	4,2
bore hole	34	9,1

The above mentioned rock anchors and mortar containers were already manufactured by various workshops

3. Material list for anchor fitting

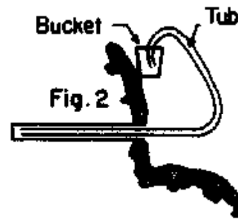
Rock anchors with length according design
Perforated mortar containers,2 half shells per anchor
Drilling machine and accessoirs
Drill rod with bit diameter min.34 mm
Galvanized wire for binding the mortar container
Cement
Steel pan (coray)
Bucket
Plastic tube ½" dia, 5 m long
Towel (mason's mortar shovel)
Hammer 5 kg

4. Fitting the anchor

Fig. 1

Blast the rock surface with small charges in order to check the rock.

Fig. 2



Drill the hole and wash out the debris. Check carefully that the hole is finally empty and clean.

CONSTRUCTION WORK Rock anchor, Purpose, description, material list, fitting and test	No.: 9.2o5 Date: 7.11.75 Sig.: [signature]

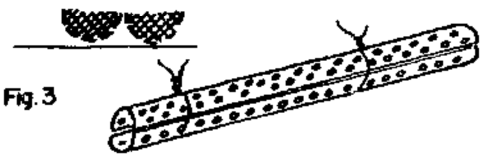


Fig.3

Fill the 2 mortar containers with a mixture of cement and water forming a paste not too liquid and not too thick, Close and bind them with wire.

Fig.4

Insert the mortar container and hammer the anchor rod into it.

Filling mortar containers.

Inserting of mortar container into the bore hole

5. Test of rock anchors

(after 14 days)
A number of tests have been done and an ultimate breaking load of 15-2o tons was found, depending on quality of the steel rod and the root dia of the thread. Bond strength never fails. With a safety factor of 3, the working load is recommended to be 5 tons per anchor.

Left:
Tatopani bridge (Budhi Gandaki) The anchors were tested with a centre hole hydraulic press to lo tons (5o% of ultimate breaking load).

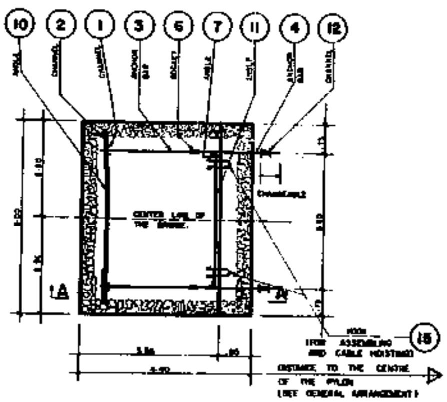
In the concrete, the addition of water is one of the most important points. To get a good concrete we should work with a small quantity of water. But neither too little a quantity because if the mixing is too dry it will be difficult to work with it. To obtain a correct addition of water the engineer or overseer must have a good portion of insistence and a very firm stand in order to overcome the lazyness of the group working with the cement.
The specifications of the concrete and the mixing proportions are given in chapter 5,"Construction Materials". All the quantities given there have to be considered very well because they fix the kind of concrete and the allavailable compressible tensions, bond stresses, sheding which are taken into consideration in the calculations.

Take also big care to the stones and boulders added to the concrete. They should be clean and wet during concreting. If that is not so, we do not have a good connection and so no good concrete. So it might even be possible that the block will not be strong enough to keep the forces resulting from the bridge.

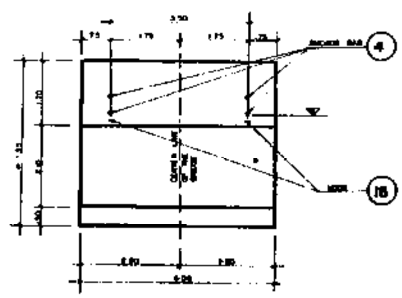
The bedding of the steelparts into the concrete is also very important. All measures required can be taken out of the Lay-out drawing from HMG Standard Designs or out of the Working-Detail-Drawings. This operation shall not be carried out until the steelwork has been finally levelled and plumbed; if necessary support the steelparts with rocks. or bamboo and immediately before granting the space under the steel shall be thoroughly cleaned. Around the steel parts there should be rich concrete in a thickness of at least 10 cm.
On the following pages there are given some examples of anchor blocks. All the things mentioned in the drawings are required and should be considered at site.

CONSTRUCTION WORK	No. : 9.302
Main Anchorage Block of a Suspension Bridge	Date : 27.2.77
	Sig. : [signature]

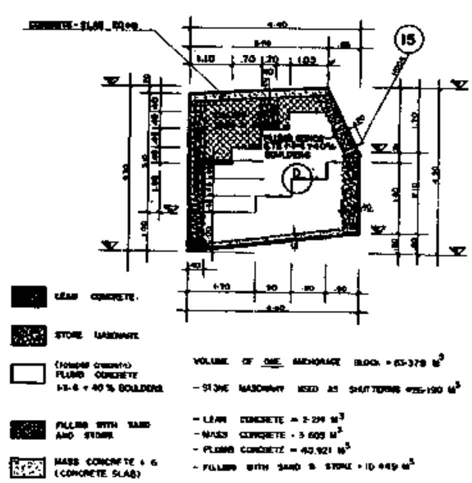
PLAN



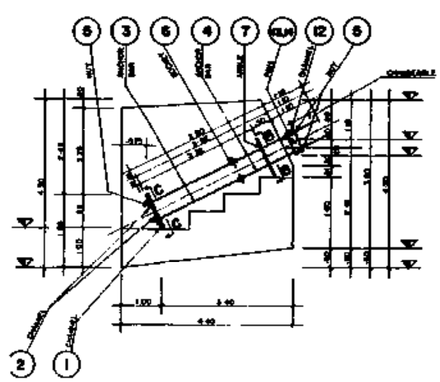
FRONT ELEVATION



SIDE ELEVATION



SECTION A-A



CONSTRUCTION WORK

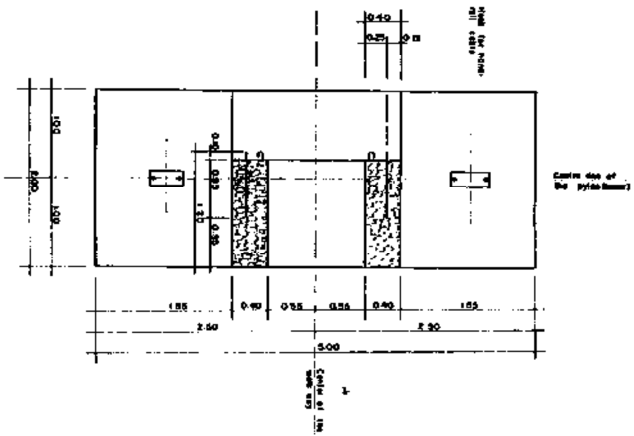
Pylon and Walk Way Anchorage

No. : 9.303

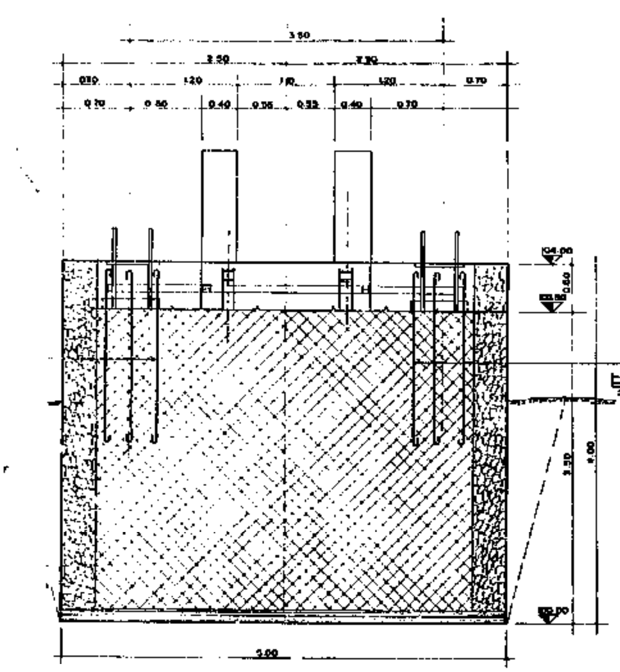
Date : 27.2.77

Sig : Landsau

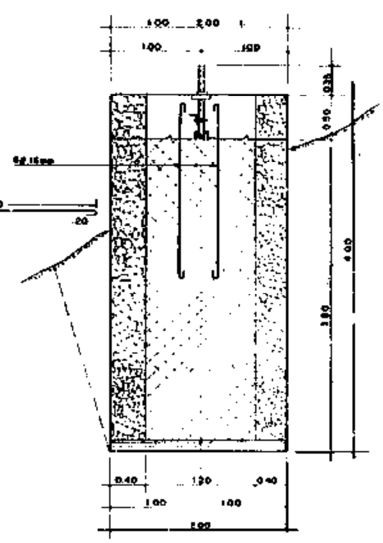
PLAN 2-2



SECTION C-C



SECTION B-B



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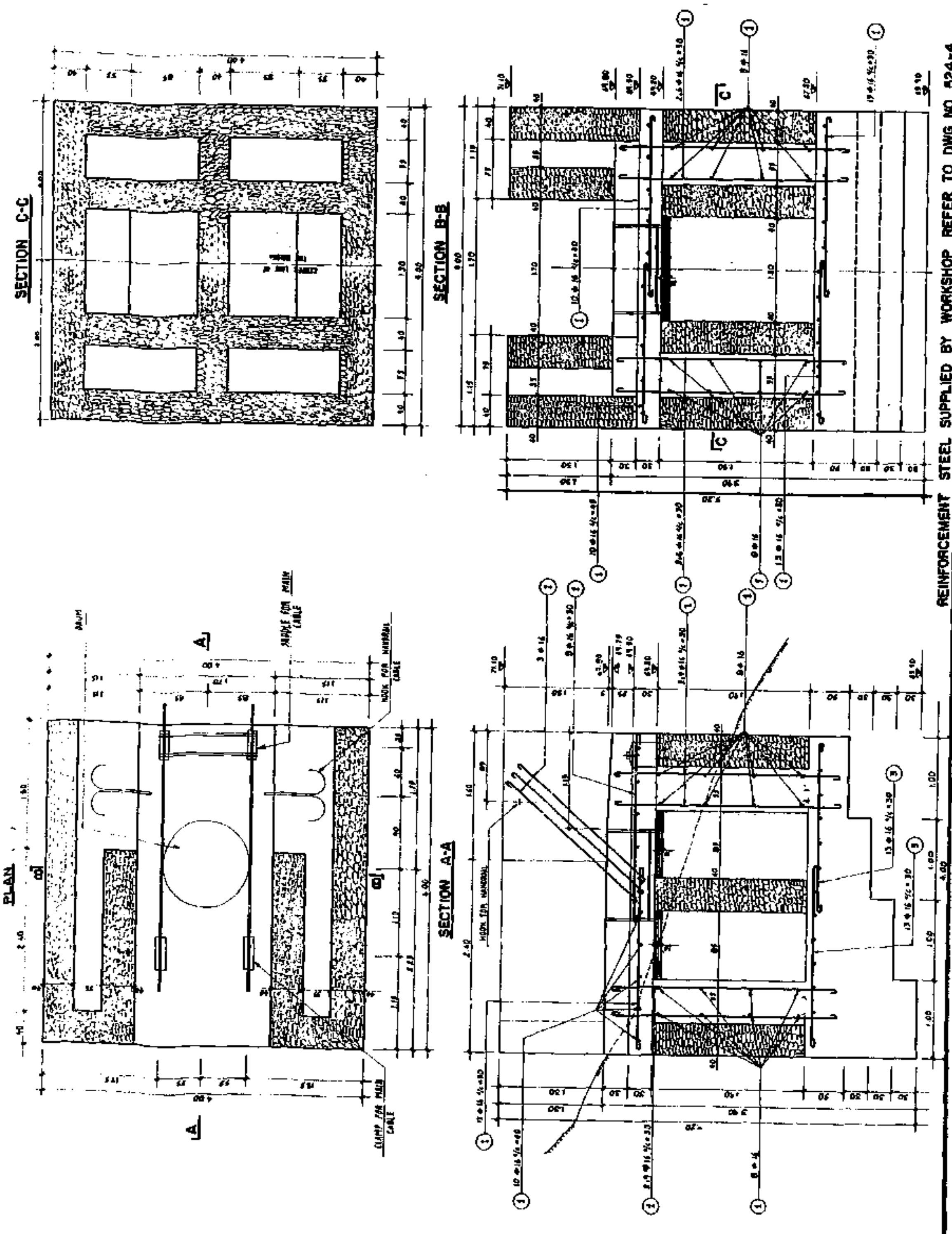
CONSTRUCTION WORK

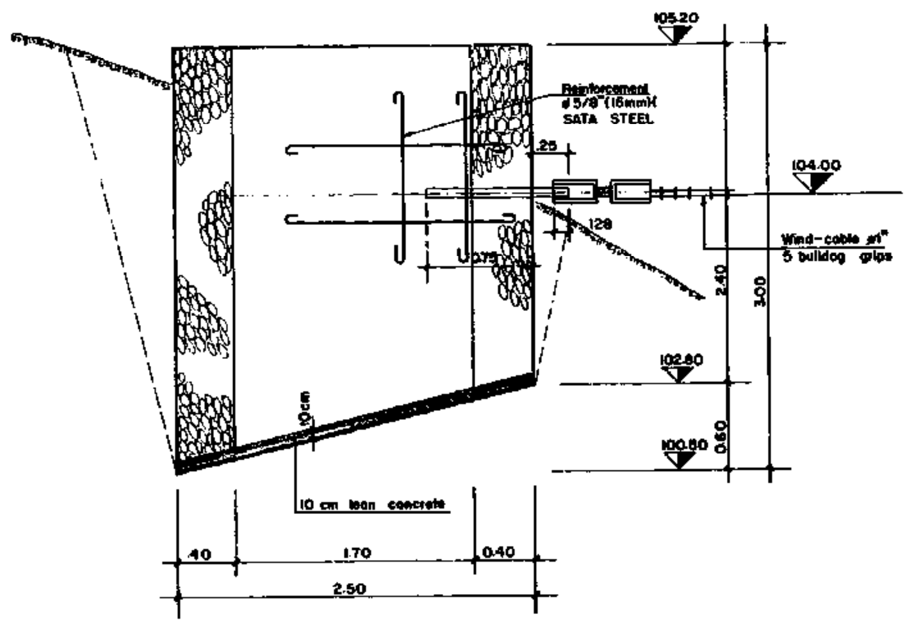
Main Anchorage of a Suspended Bridge

No.	: 9.304
Date	: 27.2.77
Sig	: Laudrau

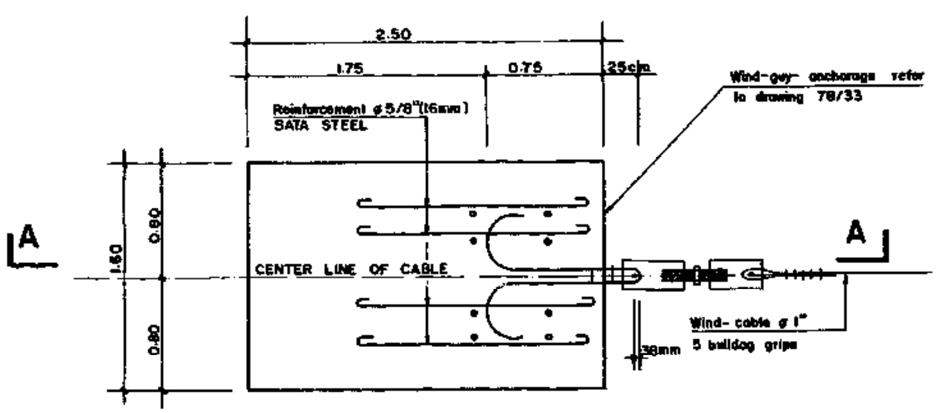


CONSTRUCTION WORK	No.	: 9.305
Windguy Anchorage	Date	: 27.2.77
	Sig	: [signature]

SECTION A-A



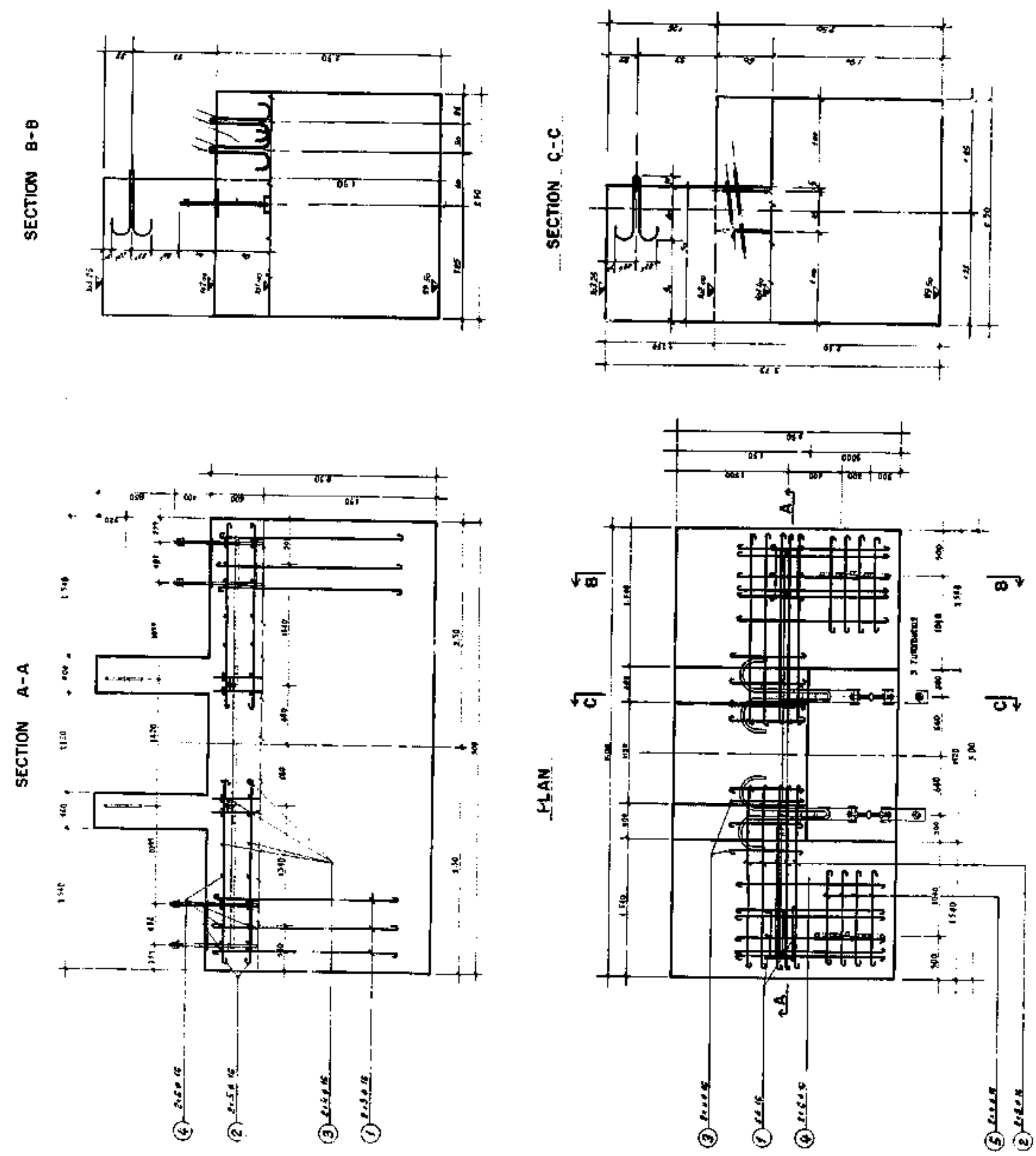
PLAN



HMG Nepal Roads Department Suspension Bridge Division

SATA, Swiss Association for Technical Assistance

After reaching a certain levèl in concreting, we have to fix the reinforcement steel. The positions of the reinforcements are given in the Working Drawings and reinforcement lists. The most important point to consider is that the holding down bolts of the Pylons are well connected with the reinforcement steel. So the vertical reinforcement should be placed around the holding down bolts in order to keep the negative bearing forces.



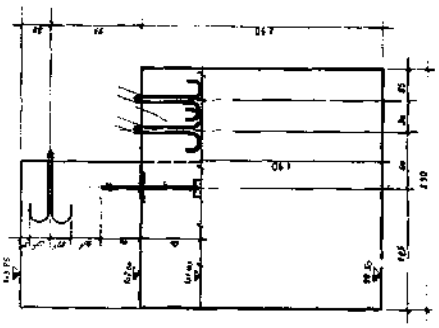
CONSTRUCTION WORK

Concrete and Masonry Work

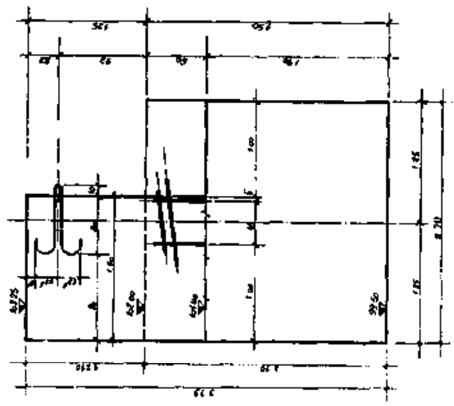
No. :	9.306
Date :	26th Feb,77
Sig :	Paudean

After reaching a certain level in concreting, we have to fix the reinforcement steel. The positions of the reinforcements are given in the Working Drawings and reinforcement lists. The most important point to consider is that the holding down bolts of the Pylons are well connected with the reinforcement steel. So the vertical reinforcement should be placed around the holding down bolts in order to keep the negative bearing forces.

