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Rural Water Supply in Nepal: Stone Masonry Course
Technical Training Manual No. 2

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RURAL WATER SUPPLY NEPAL

**TECHNICAL TRAINING
MANUAL no. 2**

*
* STONE MASONRY COURSE *
*

Prepared And Published By

Remote Area And Local Development Department, HMG

SATA - Swiss Association For Technical Assistance

UNICEF - United Nations Children's Fund

Kathmandu 1977

STONE MASONRY COURSE

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STONE MASONRY COURSE FOR RURAL WATER SUPPLY

1 - MATERIALS

1-1- sand

1-1-1- Pit sand

It is a product of weathered rocks or of volcanic deposits.

Derived from	contains	good elements missing	Quality for water work
Granitic rocks	<ul style="list-style-type: none">- coarse grains- medium and fine sand- dust	none	good
trachytic rocks	<ul style="list-style-type: none">- fine sand- dust- clay aggregates	