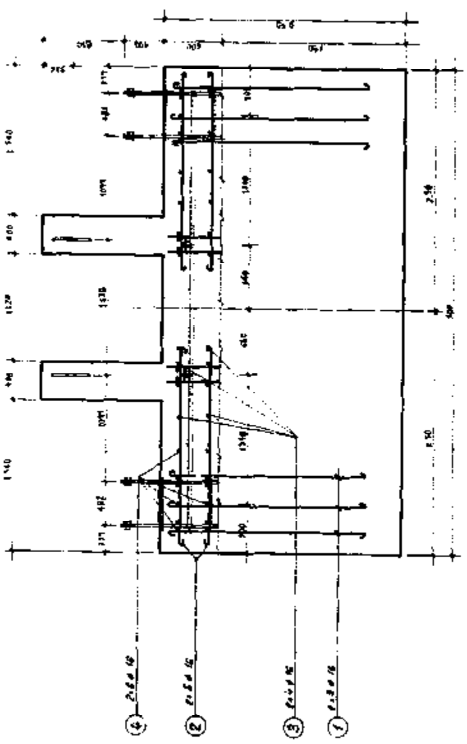
SECTION B-B



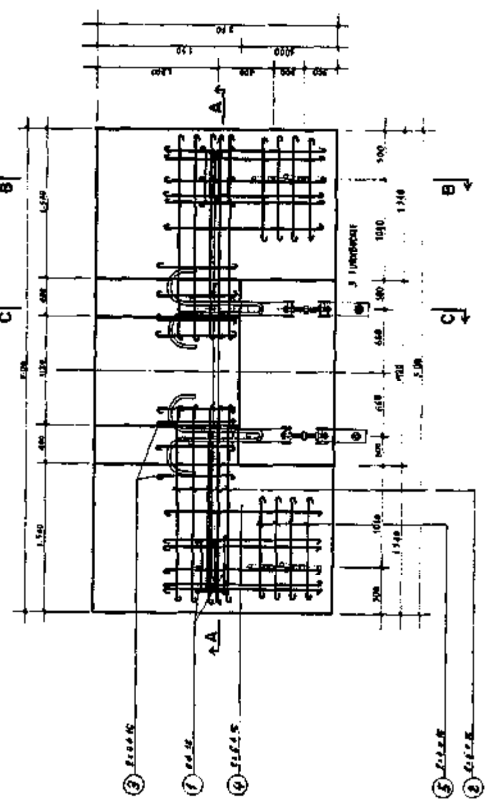
SECTION C-C



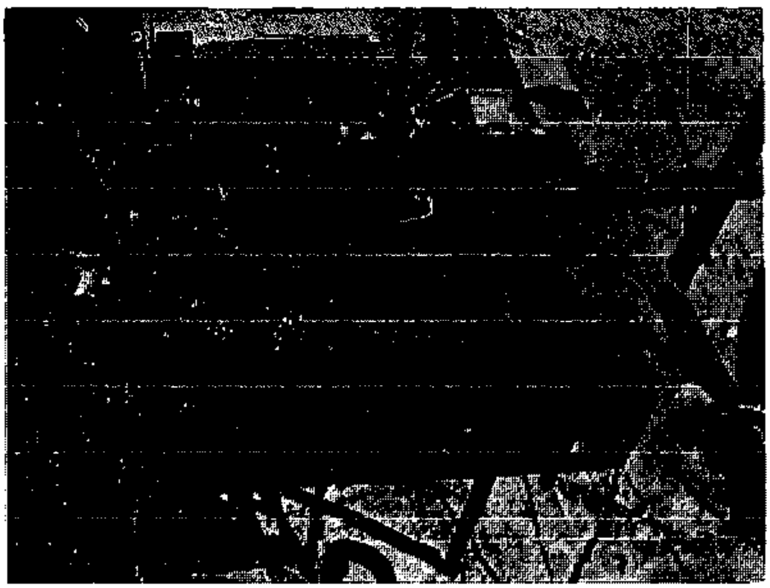
SECTION A-A



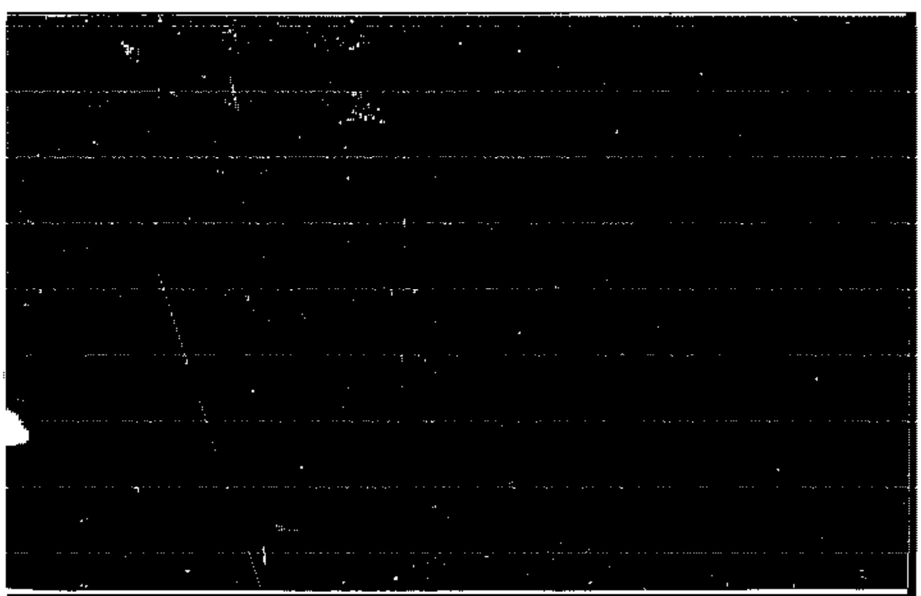
PLAN



Now the anchor parts remain which must be fitted into the anchor blocks. All measures required are mentioned in the layout drawings and Detail Drawings of the HMG Standard Design. On the following pages there are some examples of foundations from Suspension Bridges as well as for Suspended Bridges.



Pylon Base Plate of a Suspension Bridge

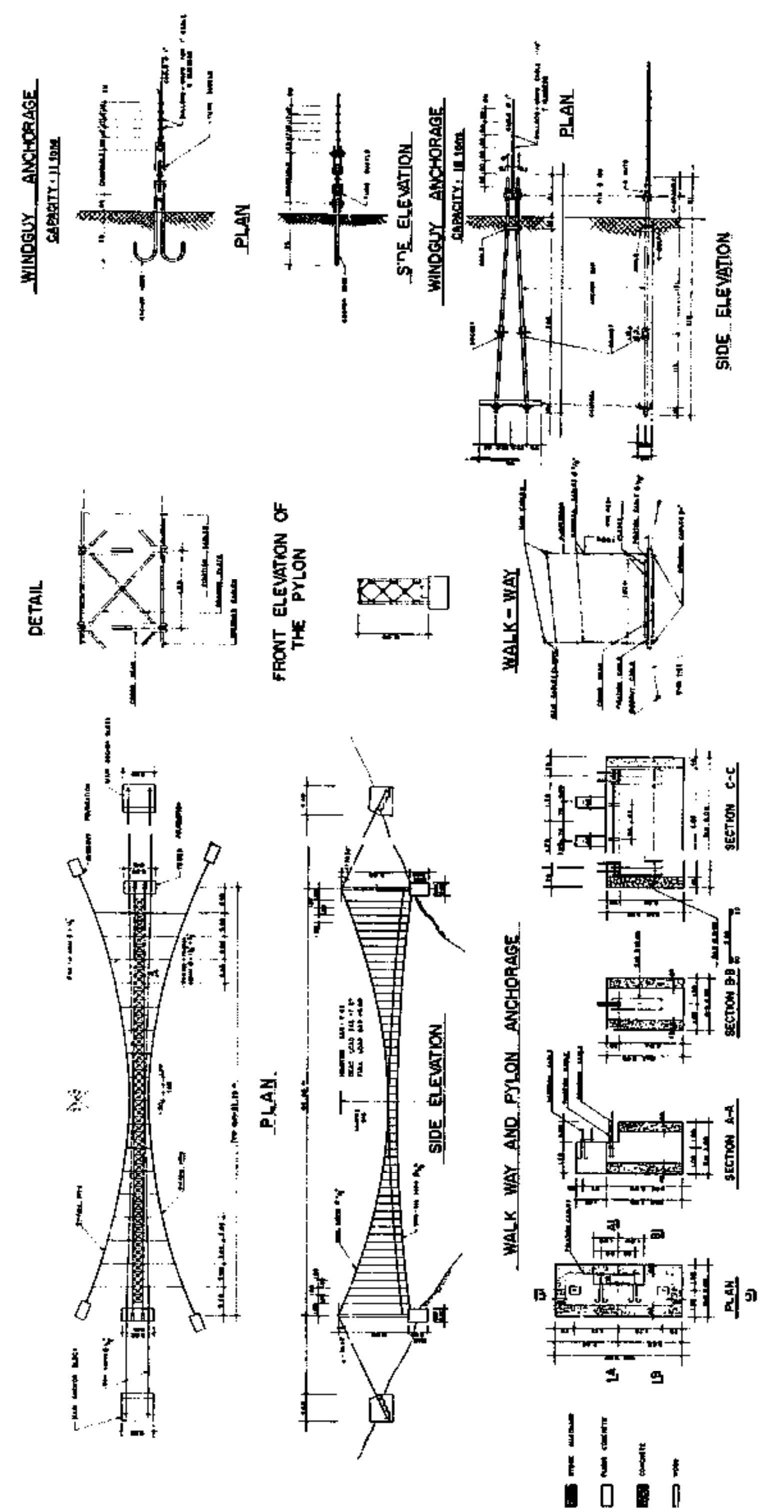


Spanning Cable and Fixation Cable anchorage hooks of a Suspension Bridge

CONSTRUCTION WORK

Lay Out of a Suspension Bridge

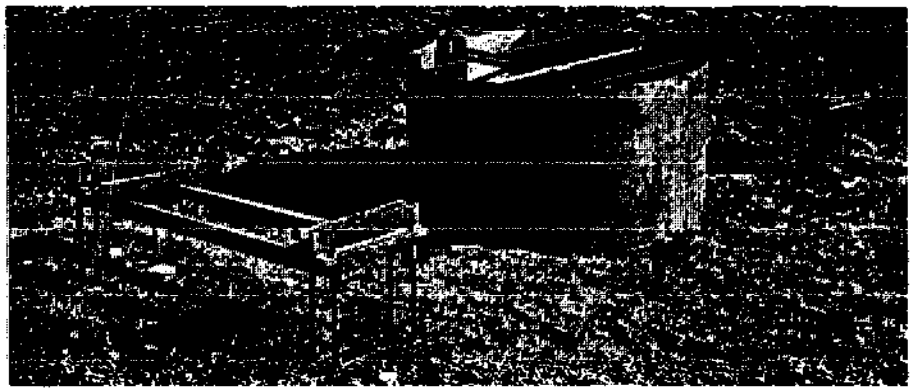
No.	: 9.308
Date	: 27.2.77
Sig	: Pandian



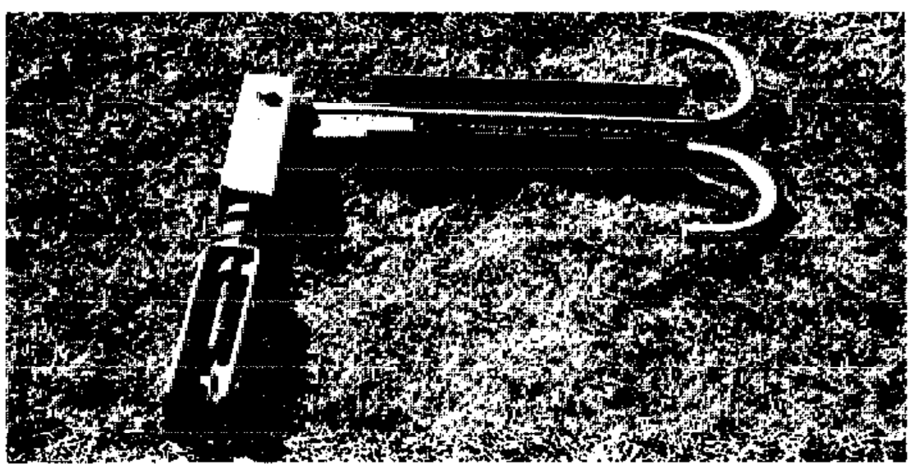
CONSTRUCTION WORK

Fotos of Anchorage parts of a Suspended Bridge

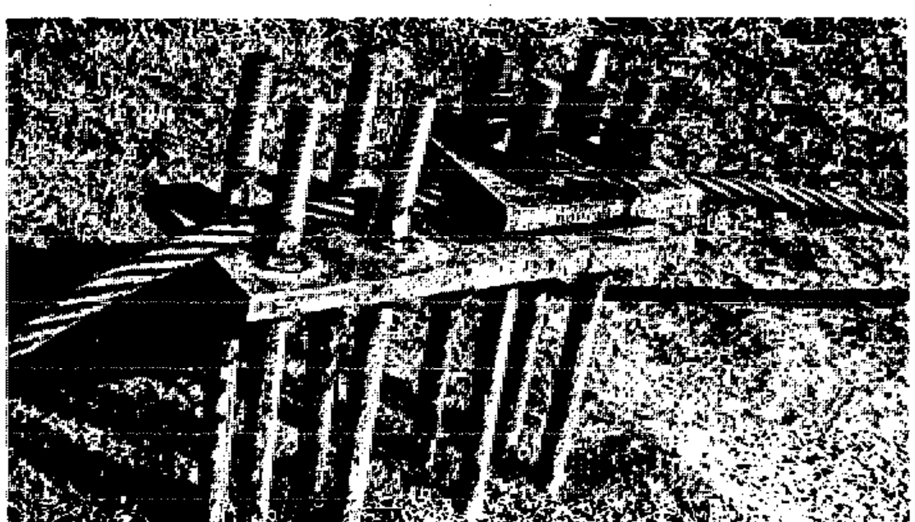
No.	: 9.309
Date	: 27.2.77
Sig	: [signature]



Saddle, Drum and Clamps of a Suspended Bridge



Handrail Cable Anchorage Hook of a Suspended Bridge

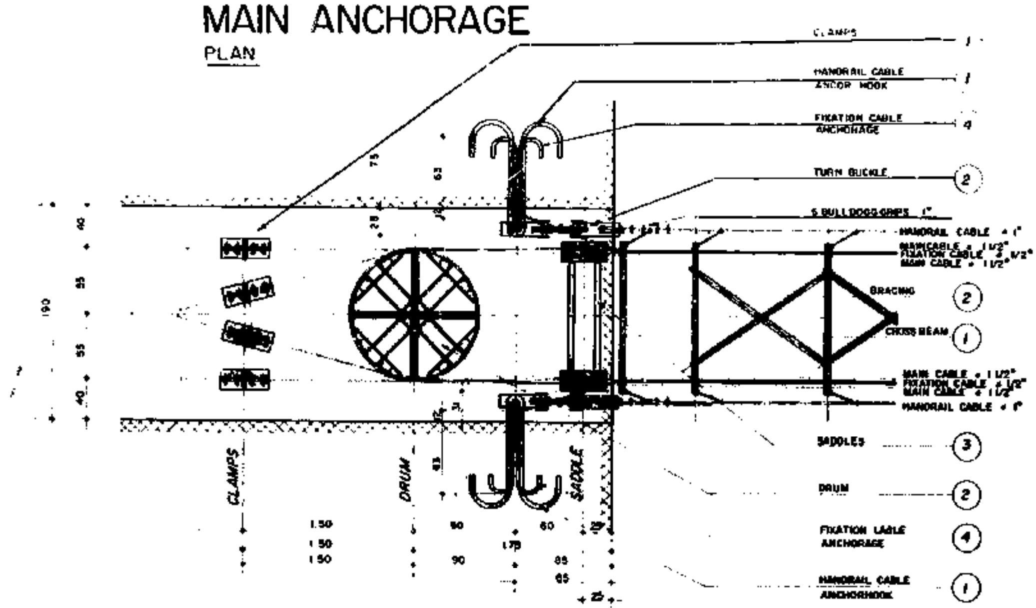


Clamp of a Suspended Bridge

CONSTRUCTION WORK	No. : 9.31o
Lay out of a Suspended Bridge	Date :27.2.77
	Sig : [signature]

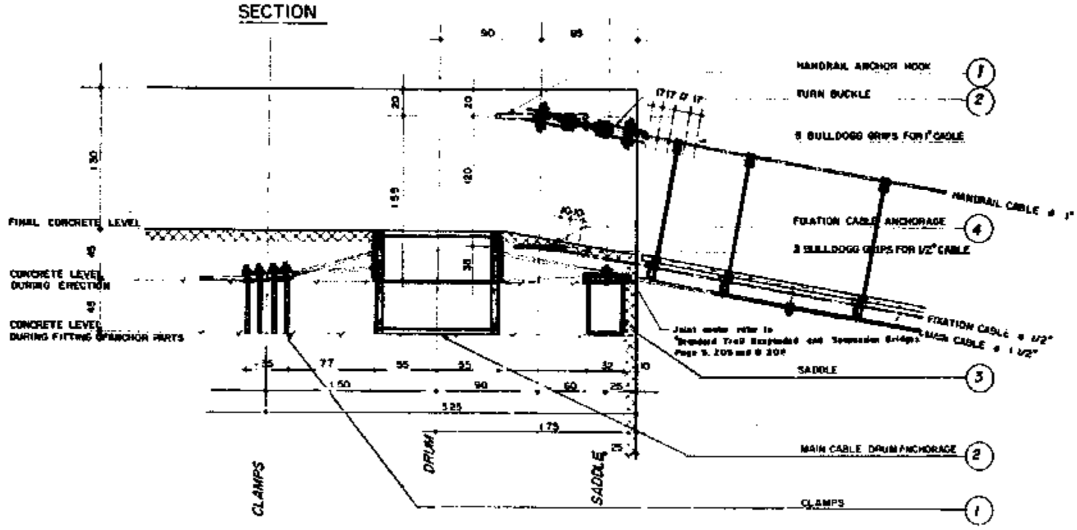
MAIN ANCHORAGE

PLAN



ONE CABLE END HAS TO BE TURN ROUND 3 TIMES

SECTION



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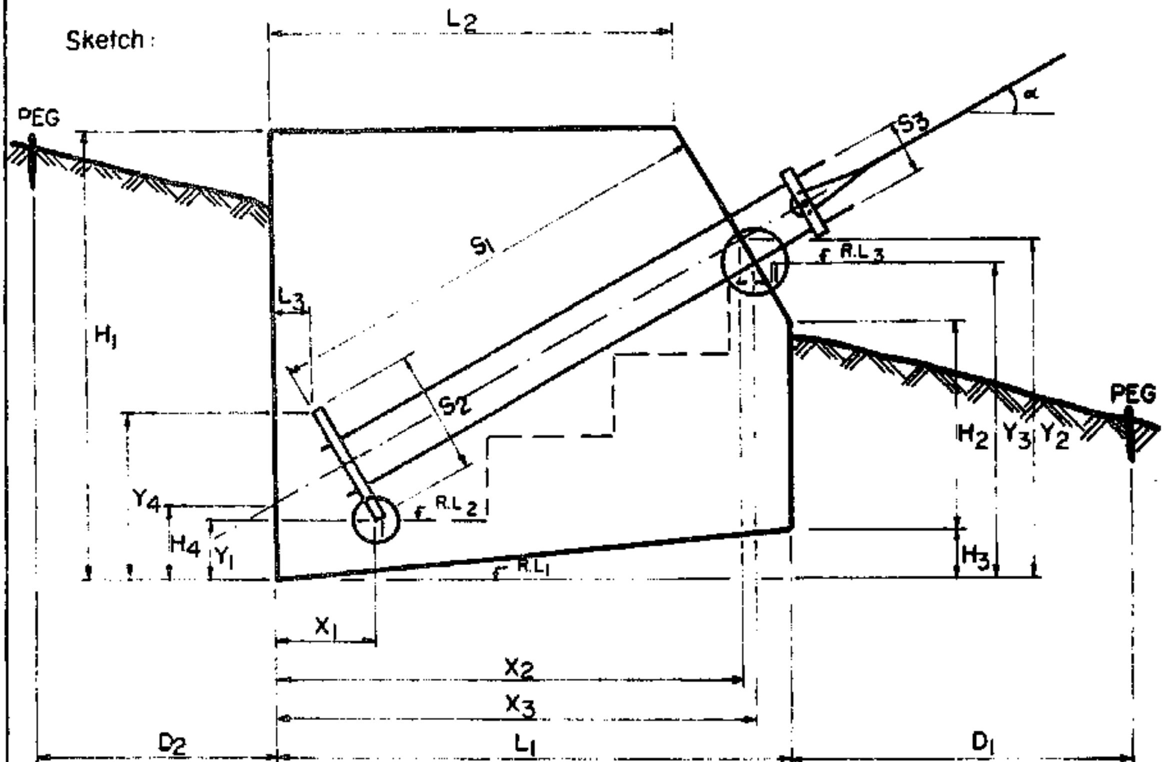
CONSTRUCTION WORK	No: 9.311
Fitting of a Main Anchorage (I)	Date: 15.9.1975
	Sig: [signature]

In the sketch below are known from the design-drawings: L_1, L_2, L_3, --- H_1, H_2, H_3, H_4,

S_1, S_2, S_3, ---

from the lay-out: D_1, D_2, --- R.L.$_1$

Sketch:



Please refer to standard Main Anchorage Block drawings span / 20

For the fitting, the two points "I" and "II" should be known

They are calculated as follows:

FOR POINT I:

$$Y_4 = H_4 + \frac{S_2}{2\cos\alpha} + L_3 \tan\alpha$$

$$\boxed{\begin{aligned} Y_1 &= Y_4 - S_2 \cos\alpha \\ X_1 &= L_3 + S_2 \sin\alpha \end{aligned}} \quad (RL_2 = RL_1 + Y_1)$$

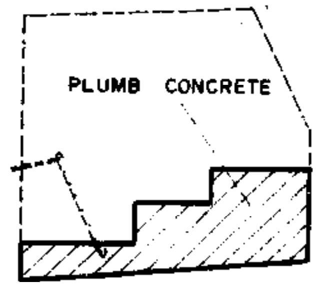
FOR POINT II:

$$Y_2 = Y_4 - \frac{S_2}{2}\cos\alpha + S_1 \sin\alpha$$

$$X_2 = L_3 + \frac{S_2}{2}\sin\alpha + S_1 \cos\alpha$$

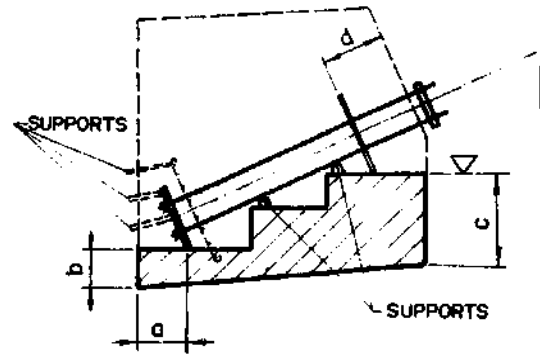
$$\boxed{\begin{aligned} Y_3 &= Y_2 - \frac{S_2}{2}\cos\alpha \\ X_3 &= X_2 + \frac{S_2}{2}\sin\alpha \end{aligned}} \quad (RL_3 = RL_1 + Y_3)$$

These calculations can be checked graphically with an exact drawing.



1. Raise the plump concrete 1:3:6 + 40% boulders up to the levels shown in the detail drawing (Standard Main Anchorage block span/20).

   If - in special cases - reinforcement steel is required already fit the bars.

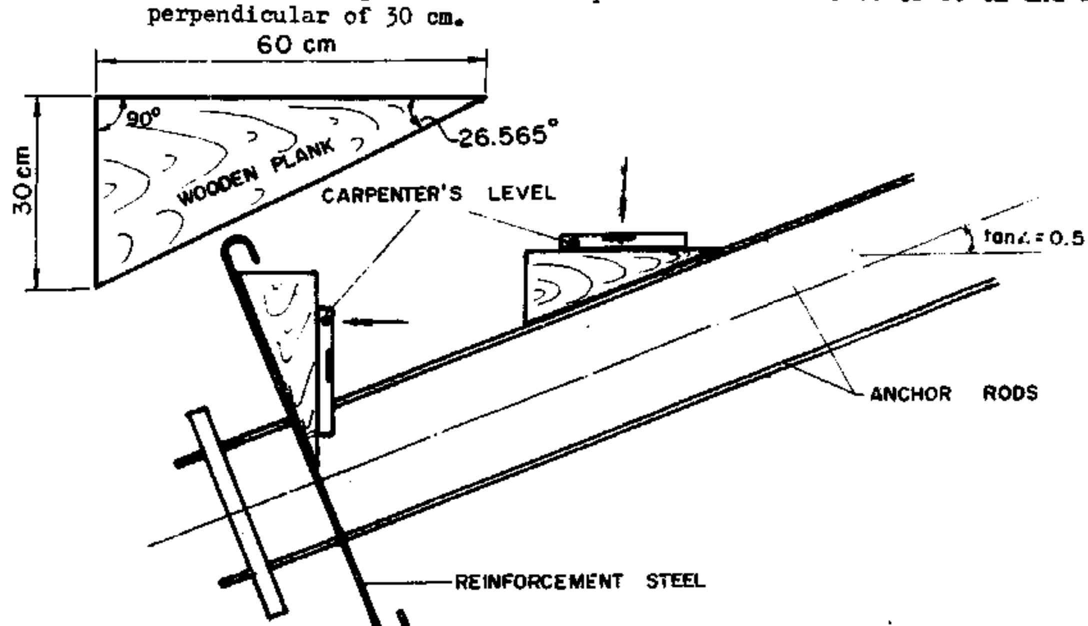


a,b,c,d refer to Standard drawings

2. Fit the anchor-parts.
   Support the parts from the back with stakes. Check the symmetry of the rods in reference to the bridge center line. The proposed supports in the front must be placed according to the standard drawing, in order to keep the correct gradient .
3. Continue the concreting and re-filling work (refer to standard drawing).

The gradient of the anchor-rods and the reinforcement steel can be checked with the aid of a plank, having the required angle, and a carpenter's level.

Example : For an angle of 26,565° ($\tan\alpha = 0.50$) - which is proposed at Standard Suspension Bridges - the wooden plank can have a base of 60 cm and a perpendicular of 30 cm.



After finishing the work the measures to protect the building have to be taken. We should try to make our best to protect the bridge for a long time. One of the most important and most efficient measures is the back filling. The backfill must be done in all types of subground buildings. The backfill protects the surface ground against erosion, sliding etc. A very important thing, also, is the drainage. If you make drainage in such a way that no water flow can occur at the bridge site, then you will most probably never have slides in this area. It is also important to see that the water can flow away from the backside of the walls and the blocks. Some kinds of Drainage and backfill are shown on the sketch page 3.401.

A very common way to protect the river bank is to provide gabian walls. The most important thing on constructing gabian walls is to fill them very well and only with stones which are bigger than the holes of the netting. The calculation of a gabian wall is also similar to the design of a gravity wall (dry stone masonry) and shown in chapter 3. "Structure Analysis" on page 3.507.

Some more types of retaining walls and their description are shown on the pages "Retaining walls and Foundation Structures for Suspended and Suspension Bridges" as part of chapter 3 "Structural Analysis".

Very often the decision about these things cannot be made out of the contour lines or out of the Survey Report. So the resident Engineer should take care of such things. Tha last rainy season might have changed the situation at Site, so that some retaining walls, gabian walls etc. might be necessary, or the foundation structures may be shifted. He should also consider exactly what might happen during next season. It might also be that some stonefall might occur during the rainy period. Also for that the resident engineer has to take care and make the required protections.

Cabion under construction

10. BRIDGE ERECTION

10. Bridge Erection

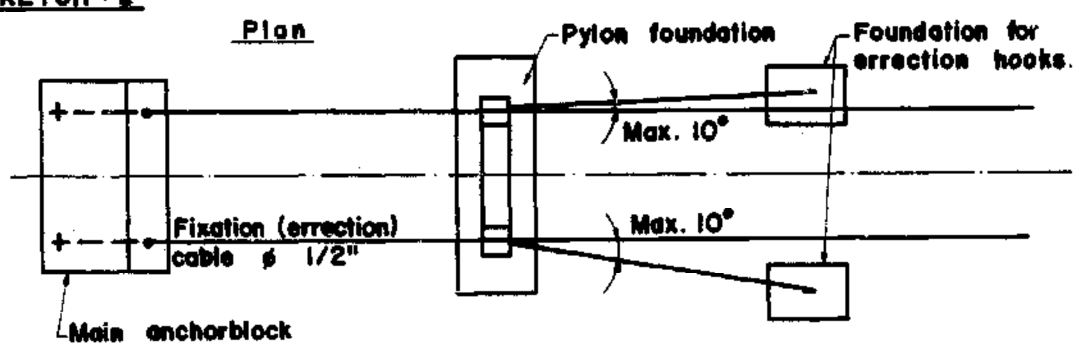
After all the concrete work has been done and all remaining excavations have been refilled, there remains the erection of the bridge. This is one of the most interesting pieces of work but also one of the most difficult and dangerous. In spite of the fact that all steel parts and cables are heavy parts they still have to be handled very carefully. The most delicate parts of the whole bridge are the cables. The cables are also very expensive and must be handled with great care. Even slight damage to the cables may make them useless. Also the important regulations such as retightening the bulldog-grip every day, retightening the nuts and putting on the lode nuts should not be forgotten. It is important to finish all jobs properly. Things like loose cable ends, badly fixed wire mesh, untied windties etc. make a bad impression and show up bad work.

This chapter shows how to erect the bridge. How to fit the steel-parts into the concrete is shown in the chapter "Construction Work".

10.1 Pylon Erection

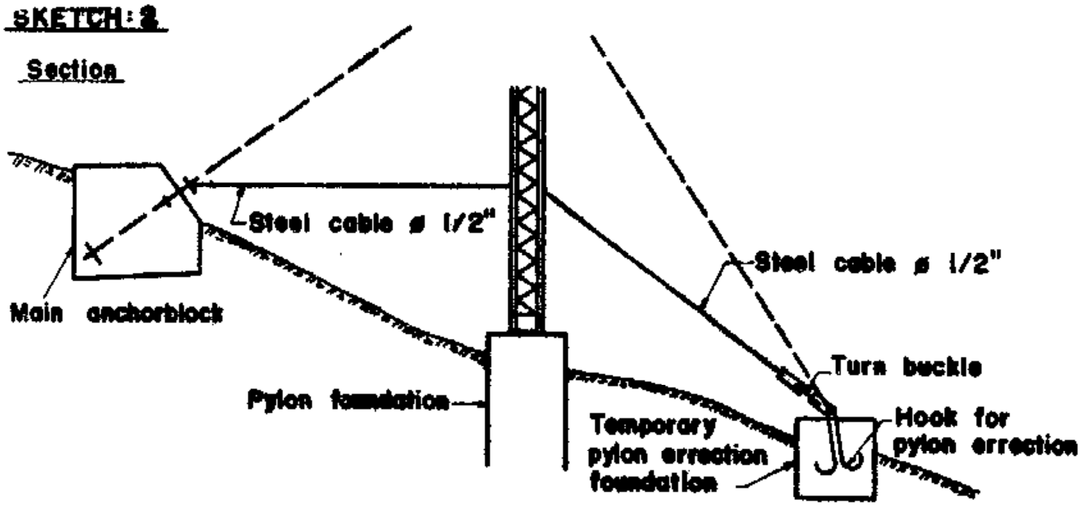
For all suspension bridges we now have hinged pylons. The erection of such a pylon is quite difficult and has to be done carefully. During erection time the pylons have to be fixed with steel cables. For this purpose we will use cables Ø ½" at site (see cost estimate for suspension bridges). The support cables have to be fixed at the front and at the back of the pylon. The cable at the back can be fixed to the main anchorage and the one at the front to the two blocks provided for this purpose. These cables, the frontstay and the backstay should always be under tension. Only then is a good fixation at the pylon guaranteed.

SKETCH : 1



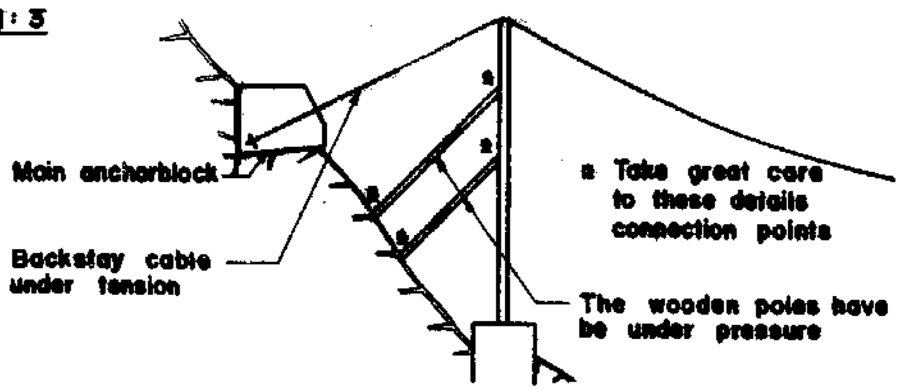
SKETCH: 2

Section



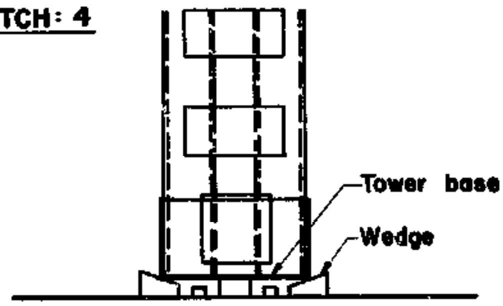
If the ground is steep, it may not be possible to fix the tower with a cable from the front. In this case the tower can be supported from the back with a wooden pale. At the front the tower may even be tied by a rope to the tower on the other bank.

SKETCH: 3



In the bearing some wedges or supports can be provided in addition to prevent movement of the tower at the beginning of the erection. However, these wedges or supports must be removed after fitting the third element of the pylon. The wedges should be of good wood or steel.

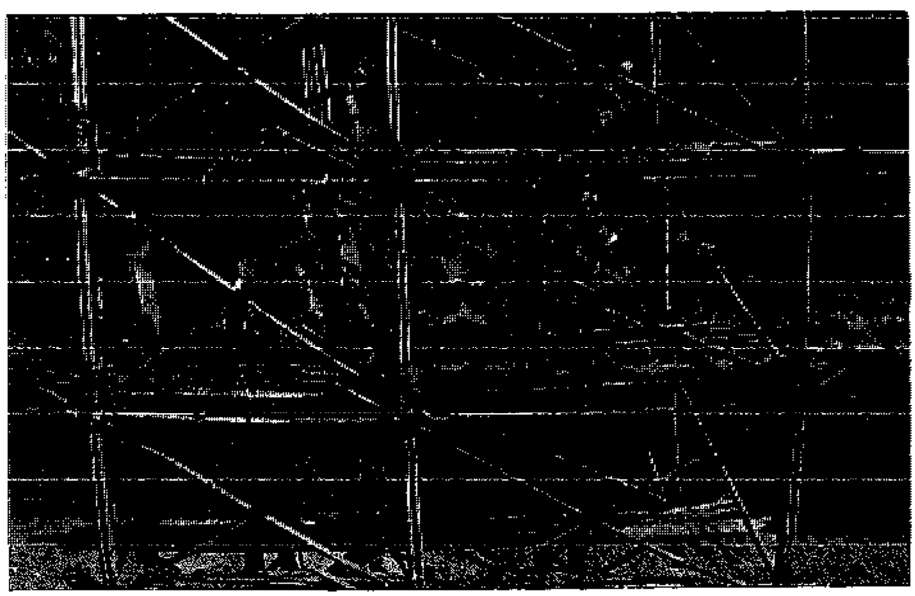
SKETCH: 4



IMPORTANT :-

Don't forget to take out these wedges after fitting the third element at the pylon

For the erection of the tower use the Standard drawing "Pylon Assembling" (span/...). One example is shown on the following page.

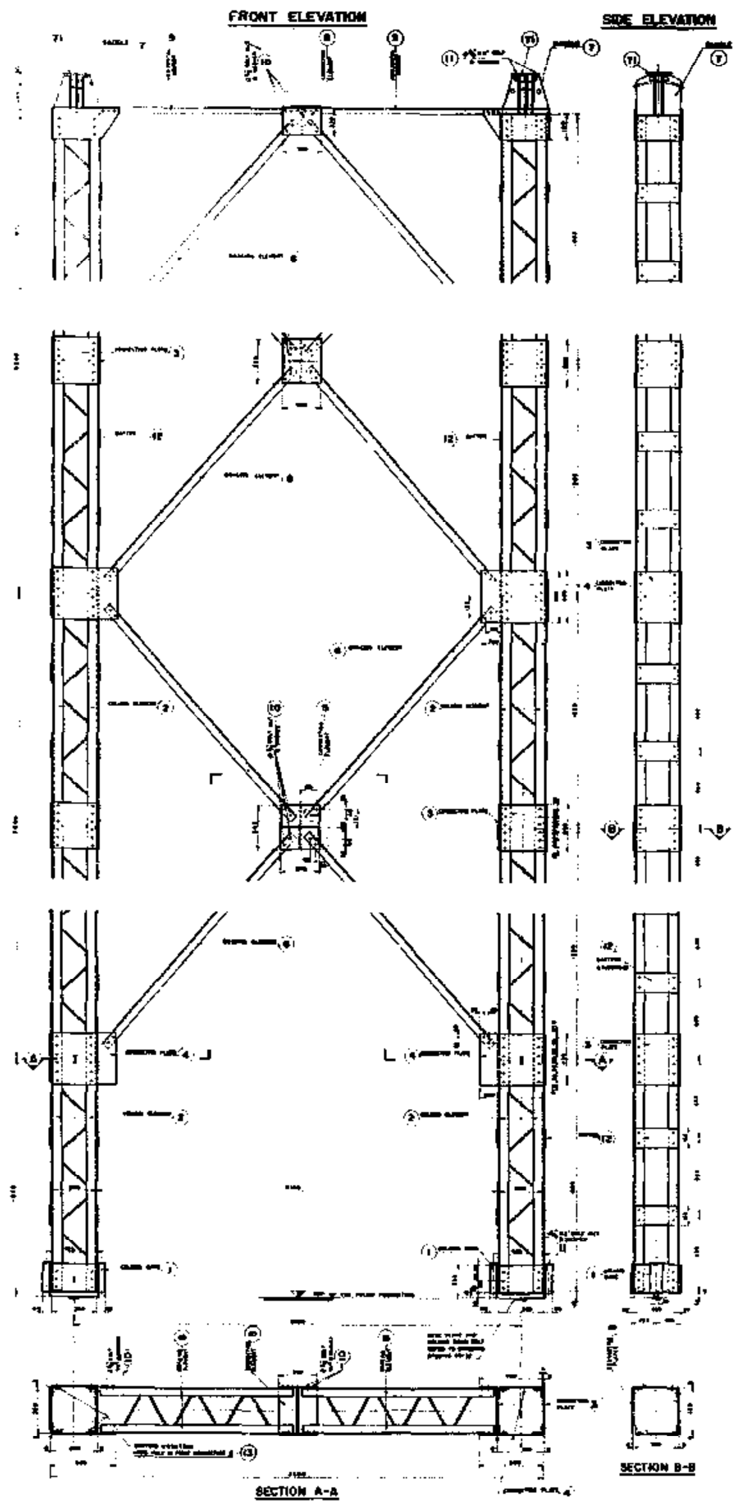


BRIDGE ERECTION

Pylon Assembling Standard Drawing 90/52

No. :	1o.1o4
Date :	25.2.77
Sig :	[signature]

Details refer to Standard Drawing 90/51



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HMG Nepal Roads Department Suspension Bridge Division

BRIDGE ERECTION		No. : 1o.1o5
Suspension Bridge	Pylon	Date : 28.12.76
		Sig : Pandiau

Scaffolding

The scaffolding is here to facilitate the work of the mechanics and not to fix the tower during erection. So the scaffolding and the tower should be fixed seperatly. There should be no connection between the pylons and the scaffolding.

Hoisting the parts

A kind of derrick, made of bamboo or other wood, may be used to hoist the parts for the erection. One possibility of how to make this derrick is shown in the sketch below.

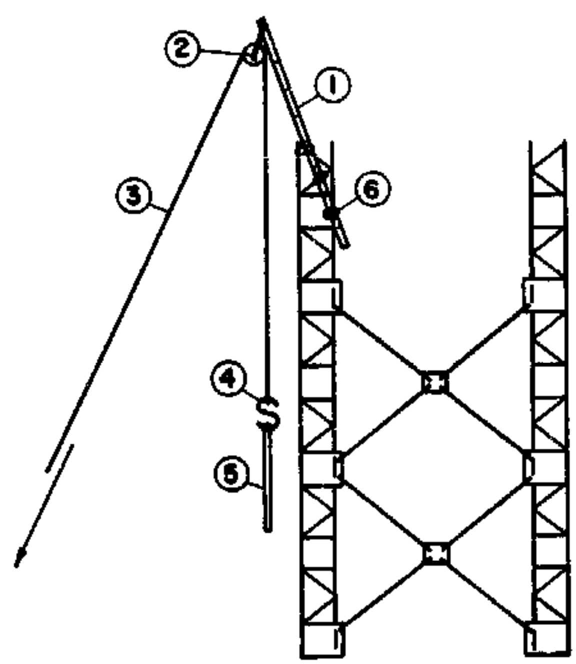
SKETCH : 5

Derrick for the hoisting of parts

A kind of derrick, out of bamboo or other wood, may be used to hoist the parts for the errection.

In the sketch is:

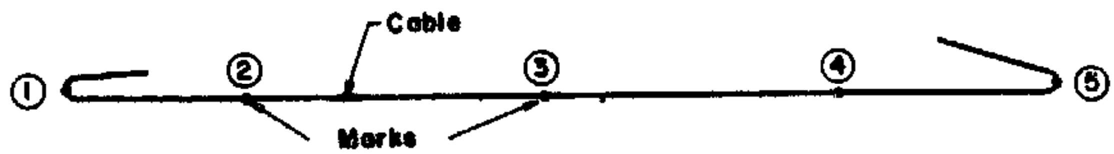
1. **A piece of bamboo or of other wood, about 5 meters long.**
2. **Pulley-wheel, fixed with a rope.**
3. **Hoisting rope.**
4. **Hook, (bent piece of a reinforcement—steel—bar.)**
5. **Tower-part being hoisted.**
6. **Strings to attach the derrick-pole to the already errected tower.**



10.2 Hoisting main cable and spanning cable

Before the cables are taken across the river, mark some of the important points for hoisting on them.

SKETCH : 6

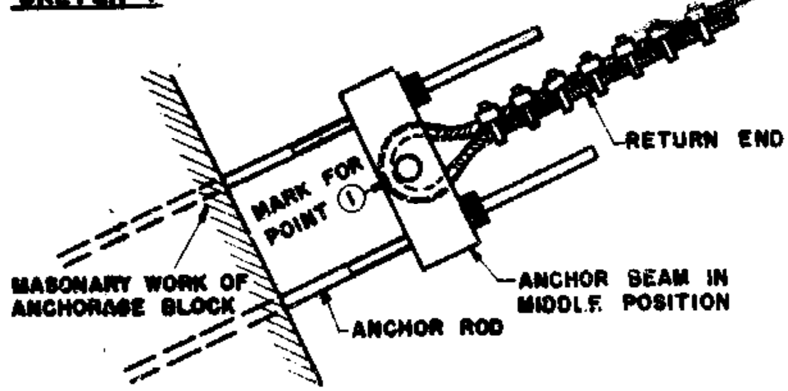


- Start on one side. Measure the length of the return-end (length required to fix the bulldog-grips). Mark point 1
- Measure the next section, the direct distance from point 1 to the tower top. Measure first with a tape as a rope at the site and then along the cable. Mark point 2
- Calculate the length of the cable between the two towers.

  $$L = l + \frac{8 \times s^2}{3 \times l} \qquad l = \text{span} \qquad s = \text{hoisting sag}$$

  Mark point 3 for the center of the bridge and point 4 for the top of the other tower.
- Measure the distance from the second tower to the fixation at the other main anchorage (also in middle position, if adjustable). Mark point 5
- Check that the remaining part has at least the length required for the clamping of the cable.

SKETCH : 7



- For the spanning cable only the marks 1 , 3 and 5 are required.

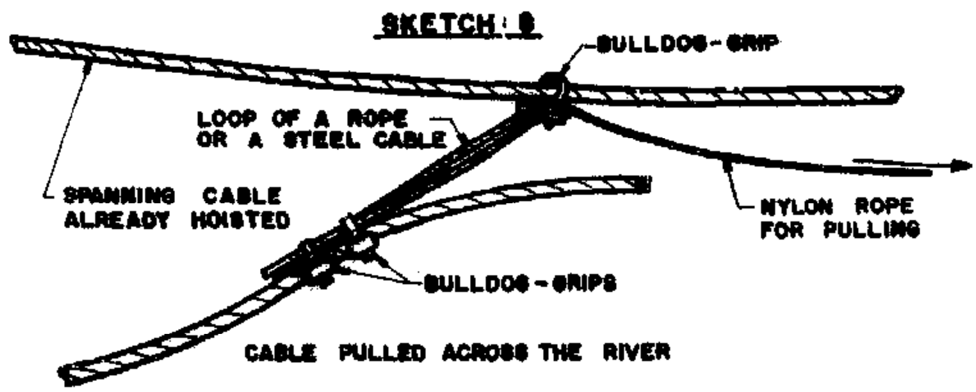
All these marks have to be made before carrying the cables across the river. The marks can be made with paint. Mark 3 can also be a bulldog-grip. The cables can be taken across the river in two different ways.

10.2.1 Pulling along the smaller cables

This method is mainly used for spans smaller than 102 m. Up to this span we have spanning cables Ø 1".

- Bring the spanning cables into position. They can be carried or pulled across the river by a few men.
- Pull the main cable along one of the spanning cables. On the sketch below a suggestion for the pulling-fixation is shown.

All these cables can be pulled by manpower.



10.2.2 Carrying the cables across the river

This method is very easy as long as they can be carried across a temporary bridge. If there is no brodge, a rope bound to the cable has to be ferried across the river and then the cable is pulled through the river-bed.

This could cause difficulties because the cable, especially the fixation between rope and cable may get struck between stones. To avoid this a second rope may be tied to the cable-end. With the aid of this rope pulling from the ferry boat, the cable-end could be lifted a little bit above the ground and with the other rope the cable is pulled at the same time through the river-bed. This is the most common and also the easiest method.

10.2.3 Hoisting the cable into the tower

a) From the Side

This method may only be applied for spans up to about 102 meters.

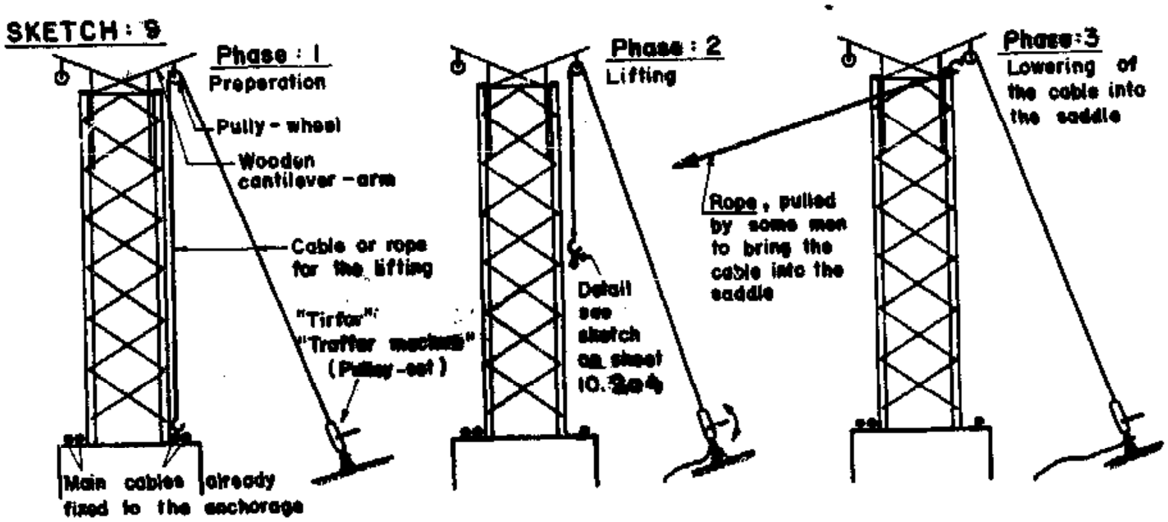
Procedure

Phase 1 — Take the cables across the river. Fix them to the mainanchor-block on both sides. Use the marks on the cables! The upstream cables should be put upstream of the tower and the downstream cables downstream.

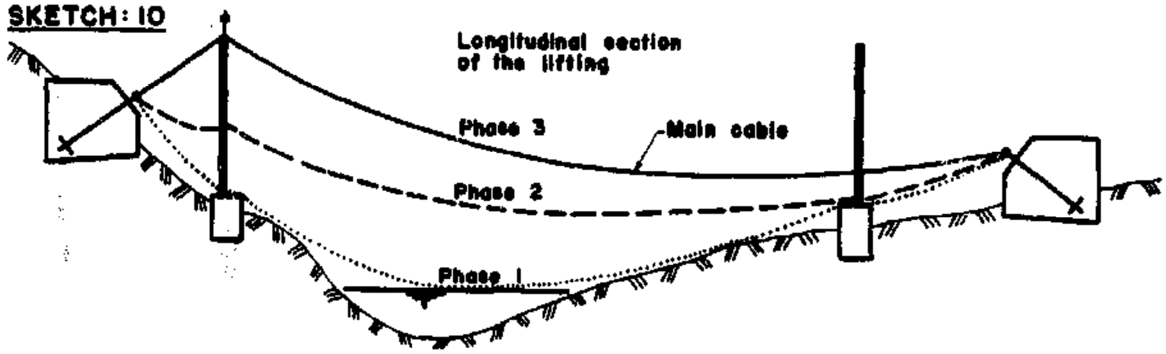
Phase 2 — Lift the cables, one by one, first the inner then the outer, onto the saddle as shown in the sketch for phase 2.

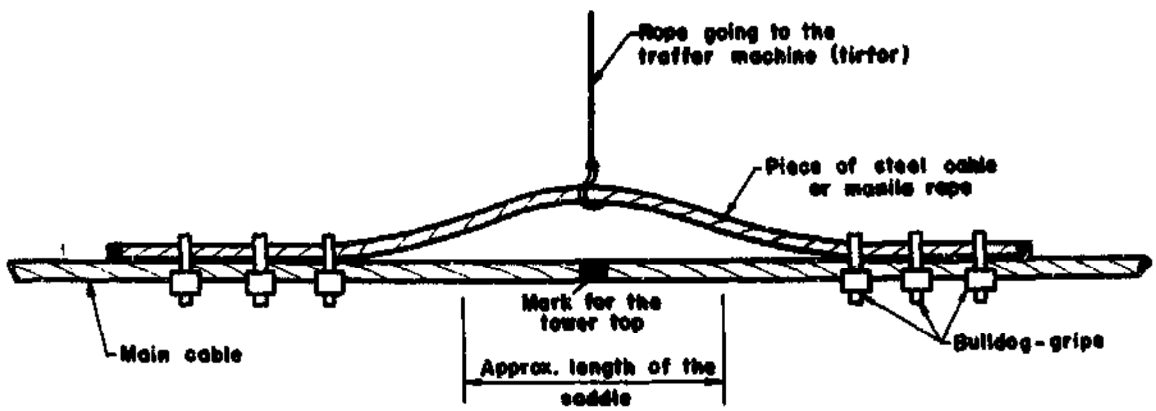
Phase 3 — As soon as the cable is a little bit higher than the saddle, loosen the tirfor machine slowly and, with an auxiliary rope, pull the cable into the saddle at the same time.

SKETCH: 9



SKETCH: 10





The main difficulties in this method are found in the construction of the wooden cantilever, How to calculate the forces on the tower-top is shown in the example below.

Example

Span 66 m

Cable Ø 1½", weight 5.5 kg/m

Overall length = 100 m

Calculation: At the end of the lifting, near the tower top, almost all the cable-weight should be lifted (F_1).

F_1 = 0.9 x 100 m x 5.5 kg/m = 495 kg

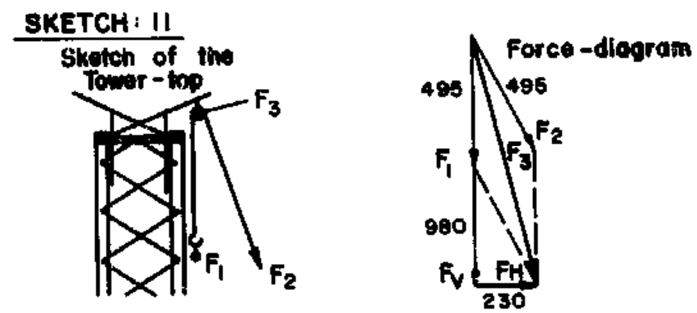
$F_1 = F_2$

out of Force Diagram F_3 = 970 kg

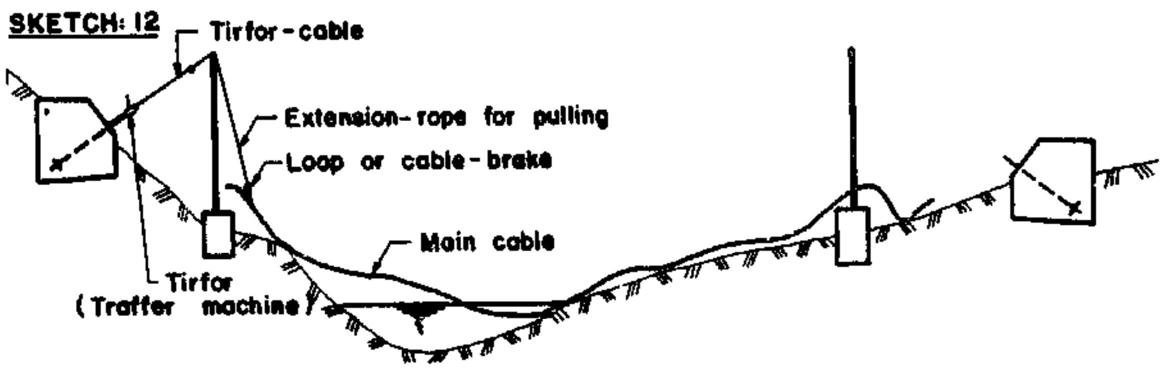
The forces to be taken by the wooden construction can be taken out of the Force Diagram.

F_V = 980 kg

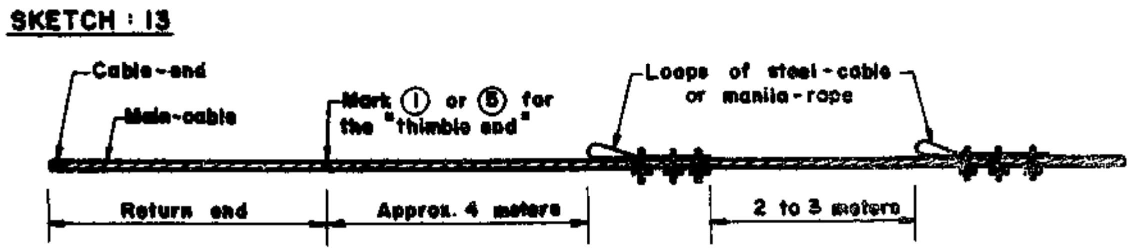
F_H = 230 kg



b) From the tower front



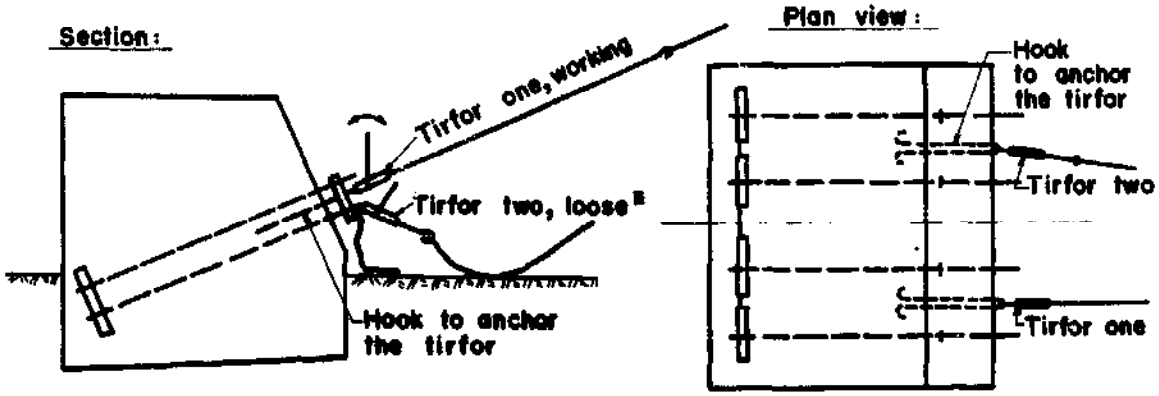
For this method you need two tirfor machines. Fix a loop at two places to the cable-end. How to prepare the cable for this hoisting method is shown in sketch 13.



BRIDGE ERECTION		No. : 1c.206
Suspension Bridge	Hoisting	Date : 28.12.76
		Sig : Landau

To each loop bind an extension rope which is tied to the cable of a tirfor. Use two tirfors. Pull in, turn with one and then the other.

SKETCH : 14



* **Tirfor two will start working as soon as the cable of tirfor one is at the end.**

This hoisting method causes difficulties on the tower-top. The sketches below show one means of passing the cable over the saddle.

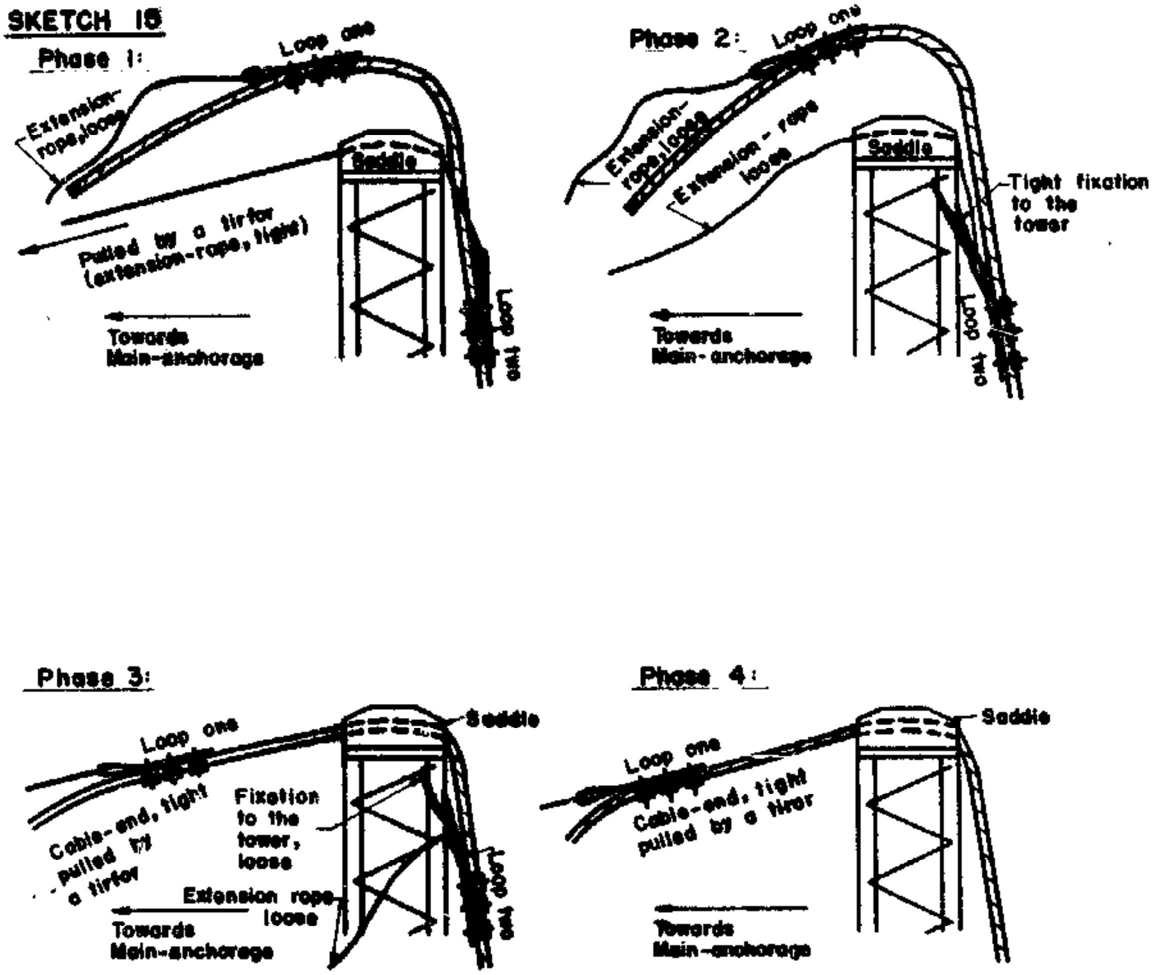
Phase 1 — When the cable-end comes close to the tower top, pull on the second loop. Pull until the first loop has passed the saddle. The cable-end with this loop is only loosely guided or even not at all.

Phase 2 — Bind the second loop tightly to the tower. Then loosen the second tirfor so that the extension-rope becomes loose and the cable only hangs on the fixation of the tower-top.

Phase 3 — Take the extension-rope of the second loop out of the saddle. Put the cable-end into the saddle and start to pull on loop one.

Phase 4 — Take away the second loop as soon as its fixation is loose. Go on pulling on loop one to which a second extension-rope is tied for tirfor two.

SKETCH 15



<u>Lubrication:</u> Keep the friction-force between saddle and ropes or cables small by using some lubricant. If available use oil. Glee or a similar product could also be used.

The maximum tensile force during hoisting in the main cable is shown in the list on page 2.303.

10.2.4 Fixing the hoisting-sag

The required hoisting-sag is given in the general arrangement and also in the list on page 2.303. With the levelling instrument you can gix the exact hoisting-sag in the following way:

- Mark the level on the tower.
- Adjust the levelling instrument in such a way that its line of sight is at the level calculated for the lowest point of the cable in the middle of the bridge. (R.L. of the tower-top minus sag).
- Pull the cable until it reaches a level of about 0.20 m higher than the erection sag.
- Clamp the cable around the thimble in the cross-beam of the anchor-rods.
- Loosen the tirfor.
- After all the main-cables have been hoisted in this manner, bring them to the required level by moving the adjustable beam.

10.2.5 Hoisting a spanning cable

The spanning cable can be hoisted in a similar way as the main cable.

- Fix the cable on one side to the anchorage (use the marks).
- Pull on the other side with a tirfor until a sag corresponding to the camber required afterwards is reached.
- Fix the cable on this sag.
- Check the sag with levelling instrument.

The force required for hoisting the spanning cable is much higher than that for the main cable although the cable-weight is smaller. This is due to the small sag. If it is not possible to hoist the walkway-cable to the required sag due to the high tensile force, the cable can be re-adjusted after the central suspenders have been connected.

10.3 Fitting the suspenders and the walkway

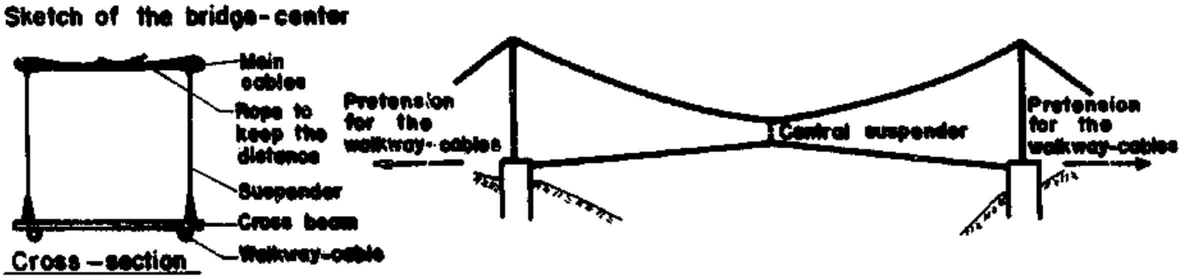
While the cables are being hoisted, get suspenders, beams and deck-planks as well as cable-car or fitter-platform prepared.

First fit the central suspender

- Send two cable-cars or fitter-platforms along the main-cables to the bridge-center.
- In the center bind the main-cables together at a distance of about the walway-width, because they will hang at the distance of the saddles.
- With the aid of two tirfors or chain-pulleys lift the walkway-cables until they can be connected with cross-beam and suspenders to the main-cables. Use the mark on the cables to position the suspenders. Check that the suspenders are perpendicular to the bridge-centerline.
- Re-adjust the walkway-cables. Tighten them as much as possible to give some pre-tension.

SKETCH: 16

Sketch of the bridge-center

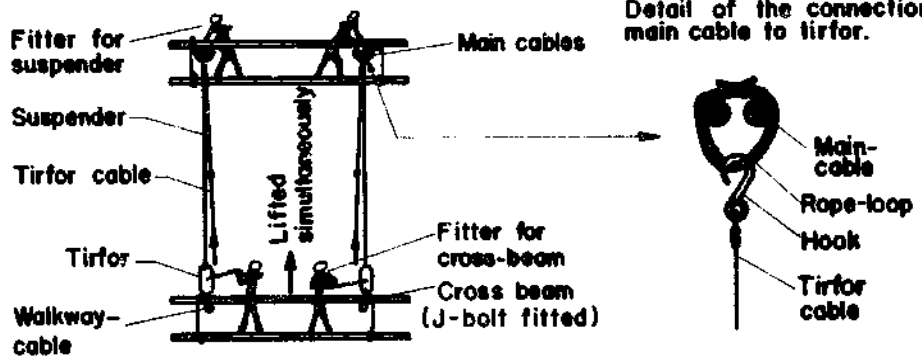


Now start fitting the other suspenders and the walkway. Start either from the towers or from the bridge-center. Measure the distance from suspender to suspender carefully, e.g. with a ganged stick. At every tenth suspender check the distance from the tower or the bridge-center to this suspender (by tape).

SKETCH : 17

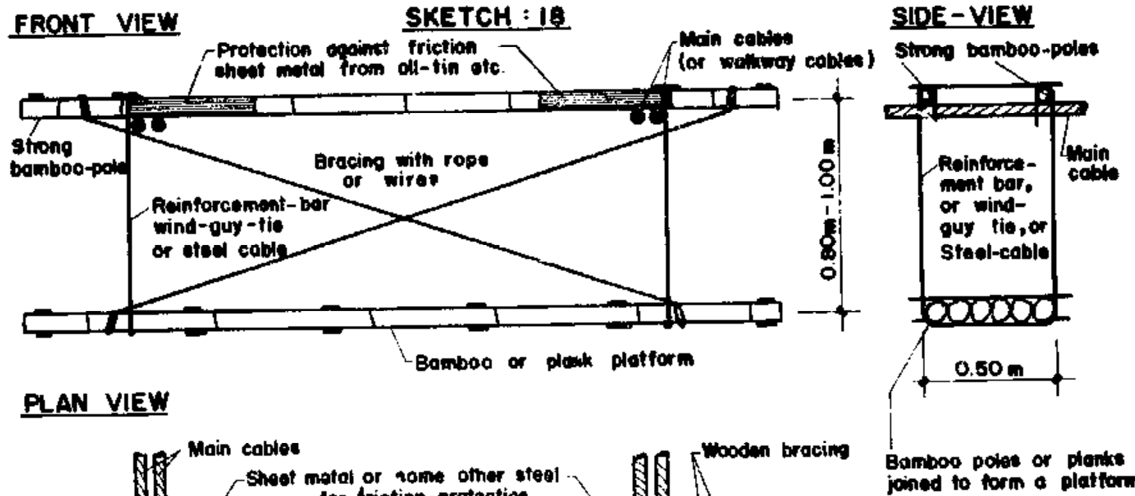
Sketch of the fitting

Detail of the connection main cable to tirfor.

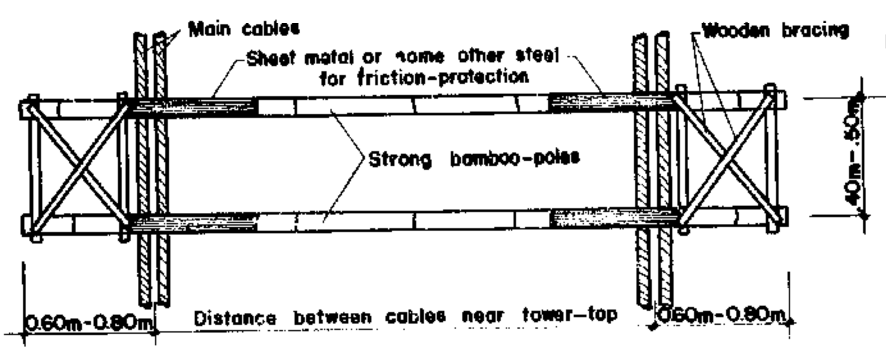


If there is only one main-cable, the hook can hang on the cable itself.

FRONT VIEW   SKETCH : 18   SIDE-VIEW

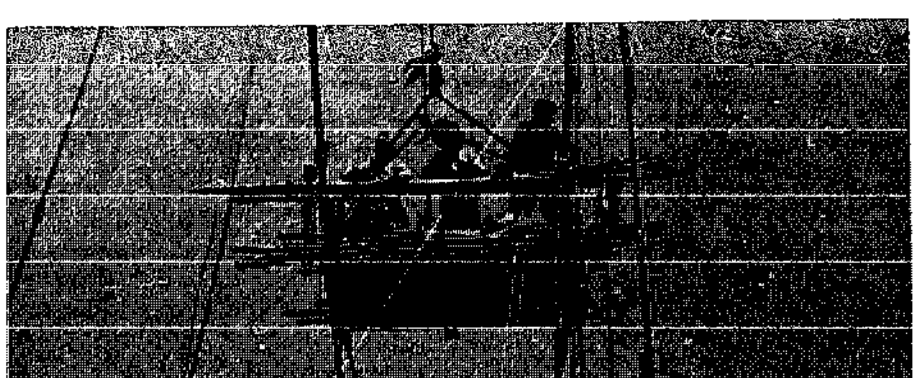


PLAN VIEW



ASSEMBLY:

First put the top portion on the main-cables. Then hang the platform under this, connected with steel-bars or cables.



BRIDGE ERECTION

Suspension Bridge

No. :	10.303
Date :	28.12.76
Sig :	Pandrau

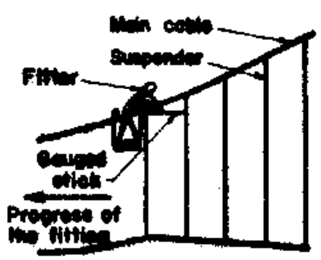
There are two main ways of fitting the suspenders: one is to start at the tower and go on up to the bridge center and the other is to start at the bridge center and go on up to the towers. The main advantages and disadvantages of these methods are mentioned below.

Fitting from the towers in towards the bridge center

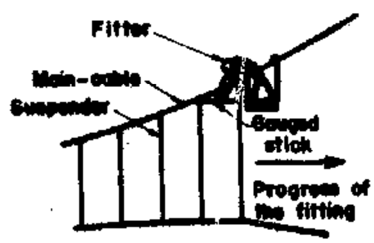
Advantages: Supply of parts is easy. The fitters for the suspenders can work in an almost upright position (near the towers and easily check the distance from suspender to suspender.

Disadvantages: Due to an unavoidable inaccuracy in the determination of the span and the measurements from suspender to suspender the remaining spacing in the bridge center will be too long or too short. This will require an adjustment of the planks and means the walkway breacing will have to be left out or adjusted. Access to their working place is difficult for the fitters.

SKETCH 19



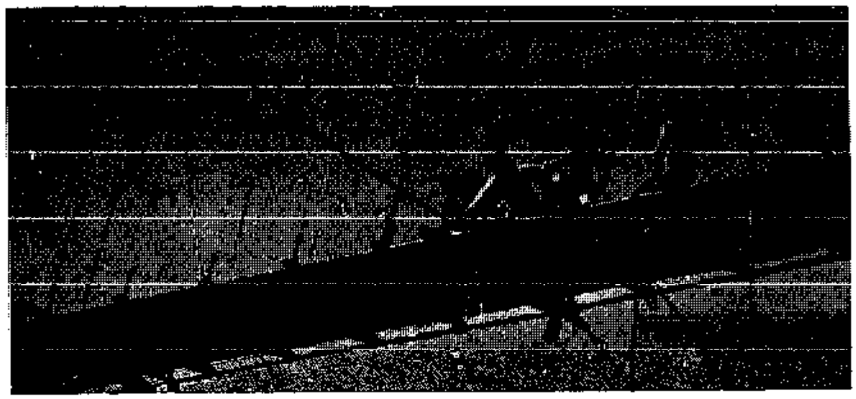
SKETCH 20



Fitting from the bridge-center out towards the towers

Advantages: No problem with the adjustment of the walkway-bracings and planks. The access to the working place is easy, the platforms can be pulled into their positions in the morning.

Disadvantages: The fitters will have to work in a bent position (near the tower). The supply of parts must be well organised. Pulleys and many ropes are required.



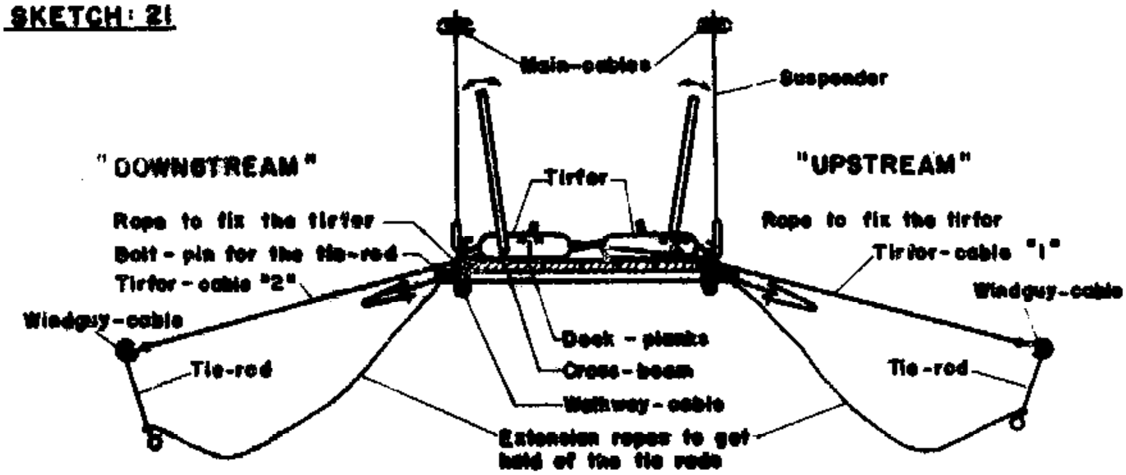
10.4 Fitting of windguy cables and ties

Here also there are two possibilities to hoist the windguy cable and connect the ties to the bridge. One is to fit first the windguy cable and then the ties, and the other is to fit first the ties and then the windguy cable to the anchorage blocks.

Procedure for the first method

After the windguy cables have been marked and the ties fixed, take the cables across the river and fit them to the anchorages. They will hang directly from one anchor-block to the other. As soon as the suspender-walkway-fitting has been completed, connect the windtie-cables to the walkway-beams. Start with this work in the bridge-center. Use two tirfors, one for the upstream-cable, the other one for the downstream-cable. Pull the windguy-cables simultaneously towards the walkway and connect the ties (see on sketch 21). Check wether the bridge is still straight. In order to get hold of the windguy-cable throw the hooked end of the tirfor-cable down from the walkway on to the cable. If the tirfor cable is too short add an extension-rope.

SKETCH: 21



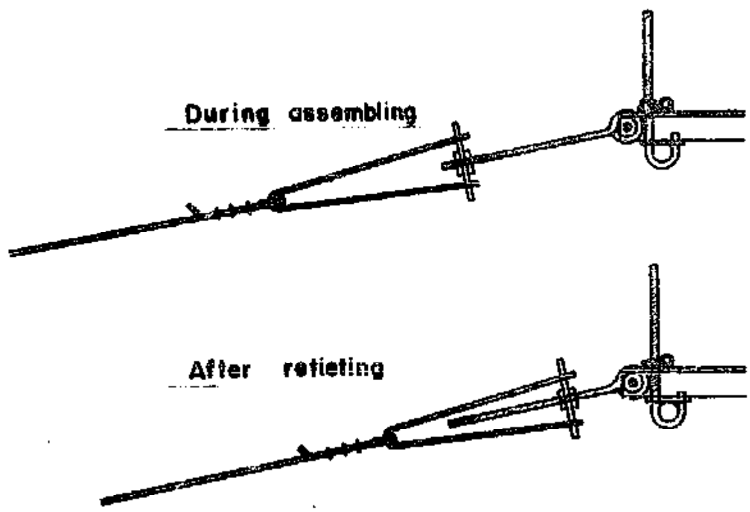
Continue to connect the ties with the walkway. Displace the tirfors for every tie. Always pull symmetrically and check the alignment of the bridge.

Procedure for the second method

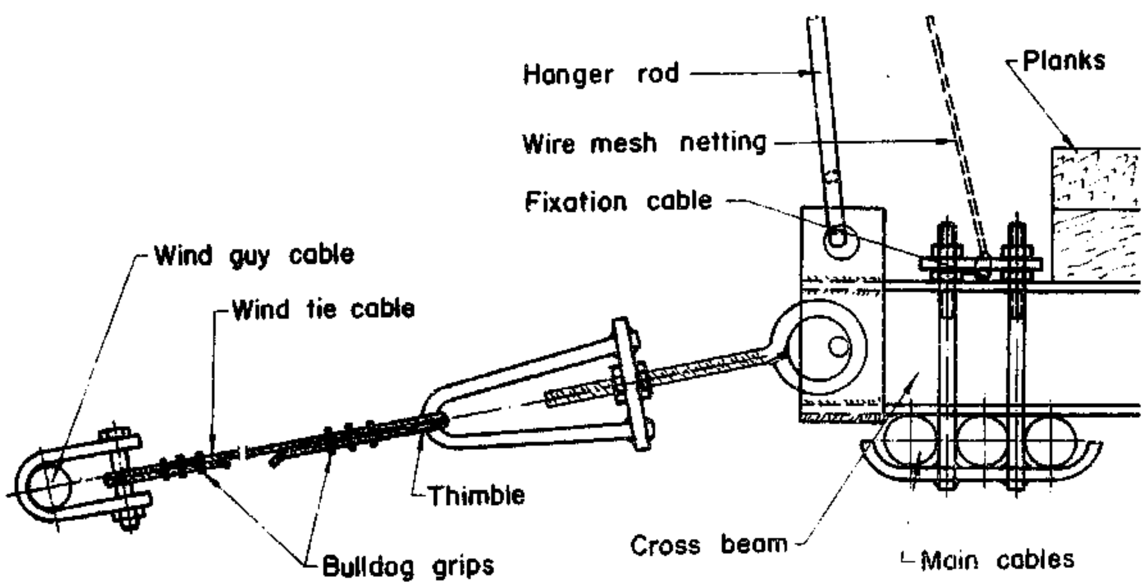
Mark the windguy cables and fit the windties as in method one. Bring the windguy cable in position along the bridge (outside the suspenders) and fix the windties to the walkway beams. After that fix the two ends of the windguy cable to the anchorage. With the tirfor you have to give the required pre-tension in the windguy cables. Tie both windguy cables simultaneously to avoid an unsymmetrical load on the bridge.

After finishing all these jobs retie the windties with the clamps provided for this purpose.

SKETCH 22



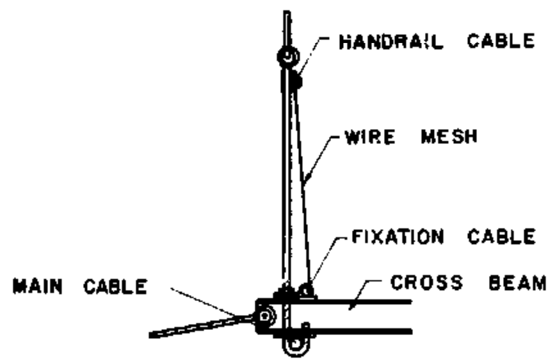
All measurements required for this work, such as the distance between the ties and the windguy cable and the length of the ties are given in the general arrangement.



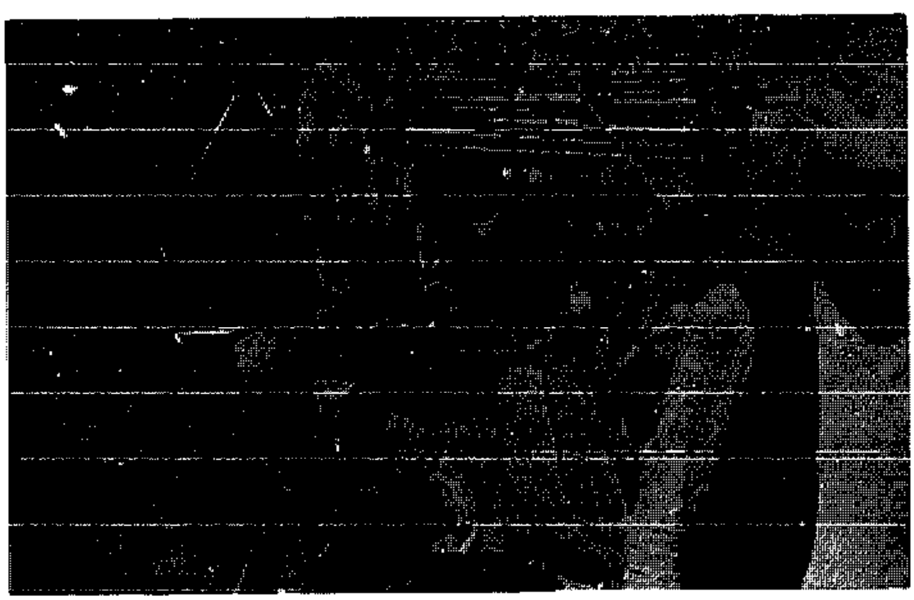
lo.5 Finishing off

There now remains the fitting of the Fixation Cable,Handrail cable,wiremesh and planking.The wiremesh has to be fixed properly at the fixation cable and at the handrail cable.

SKETCH



The planking should also be well and correctly fixed.All work required to finish off the bridge are mentioned at the end of this chapter.



Fitting of planking

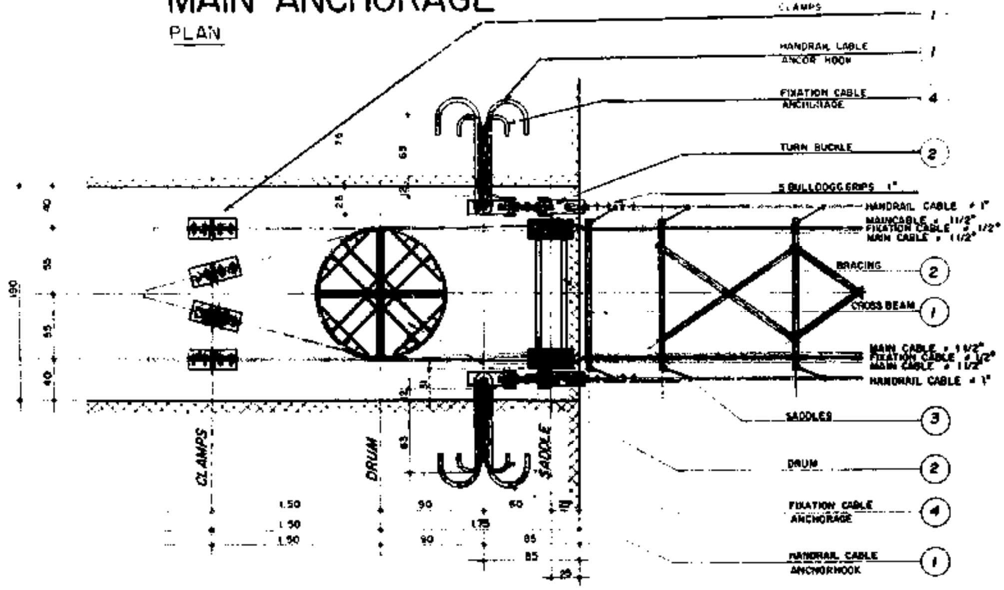
10.6 Erection of a suspended bridge

10.6.1 Fitting of main cable and handrail cable

The method of how to pull the cable over the river is the same as shown under suspension bridges. The only difference is the fixation of the cables. Each maincable has to be turned round the drum three times, sometimes even more. If this is required it is mentioned in the general arrangement. The cable end has to be fixed with clamps at the back. All hooks and clamps and the drum are shown in the lay-out example below.

MAIN ANCHORAGE

PLAN



ONE CABLE END HAS TO BE TURN ROUND 3 TIMES

BRIDGE ERECTION

Suspended Bridge

No. : 1o.6o2

Date : 28.12.76

Sig : Pandrau

The following procedure should be used to get the cable into the right position:

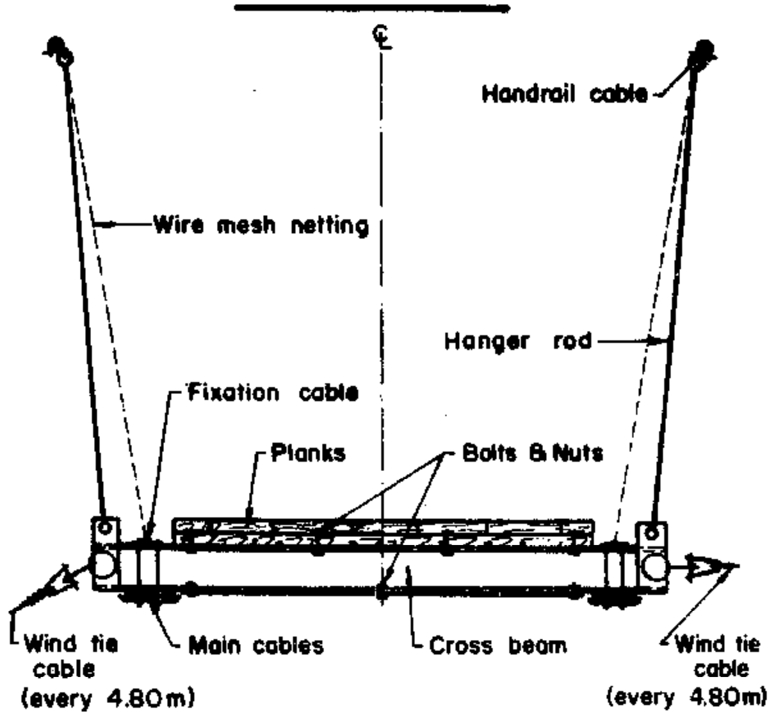
1. Turn the cable three times round the drum on one river bank.
2. Fix the cable end with the clamps.
3. Do the same thing on the other bank. The sag should be about 20 cm less than the required hoisting sag.
4. Loosen the clamps and adjust the main cable to the correct sag. The cable will move round the drum if you hammer smoothly with a wooden or rubber hammer on the cable around the drum.

After fixing the main cables fix the handrail cable in a parallel position to the main cable. The handrail cable is fixed to the turnbuckle hanging on the handrail anchorage hook (see lay-out drawing).

10.6.2 **Walkway and hanger fitting**

The walkwau m.s. cross beam channel and the hangers will arrive at the bridge site as one unit -e.g. the hangers are menbers of the cross beam unit. To fit this item no trally or such is required.

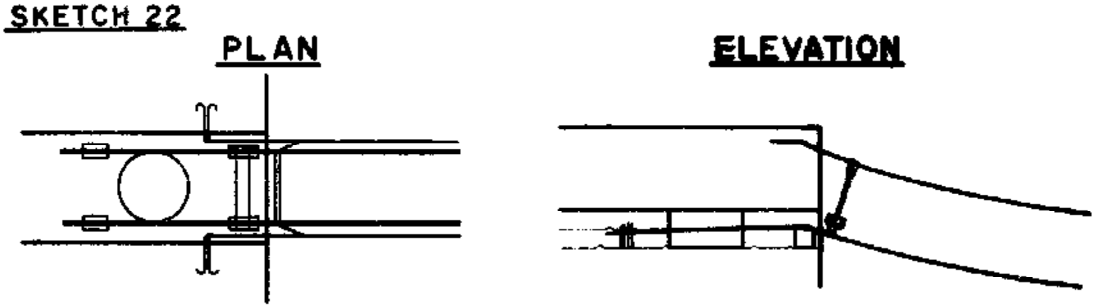
WALK-WAY



Fitting Procedure

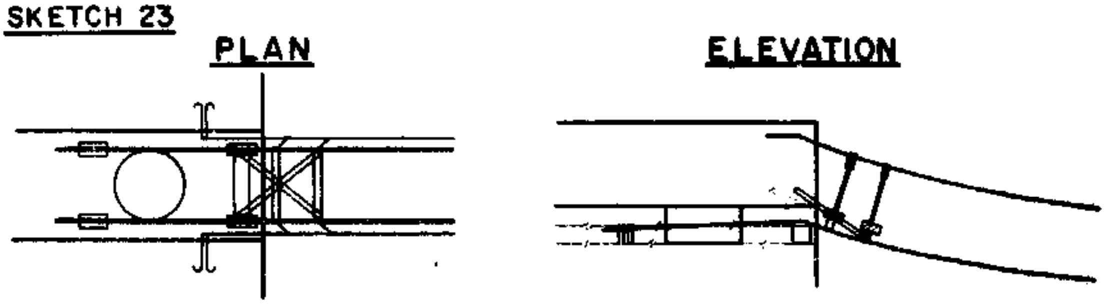
1. Hang up the first walkway element in the handrail cable and tie it to the handrail cable and the main cable.

SKETCH 22



2. Fix the bracing flats on the next element. Fix also the bolt at the crossing point. Hang this element just in front of you on the handrail cable.

SKETCH 23



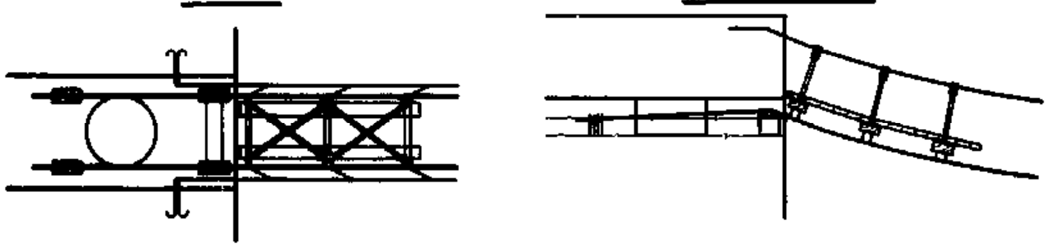
3. Push this whole element in front until you can fix the bracing onto the channel where you are standing.

SKETCH 24

4. Now you can lay some planks over to this new cross beam and go on and fit all nuts required and fit the main cable to the channel.

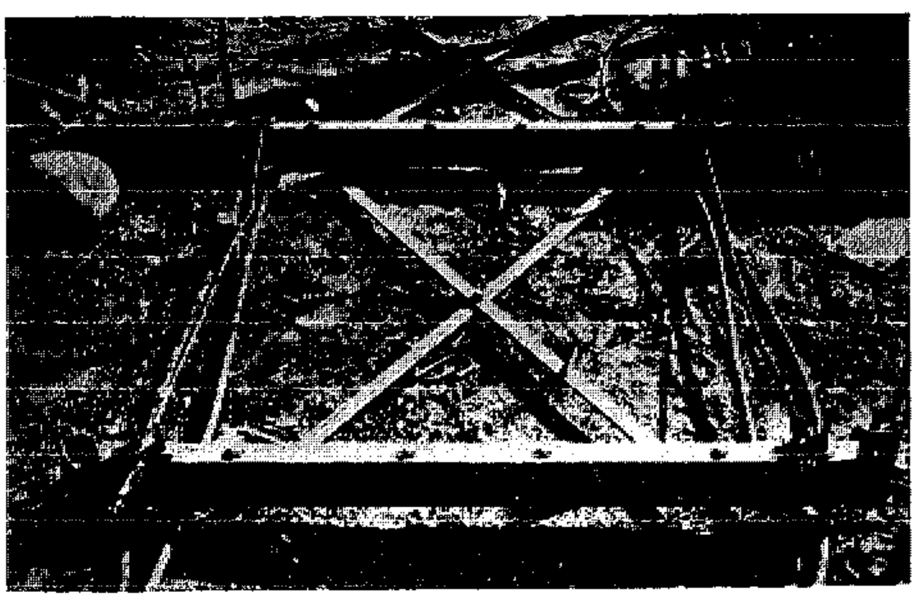
SKETCH 25

PLAN ELEVATION



5. Now everything is ready to bring the next cross beam and fit it in the same way as shown.

After fitting the whole bridge retighten all nuts and fit all locknuts. Then you can fit the remaining planks, the fixation cable and the wiremesh.



Fitted walkway of a Suspended Bridge

10.7 BRIDGE ERECTION USING PARALLEL WIRE CLUSTER (P.W.C.) CABLES

10.7.1 ERECTION PROCEDURE

After completion of the foundations, as far as necessary for the wire anchorages, the "spinning" or pulling of the wires or wire groups can be commenced. The pulling and adjustment is in principal exactly the same as for stranded wire rope cables, except that the forces employed are very much smaller.

For small bridges up to 80 m span, a pilot wire is pulled across from one anchorage and adjusted to the correct level. The remaining wires are then erected using the pilot wire as a guide. Following this, work can commence on the erection of the walkway which is fixed to the cross-beams. In order to allow for any irregularities in the parallel wire groups it is also possible to connect the cross-beams together with wire netting. The cross-beams are then pulled loose across the wires from both banks to the middle. In this way possible differences in the wire length are allowed for. All other erection stages are normal, such as erection of the wires for the handrails and wind bracing and fixing of the clamps and other fittings on the walkway.

For larger spans it is advisable to work from a cat-walk, which as an erection aid is simply designed and easy in construction. It consists of 2 main cables (12 wires for 300 m span), timber cross-beams at 1.5 m centres and wire mesh. The handrail supports are fixed with steel bar stirrups at every second or third cross-beam. Single bridge wires are used for both handrail and middle rail. If one river bank is difficult to reach, then the cat-walk can be erected as the first stage of construction.

The cat-walk can be anchored on either bank with the help of tree trunks sunk into the banks. Erection of the cat-walk cross-beams and the wire netting is carried out from each side. Since the wire netting is continuous and the cross-beams hang underneath the cables, the erection work can also be continuous. For this purpose a draw rope is used from each side in order to pull the cross-beams and the wire netting into the middle. When both ends reach the middle, they are joined and the cross-beams clamped to the cat-walk cables.

The cat-walk cables can be used later as either handrails or wind-guys and incorporated into the final bridge. With the completion of the cat-walk and the foundation, the pulling and erection of the main cables is a comparitively simple business. After the erection of the pilot wires for each cable, the remaining wires are pulled over and adjusted in the middle to the same level as the pilot wire. After pulling across between 30 to 40 wires, temporary clamps are installed at every 30 to 40 m so that the loose wires are prevented from being displaced by either wind or sun effects. After this the permanent cross-beams can be installed working from the middle outwards. All remaining works follow in the same order as for normal wire rope cable bridges. It should be noted that the use of cat-walks is also well suited for the other wire rope cable bridges in order to achieve optimum erection. The cat-walk is especially useful for the adjustment and collection together of the cables as well as enabling much smaller pulling forces to be used during the pulling across of the ropes. The safety of the whole operation is also considerably increased.

For the laying out and bundelling of the wires the previously mentioned temporary clamps should beused for quick opening and shutting. After pulling across and adjustment of the first wires, these clamps can be tied to the wires with thin wire or adhesive tape. After further pulling, the wires are erected along the side of the parallel wire cable and adjusted for height. In the evening after the temperature has fallen the remaining loose wires are incorporated into the cable after the opening of the clamps.

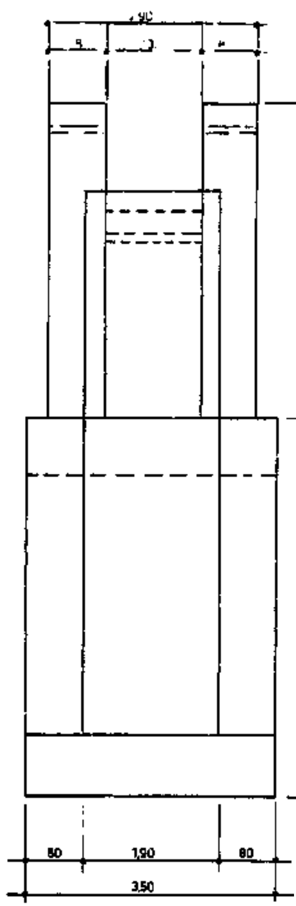
The next morning any remaining wires are incorporated into the cable and the clamps shut again. This procedure holds good for all parallel wire cables as well as for windguys, which have to be pretensioned during erection. After the clamps have been attached to the windguy cable, the ties can be attached which, with the help of further clamps are used to provide the necessary pretension. The temporary erection of the windguy cable is carried out vertically from bank to bank.

10.7.2 P.W.C. CABLE ANCHORAGES

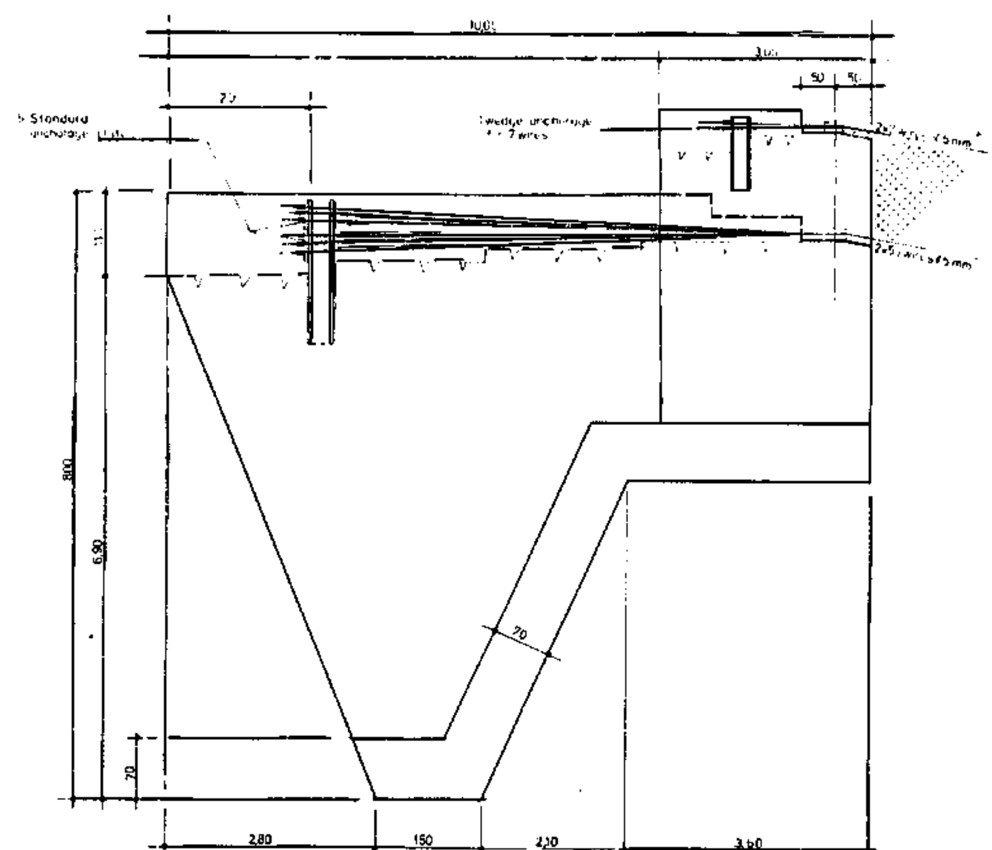
In order to anchor the main P.W.C. cables the wires are looped around the anchorage drum at one bank. On the other side an adjustable anchorage device has to pick up the two wire ends coming from the other end of the bridge. There are two ways of anchoring these. The ends can either be wound around concrete drums and fixed with wire clamps or fixed using cones and wedges. A steel plate is provided with conical holes in which the cones and wedges of each wire end are incorporated.

After completion of the erection work the anchorage system has to be embedded in concrete. The protection against corosion is provided by the application of several layers of bituminous paint.

SECTION A-A



ANCHORAGE BLOCK LEFT BANK
WIRE SYSTEM



HMG Nepal Roads Department Suspension Bridge Division

SATA, Swiss Association for Technical Assistance

BRIDGE ERECTION

Single wire,Anchorage Block type

No. : 1o.7o4

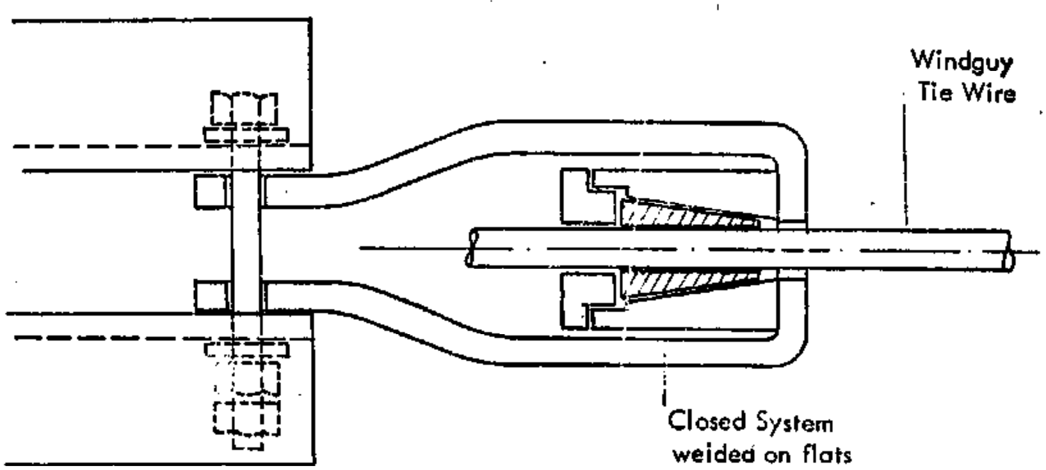
Date : 28.12.76

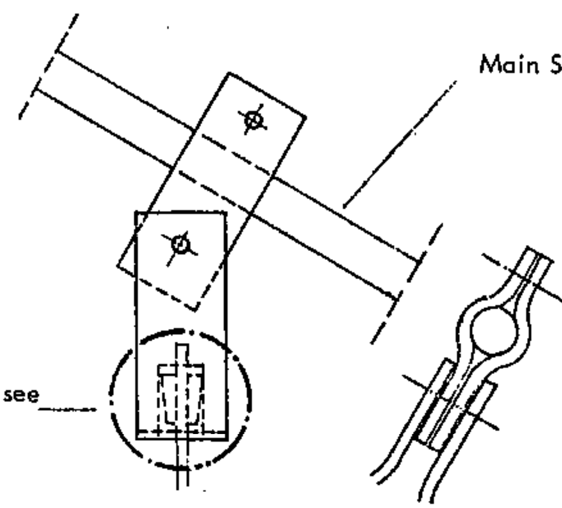
Sig :

BRIDGE ERECTION
:
Single wire

No : 10.705	
Date : 28.12.76	
Sig : [signature]	

DETAIL OF SINGLE WIRE ANCHORAGE





10.8 Final Check-Up

The points mentioned in this chapter are important for the lifetime of the bridge (pre-stress, check of all nuts) and the comfort of the bridge-crossing (pre-stress, smooth curvature). Even after the successful completion of a bridge-construction these points should never be neglected.

1. Smooth curvature of the suspension bridge.

For the fitting of the walkway all suspender-adjustments (turnbuckles) have been put in the same position. After completion the walkway may still zigzag up-down and left-right. Now adjust suspenders and windguy-ties in order to give the bridge a smooth and straight line.

These adjustments are in particular:

- Cross-beams should be horizontal. Check with a carpenter's level or by standing over each beam, legs straddled, and "feeling" the uneveness.
- Due to the windguy-ties the bridge may also zigzag upstream-downstream. Adjust the ties or even the whole windguy-cable until the bridge ist straight. Check by eye, looking from the tower along the walkway.
- The camber of the bridge should show a smooth line. Adjust the suspenders which are higher or lower than this line. Check by eye, keeping the eye near the walkway-cable.

2. Pre-stress in the cable.

Spanning-, windguy- and sidestay-cables should be pre-stressed. This pre-stress can be applied by the tirfor. Fix a loop on to the cable and anchor the tirfor near the cable-end. (Similar to the hoisting). Pull as much as possible, use even a pulley-block to increase the force.

Tighten the movable adjustment. Do not open the bulldog-grips unless the adjustment-beam is at the end of the thread.

Pre-stress during the hottest time of the day when the elongation of the cables reaches its maximum. Pre-stress two or three times, on consecutive days.

The pre-stress in the spanning-cables of a suspension bridge can be increased by loading the whole bridge with sandbags or stones (up to $\frac{1}{2}$ of the life-load). After the cable-fixations have been tightened, unload the bridge again.

This work could affect point 1 and thus require some re-adjustment of the walkway.

3. Check of all nuts.

All the nuts and bolts of pylons and walkway should be controlled and retightened. Do this work systematically so that no bolt remains unchecked. Damage the threads of bolts under regular dynamic stress (e.g. bolts for the connection of windguy-ties to the cross-beams) in order to avoid a self-opening of the nuts. This is not necessary if a lude nut is provided for this purpose.

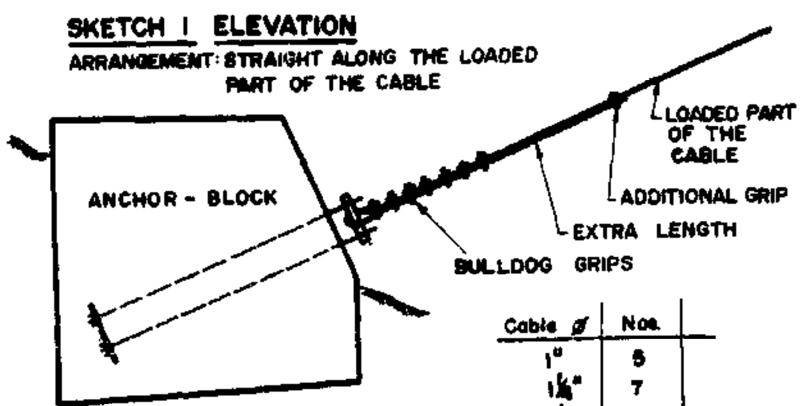
4. Tightening of bulldog-grips, Arrangements for cable-ends.

All bulldog-grips have to be checked and tightened again. Already during the erection-time they must be checked every morning and evening. All cable-ends should be seized and bound with wire to avoid an opening of the cable.

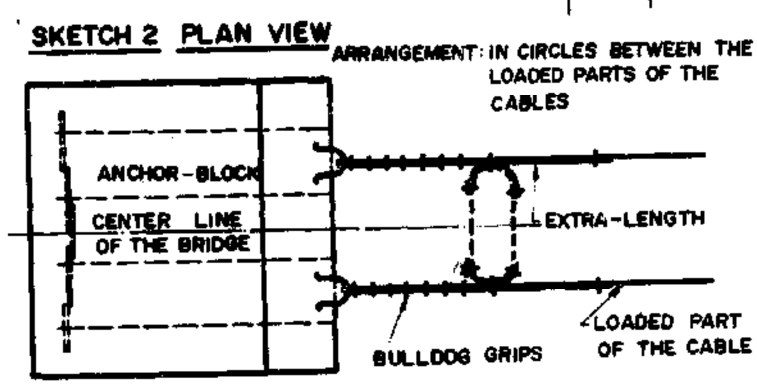
The remaining cable (extra-length) should be fitted with wire or better some spare-bulldog-grips to the loaded part of the cables.

On the rigth two possibilities are suggested for this arrangement.

Unless there is a particular reason, do not cut the remaining pieces of the cables. If ever one day the bridge is dismantled and set up at another site, this extra-length of cable may be useful.

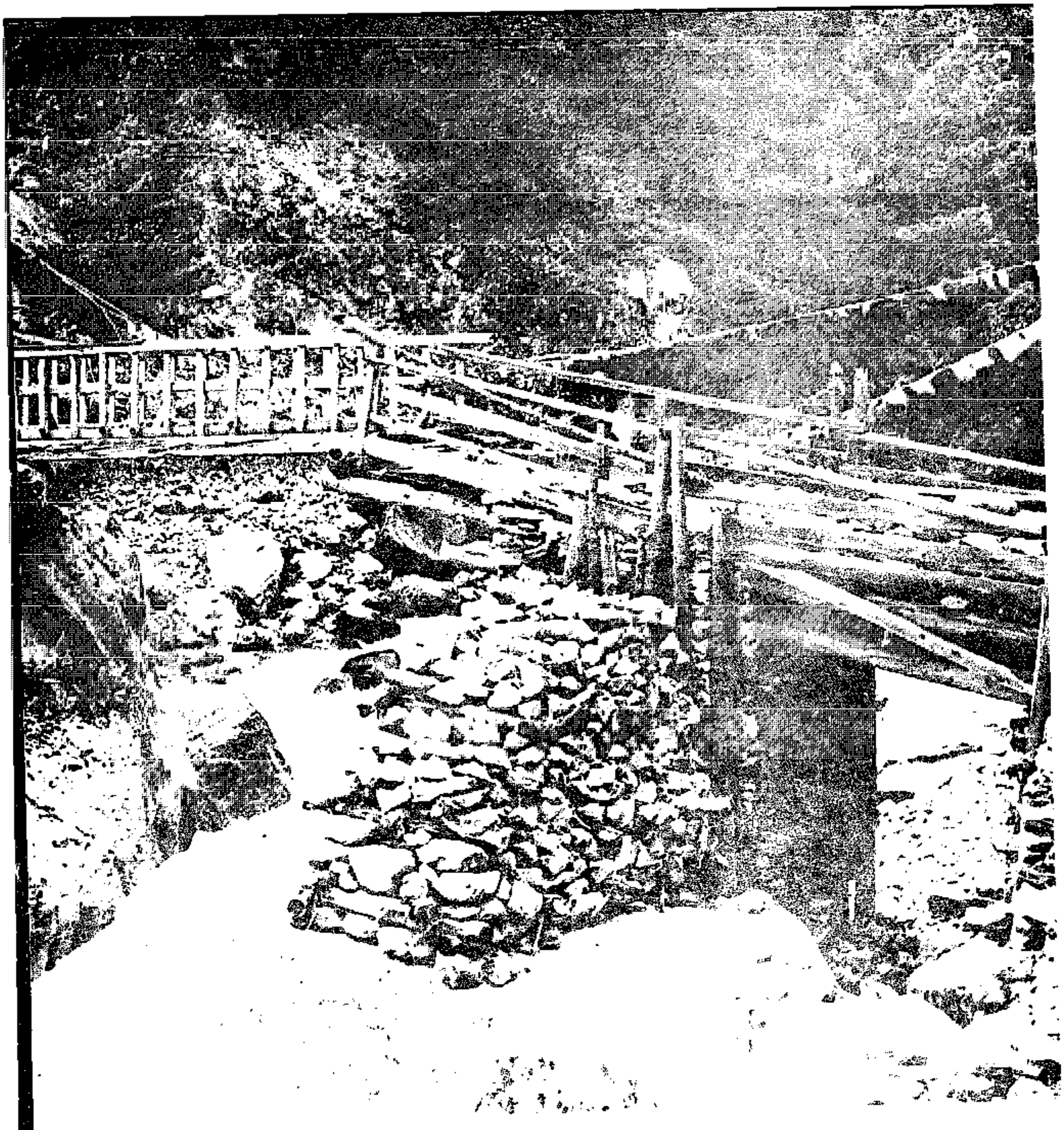


Cable Ø	Nos.
1"	5
1¼"	7
1½"	7



5. Fitting of the wiremesh-net.

Pay attention that also the fitting of handrail-cable, fixation cable and wiremesh-net is done in a neat and clean way.



II. TRAIL IMPROVEMENT

11. <u>Trail Improvement</u>

Very often on the way to a bridge- or survey-site you have to pass old bridges. Sometimes they are in very bad condition or even not crossable. With a small maintenance work these bridges could be brought in a proper condition. If you see such bridges on the way, make a small maintenance report as shown below in the example of Tamor Khola. The work required should be in a good proportion with the bridge type. Of course it is not possible to bring the bridge in a condition like a new one, but to maintain it that it will be useful for some more years.

<u>Bridge over Tamor Khola</u> by Handrun
Span: 64 m
Koordinates: 87°37'/27°23'   Map 75/N/15

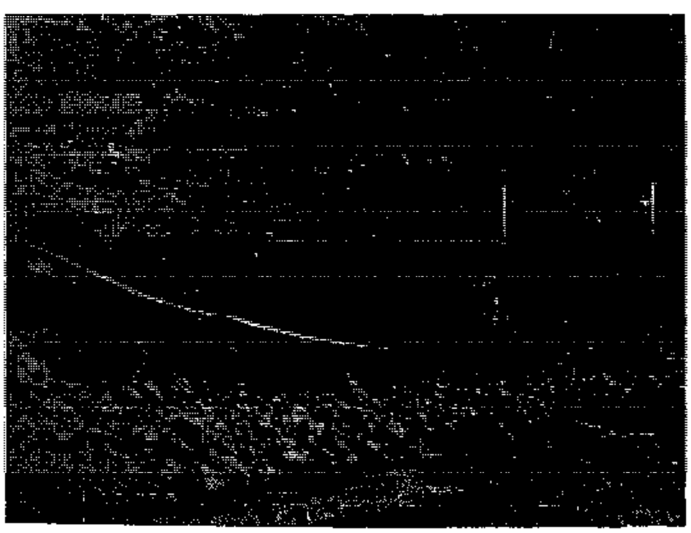
<u>Actual condition of the bridge</u>

The main cables of this bridge are hanging in unequal position. Also about 50% of the suspenders are not in good condition. The planking also needs a revision.

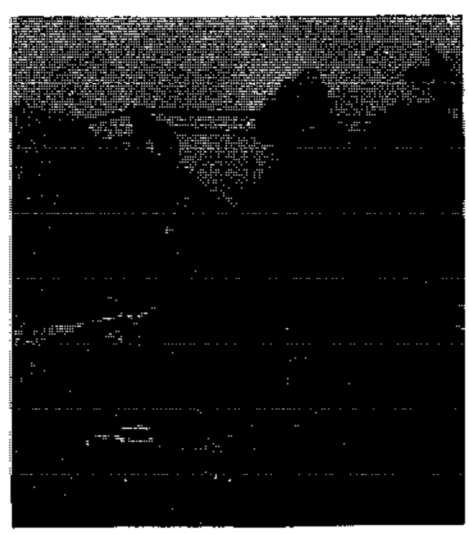
<u>Works required to do</u>

- Revision of the planking
- Replacement of some suspenders
- Correction of the cable position

View from left bank



Wooden tower of the bridge



TRAIL IMPROVEMENT

Maintenence Reports

No. : 11.102

Date : 27.2.77

Sig : Landiau

Bridge over Tamor Khola near by Thumba

Span: 41 m

Koordinates: 87°40.5'/ 27°23'   Map 72/M/15

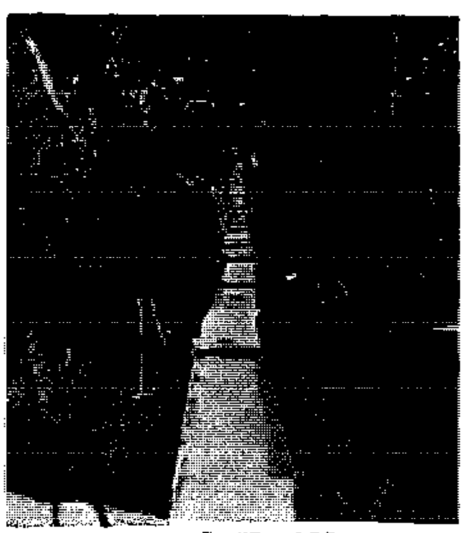
Actual condition of the bridge

This old chain bridge is not in bad condition. Only the planking is too old and should be changed. The suspenders in the middle are very short, so that it is difficult to cross the bridge with heavy loads. Like all chain bridges it swings very much during walking.

Works required to do

- new planking

Bridge over Tamor Khola



View from left side

View from right side

TRAIL IMPROVEMENT Maintenence Reports	No : 11.103 Date : 27.2.77 Sig : [signature]

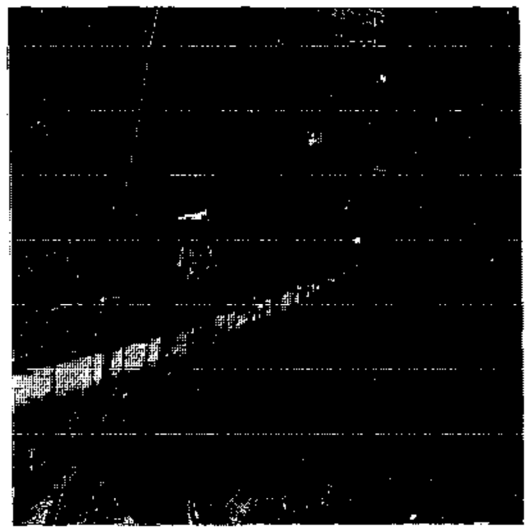
Bridge over Sinse Khola near confluence with Tamor Khola

Span: 34 m

Koordinates: 87°42.5'/ 27°26'   Map 72/M/15

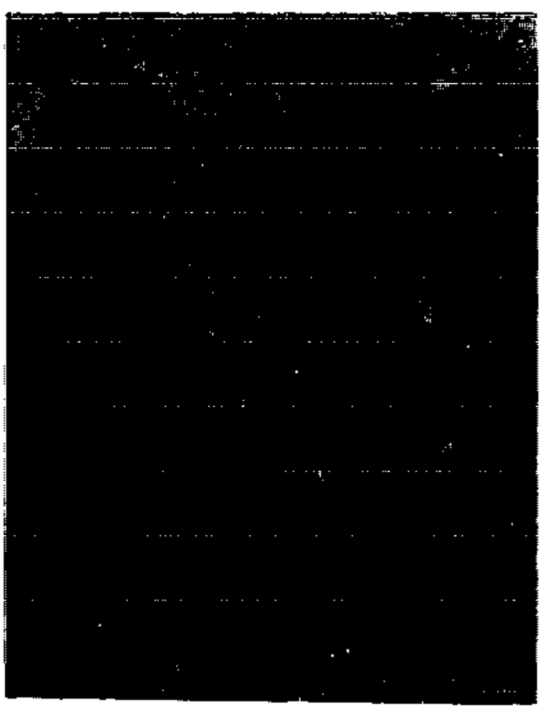
Actual condition of the bridge

The condition of this bridge is not bad. At the moment no special maintenance work is required.

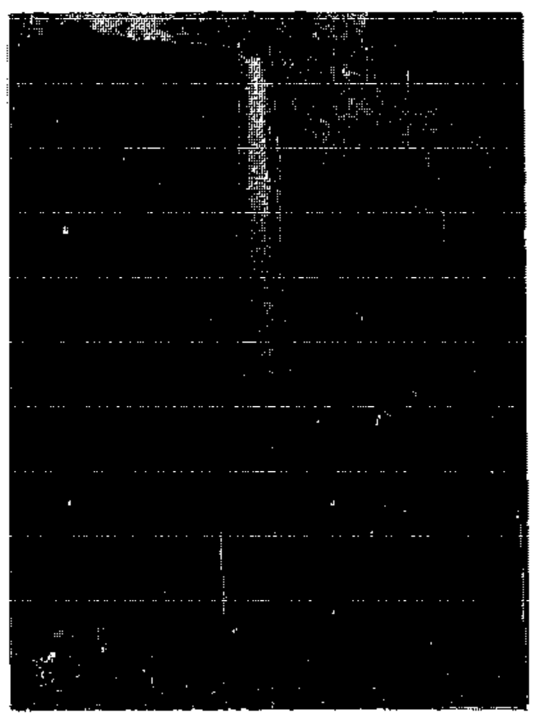


Side view of the bridge

Wooden tower of the bridge



Walkway



TRAIL IMPROVEMENT

Maintenence Reports

No. : 11.104

Date : 27.2.77

Sig : Laudrau

Bridge over Tamor Khola near Sinwa

Span: 83 m

Koordinates: 87°42'/ 27°27'

Actual condition of the bridge

This bridge is in a very dangerous condition. The tower (masonry tower) is partly broken. Also the plànking is in a very bad condition. The best way to maintain this bridge is to built a new bridge.

Front view of the bridge

Tower left bank

Detail of planking

SATA, Swiss Association for Technical Assistance

TRAIL IMPROVEMENT Maintenence Reports	No. : 11.1o5 Date : 27.2.77 Sig : [signature]

Bridge over Tamor Khola near Numa Khola Dhoban

Span: 63 m

Koordinates: 87°44.9'/ 27°29'   Map 72 M/11

Actual condition of the bridge

Due to the length of the bridge the wind load is quite high. This bridge does not have windguy anchorage. Due to that it wings very much in windy times.

Works required to do

- Windguy is very necessary.

Front view of the bridge

Detail of the bridge

TRAIL IMPROVEMENT	No : 11.106
Maintenence Report	Date : 27.2.77
	Sig : Pandvan

Bridge over Tamor Khola near Simbua Khola Dhotan

Span: 43 m

Koordinates:

Actual condition of the bridge

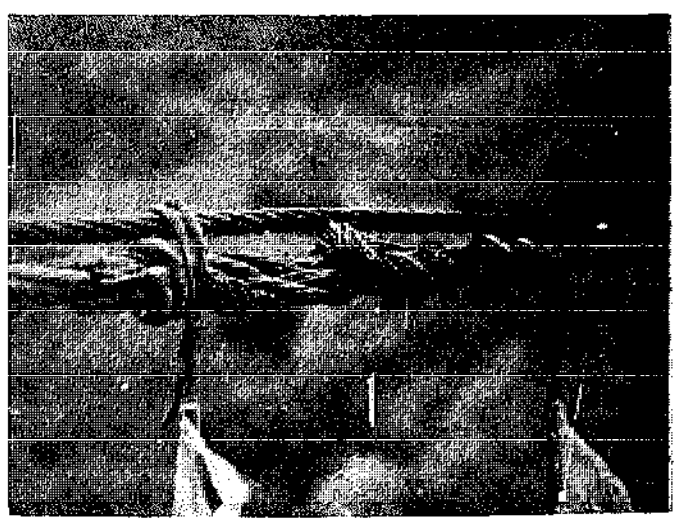
This bridge fell down on 2020. With the remaining parts they built this new bridge. But one of the cable is in a very bad condition. The bridge itself is not bad but the cables will not work for a long time.

Works required to do

- New main cables

Walkway

Cable connection



SATA, Swiss Association for Technical Assistance

TRAIL IMPROVEMENT Maintenence Reports	No. : 11.1o7 Date : 27.2.77 Sig : Vaudan

<u>Bridge over Tamor Khola</u>

Span: 25 m

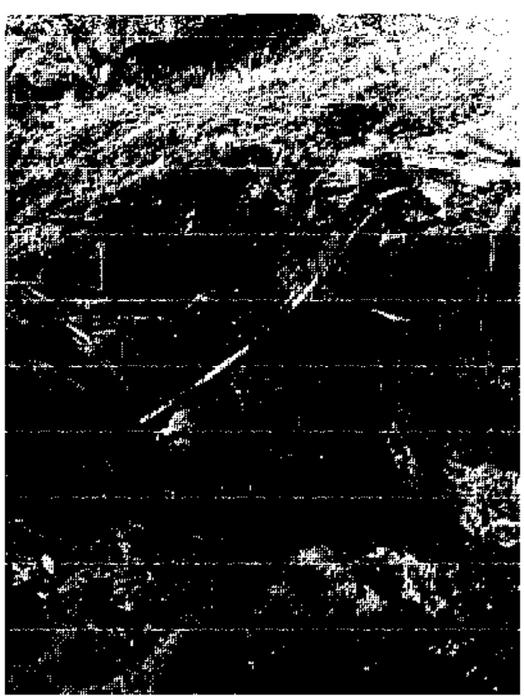
Koordinates:

<u>Actual condition of the bridge</u>

On this bridge some maintenance work has been done some time ago. There is a new planking. So no more maintenance work is required at the moment.

Walkway

Left bank



Right bank

TRAIL IMPROVEMENT

Maintenence Reports

No. : 11.1o8

Date : 27.2.77

Sig : Landau

Bridge over Tamor Khola

Span: 23.30

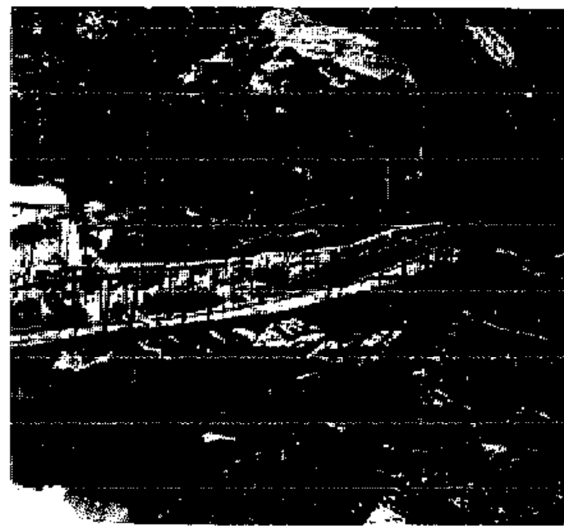
Koordinates:

Actual condition of the bridge

The suspenders are not attached in correct position. Also the planking is not very good. The sag of this bridge is too less.

Works required to do

- ✓ Correct the suspender-position
- Repair the planking
- Correct the cable-position



Left bank

Walkway

Right bank

12. MAINTENANCE

MAINTENANCE General	No : 12.101 Date : 1st March 77 Sig : [signature]

It is a generally uncontested fact that constructions should be checked regularly and require periodic maintenance work. If this is neglected the constructions are damaged and if they are not maintained regularl, , the costs for repairs become unreasonable. They may even collapse which leads to expensive new constructions.

In tragic cases even lives may be lost. A bridge does not fulfill its purpose if for example it becomes useless due to look for other routes.

It is legimate to wise that existing and new bridges can be checked and maintained by a repairs service. To make this possible the following is necessary :

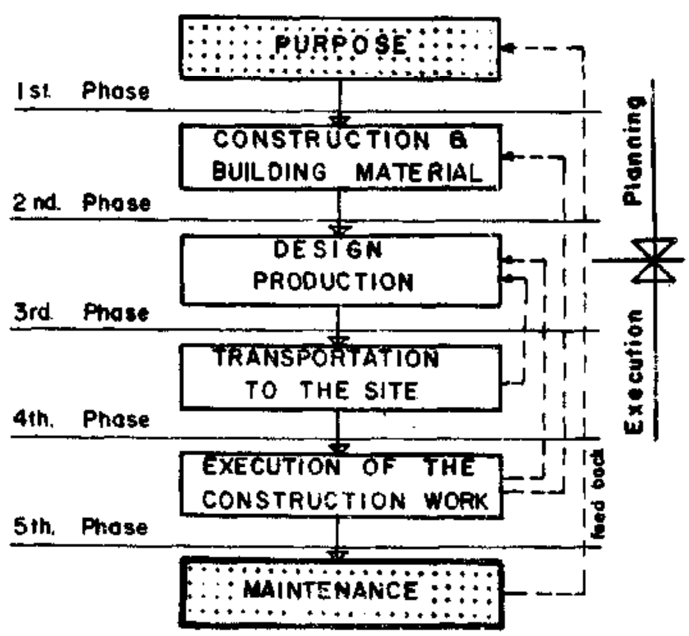
- a record of existing constructions
- a supervision service
- plans for the necessary repair work
- money
- organisation and execution

The following two maintenance reports have been added to the record of existing constructions which are in need of maintenance and repair work (refer to pages 12.201 to 12.303). Maintenance reports compiled by SATA - Engineers may provide a solution as to how to report on bridges which are in need of maintenance work.

It is important to mention that the reports should contain exactly what material and work are necessary. This typ of report could easely be written up for example when visiting building sites.

However it seems important to me to stress the fact that the organisation of maintenance is a component of the construction work. A bridge is not finished just because it has been inaugurated and opened to the public.

CONSTRUCTION PHASES



MAINTENANCE

Maintenance Report of the Adamghat Suspension Bridge

No.	: 12.201
Date	: 1st March 77
Sig	

Adamghat Suspension Bridge, completed 1977

Trisuli River, Span 113,20 m

Condition of the Bridge on April 1976

Presently the wind guy cables are hanging useless. The tie rods to the walk - way (gangway) cable are not in the correct positions nor are they attached properly. Because of this the bridge swings too much and the walk-way is slightly crooked. The windguy anchor blocks are placed completely out of the center line of the wind guy cable. The main anchorage on the right bank is needing a lot of backfilling, otherwise there will once be an erosion problem.

Work required for finishing the bridge

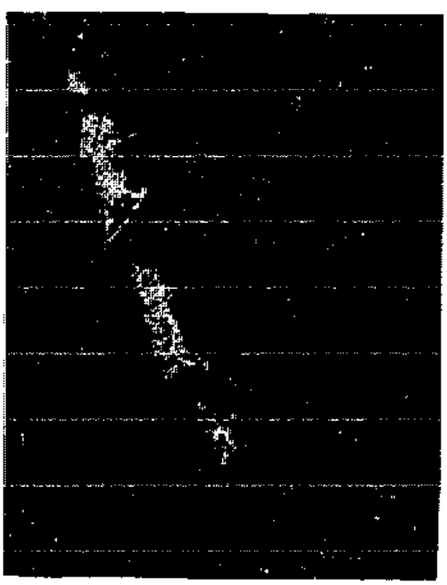
a) Backfilling on the top behind the main anchorage block on the right river bank; about 25 M3

b) The wind tie rods have to be replaced with wind tie cables Ø 3/8".

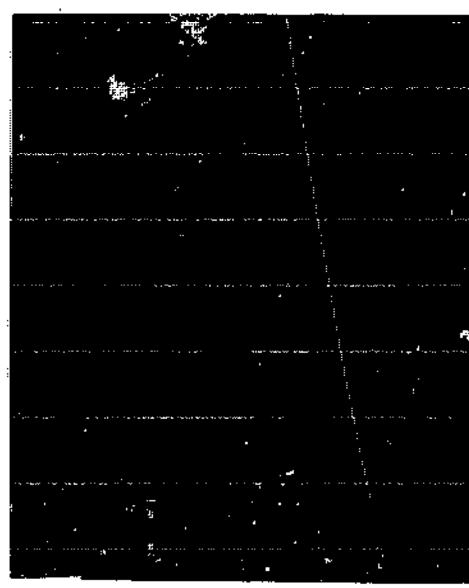
c) There are on every second suspender one hand rail cable to be fixed.

d) The walk way cable should be tightened properly.

View of the left main cable anchorage block



The wrong placed wind guy anchor block on the left river bank



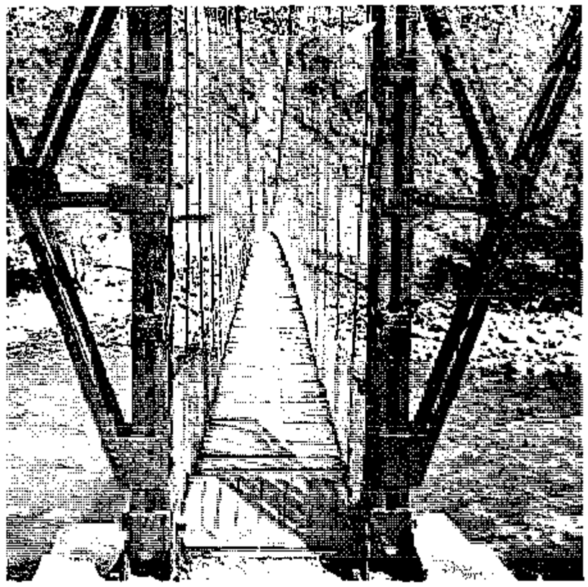
MAINTENANCE

Maintenance Rep-rt of the Adamghat Bridge (continuation)

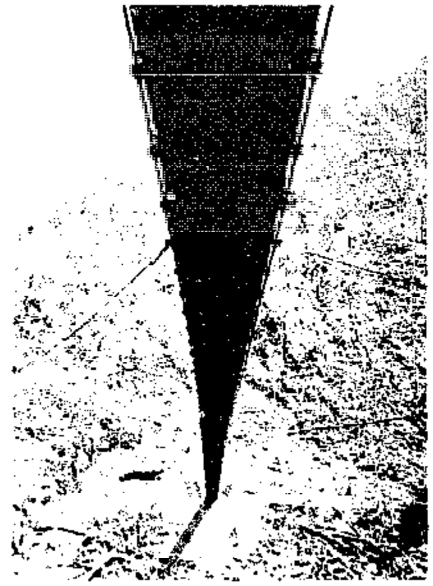
No. 112.202

Date 1st March 77

Sig :

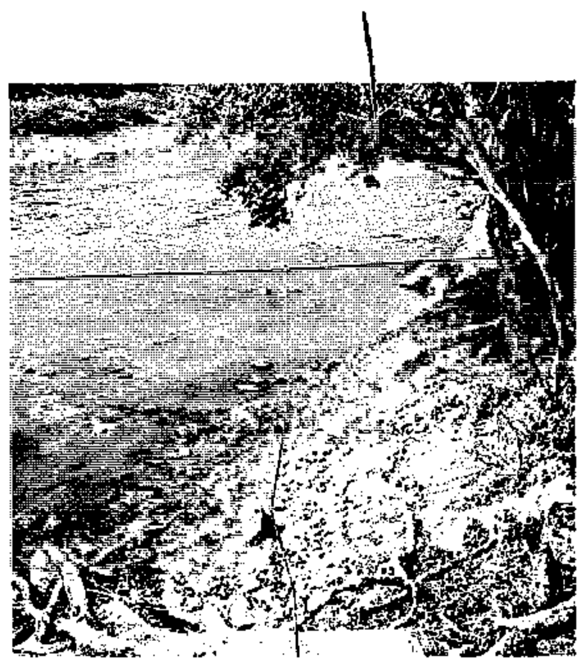


walk-way of the Adamghat bridge



soffit of the bridge

front elevation of the main anchorage block on the left bank



untightened wind tie is to replace with cables

MAINTENANCE Maintenance Report of the Jairamghat Suspension Bridge	No. : 12.301 Date : 1st March 77 Sig [signature]

Jairamghat Bridge, Dudh Kosi

1. Condition of the bridge on 29 Jan. 1976

Presently the wind guy cables are hanging useless. The tie rods to the walkway cable are not in the correct positions nor are they attached properly. Because of this the bridge swings too much when the wind blows and the walkway is crocked. One wind guy anchor block is being eroded by a stream when it rains.

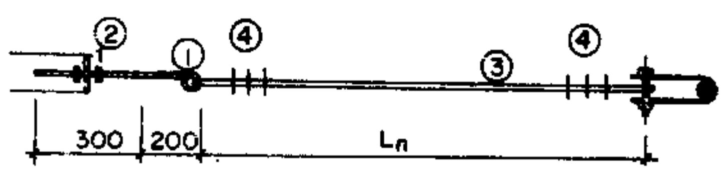
The suspender rods are presently attached to the walkway cable clamps with only one 5/8" Hex. Nut. In addition many of these nuts are missing. Each attachment requires two 5/8" Hex Nuts.

The decking planks are also worn out and should be replaced.

2. Work required for repair

a. Wind Guy Cables;

New [illegible] cables should be installed on the entire bridge.

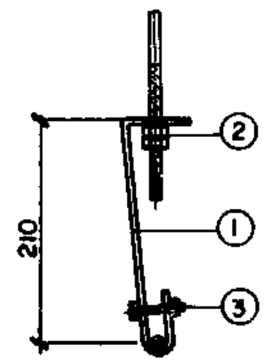


Pos	face (mm)	PC
1.	ø 16, 300, 200	18
2.	5/8" Nut	54
3.	Cable 3/8"ø l_1 = 2.0 m l_2 = 4.5 m l_3 = 8.0 m l_4 = 12.5 m	4 4 4 4
4.	Buldoggrip 3/8"	100

L_1 = 0
L_2 = 0.55m
L_3 = 2.45m
L_4 = 5.66m
L_5 = 10.16m

b. Suspender Rods:

Second nuts should be attached and existing nuts tightended. One walk-way cable clamp is also required.



Walk - Way Cable Clamp

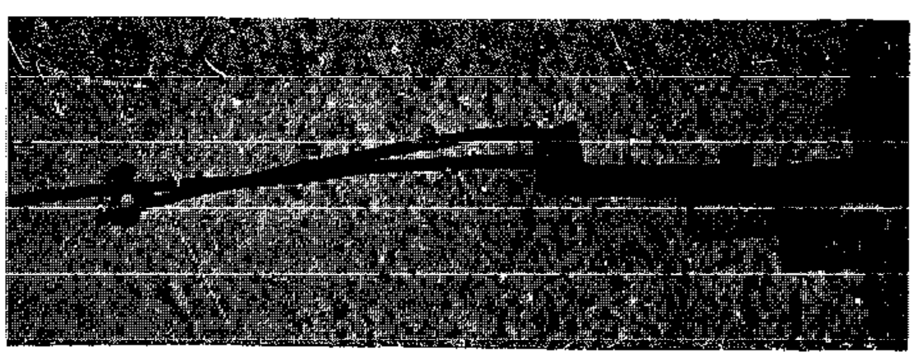
		Pcs.
1	230, 60, 8, 25, 8, Flat 350/65/8, rest	1
2	5/8" Nut	210
3	3" x 1/2" Ø Bolt - Nut	1

c. Decking:

Six or seven planks should be replaced.

3. Costs

Steel and cables	3500/- Nc
Work and transportation	1000/- Nc
T o t a l	4500/- Nc



Tie rod and connection to walkway

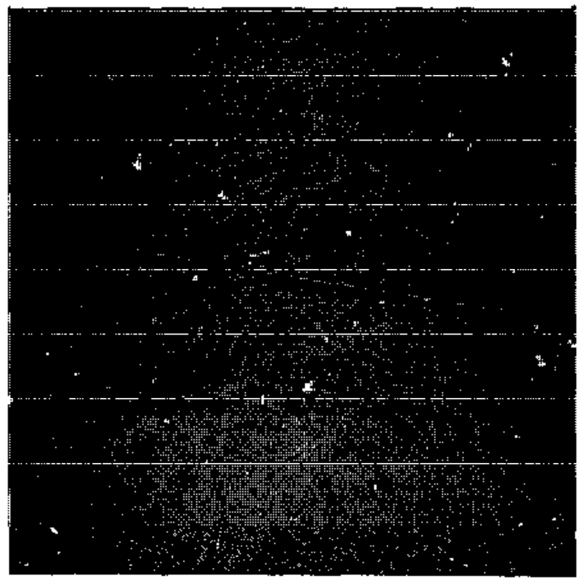
MAINTENANCE

Maintenance Report of the Jairamghat Bridge
(continuation)

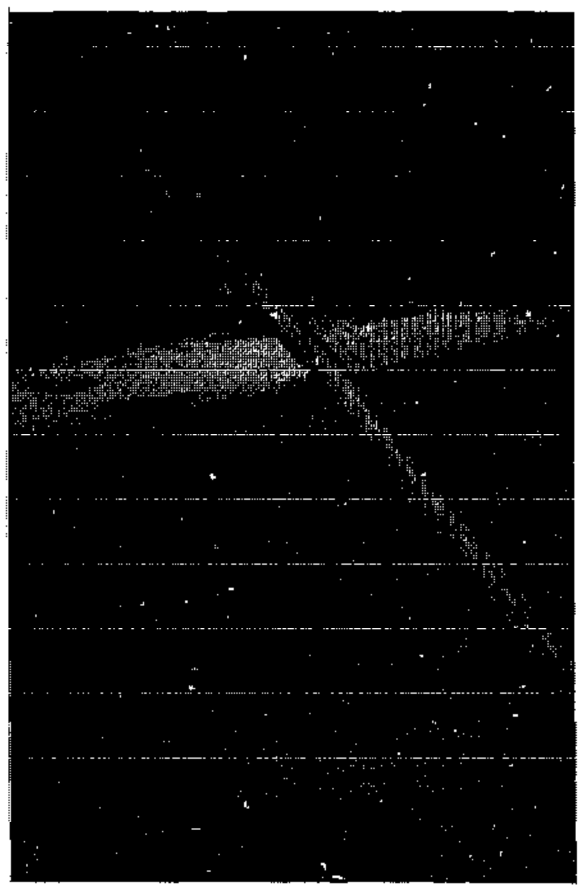
No : 12.303

Date : 1st March 77

Sig [signature]



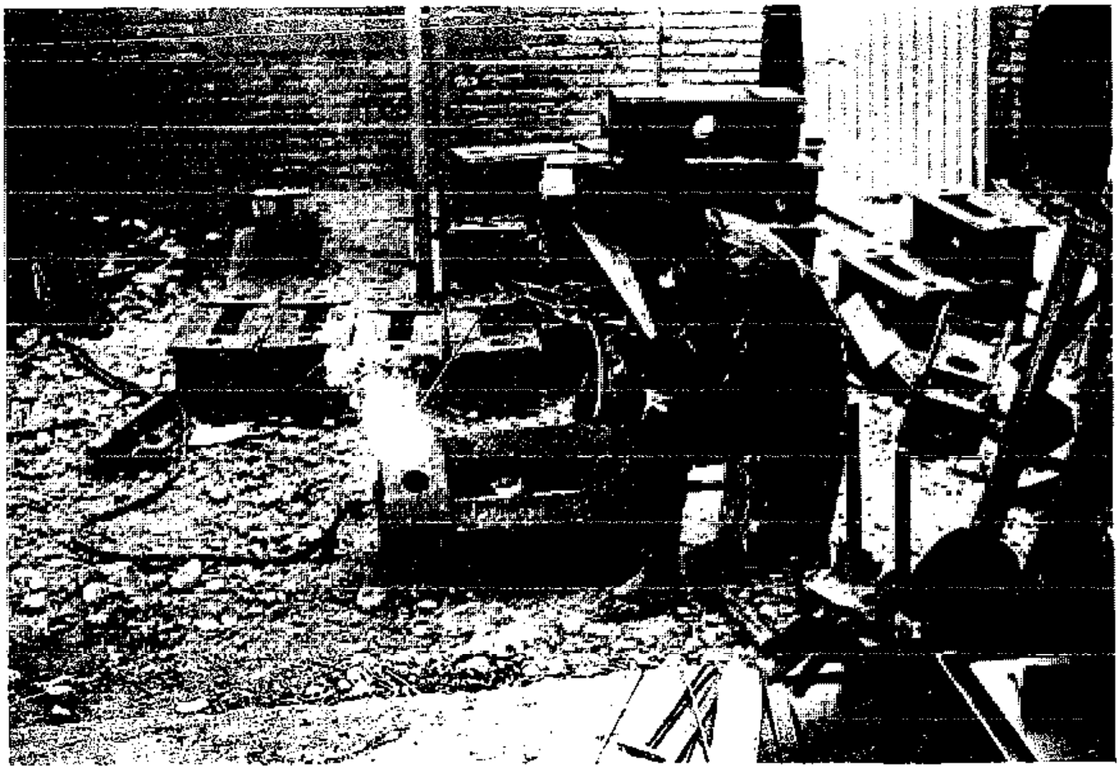
Tie rods and windguy cable



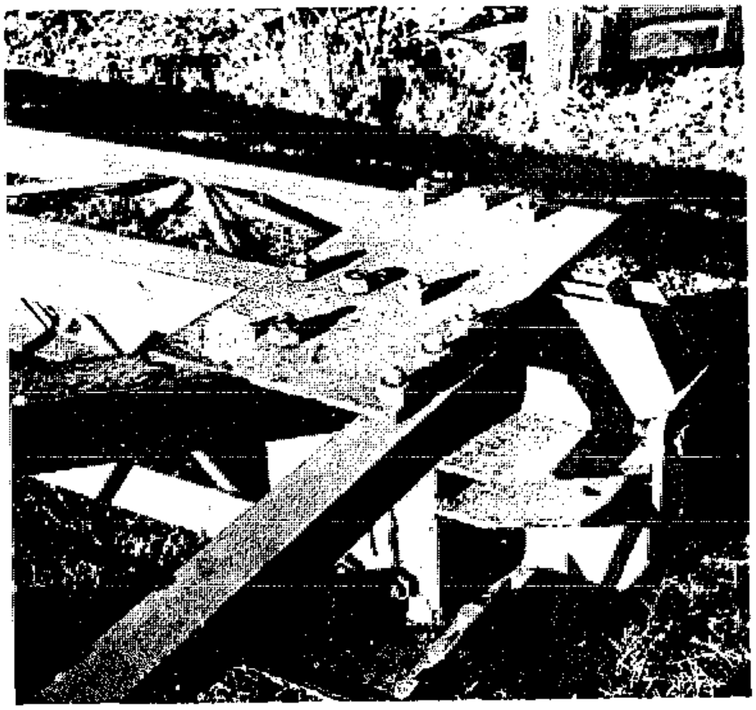
The windguy cable is not
in the correct position.
It should be a parabola
and not straight.

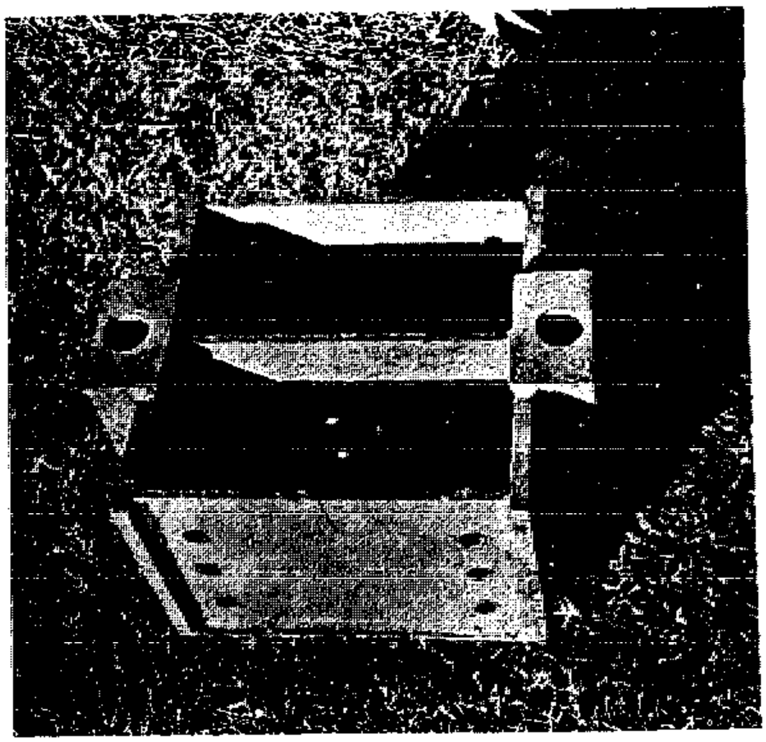
13. PHOTOS OF STANDARD STEELPARTS

PHOTOS OF STANDARD STEELPARTS		No : 13.101
Suspension Bridges	cross-beam of main anchorage pylon bracing element	Date : 1st March 77
		Sig : [signature]

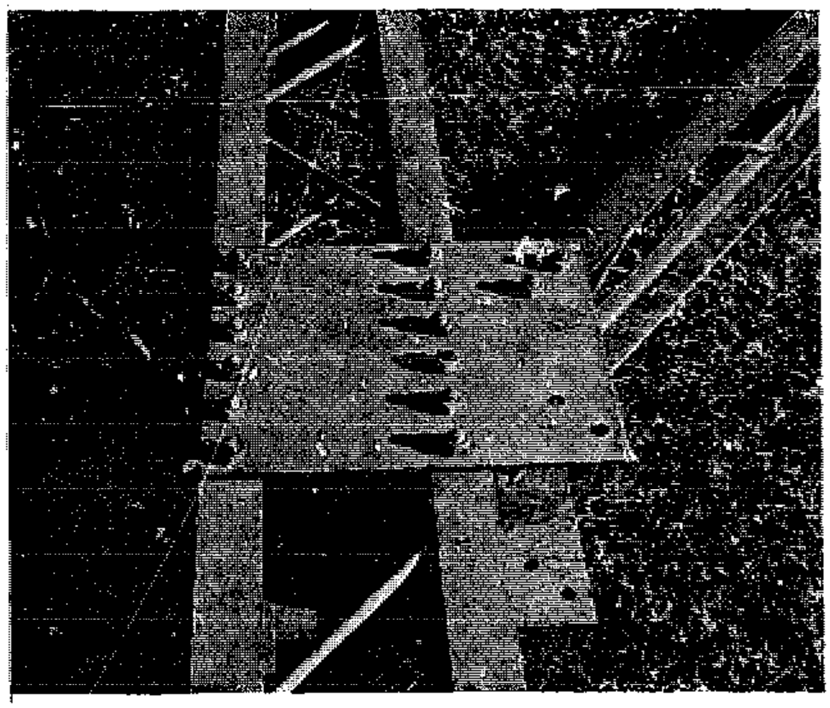


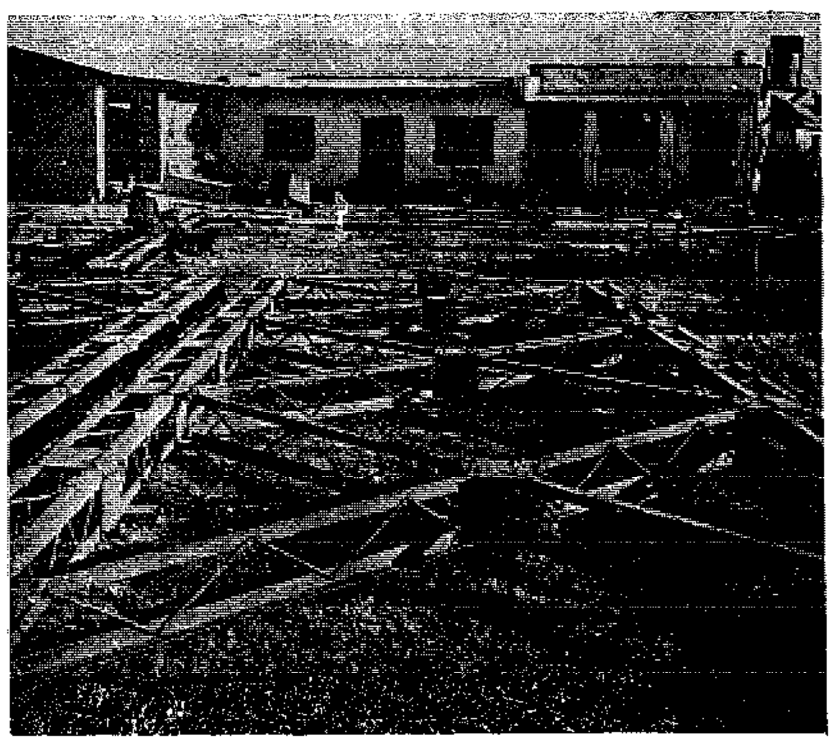
PHOTOS OF STANDARD STEELPARTS		No : 13.102
Suspension Bridges	pylon's cable saddle column shaft hinge element	Date : 1st March 77 Sig : [signature]



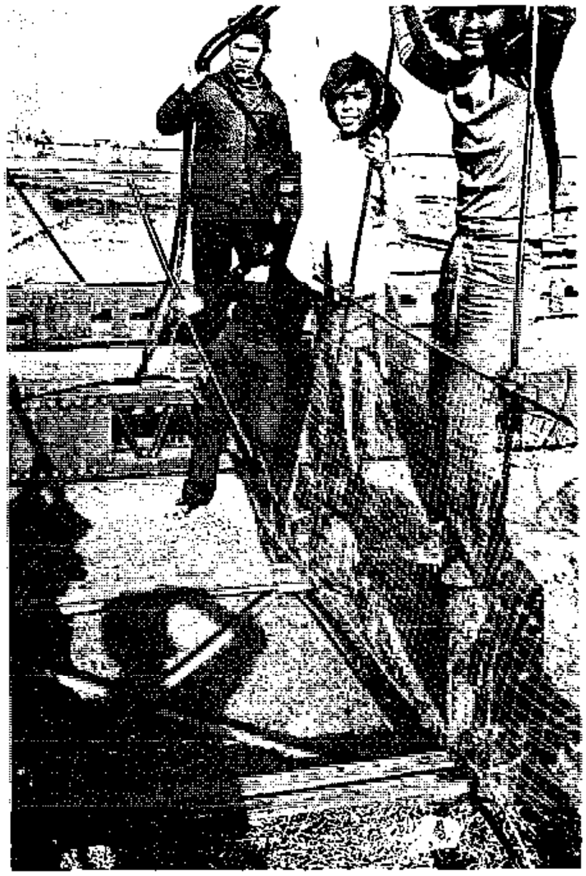


PHOTOS OF STANDARD STEELPARTS		No. : 13.103
Suspension Bridges	connecting plates pylon's shop assembly	Date : 1st March 77
		Sig :





PHOTOS OF STANDARD STEELPARTS		No. : 13.104
Suspension Bridges	walk-way column element J-bolt for walk-way	Date : 1st March 77
		Sig : [signature]



PHOTOS OF STANDARD STEELPARTS

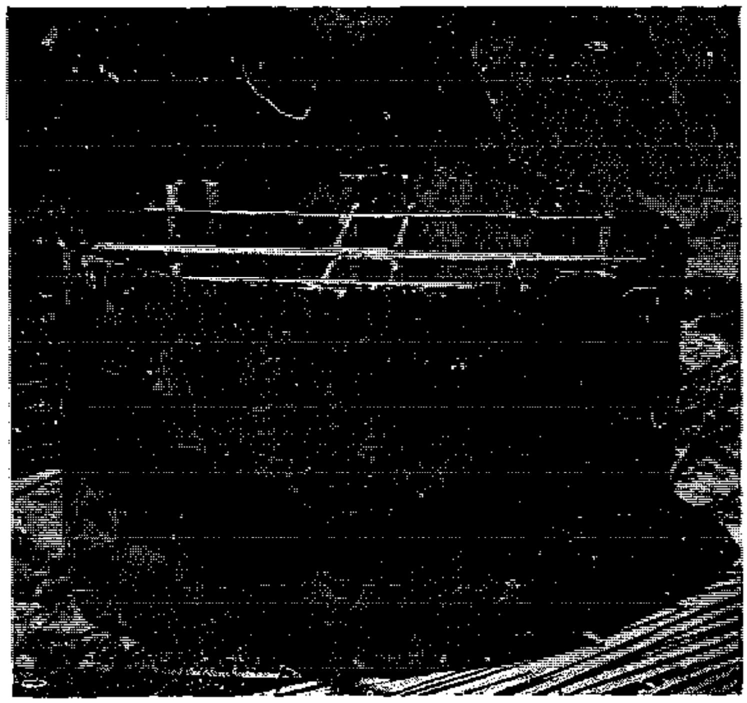
Suspended Bridges

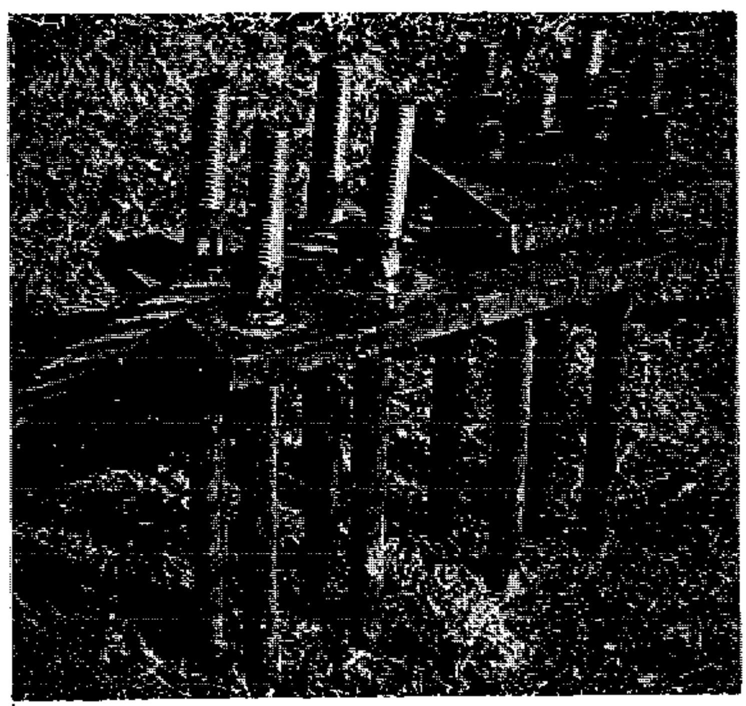
main cable drum anchorage
main cable-end clamp

No. : 13.201

Date : 1st March 77

Sig : for [signature]





PHOTOS OF STANDARD STEELPARTS

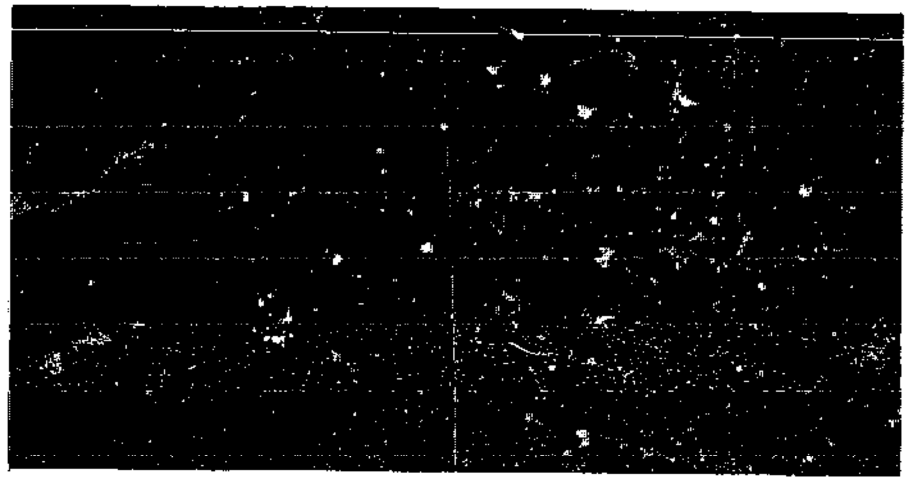
Suspended Bridges

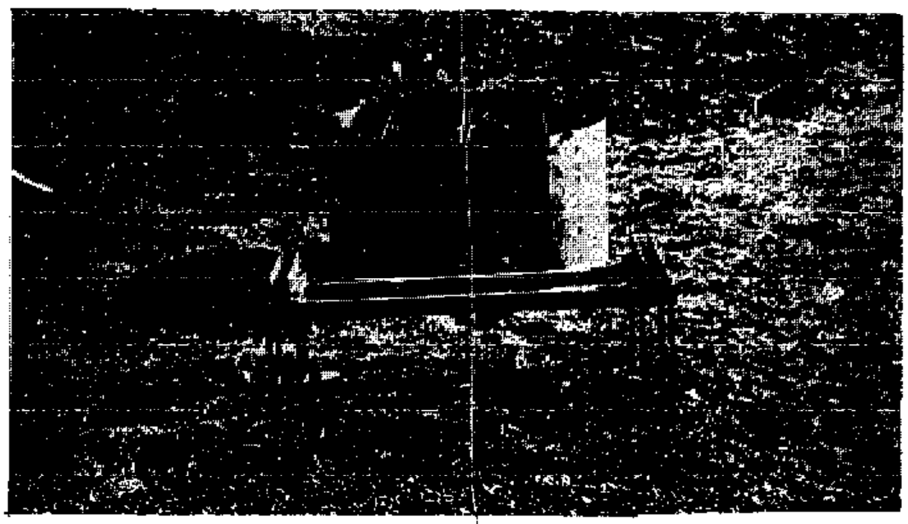
main ancherage unit (s.e)
main ancherage unit (f.e.)
cable saddle

No. 13.202

Date 1st March 77

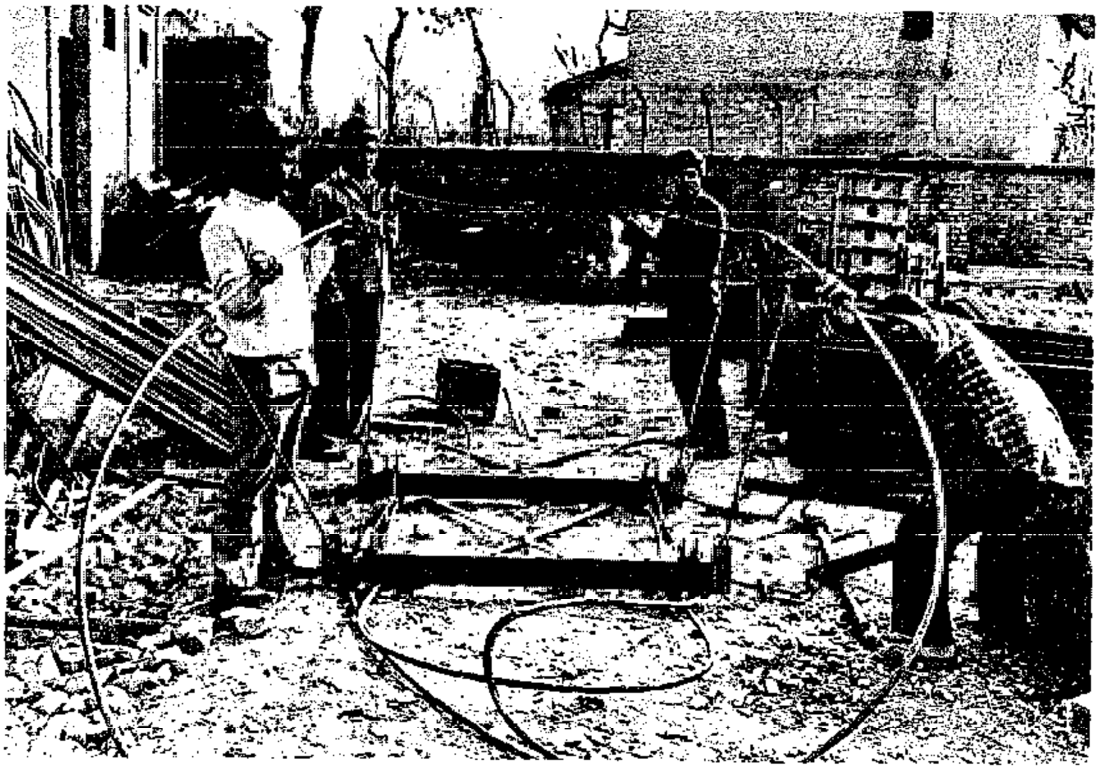
Sig :

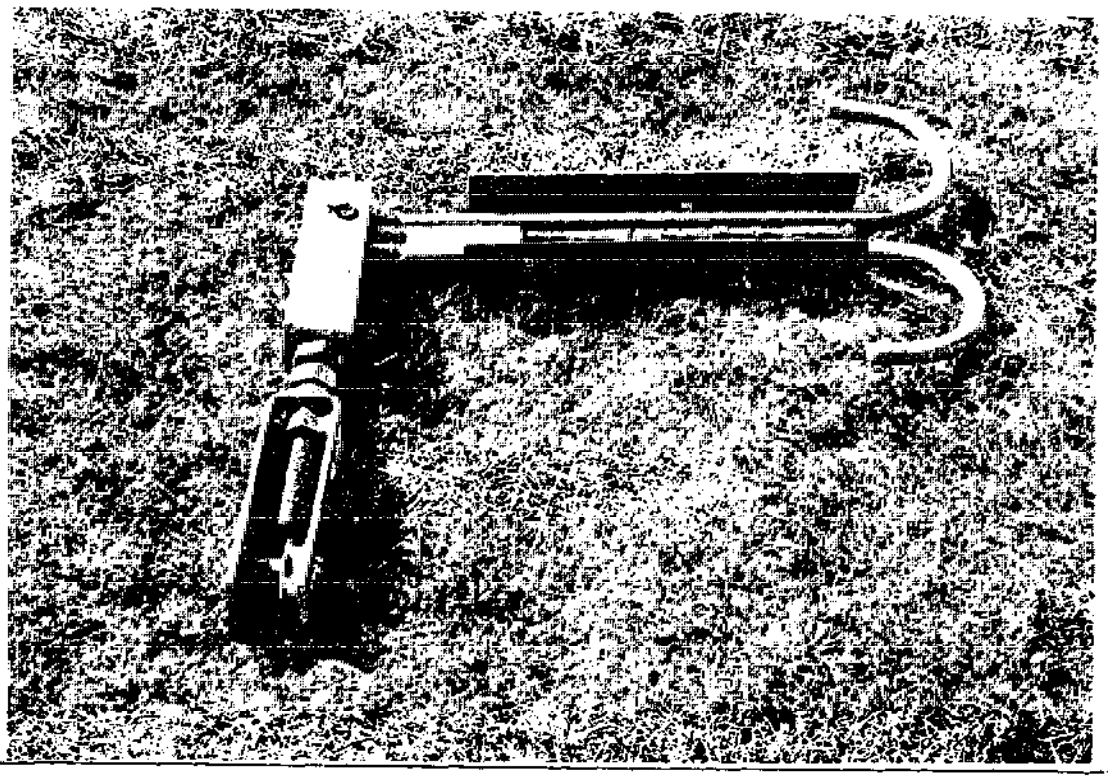




PHOTOS OF STANDARD STEELPARTS

Suspended Bridge	walk-way's shop assembly hand-rail cable anchorage	No. : 13.203 Date : 1st March 77 Sig : [signature]





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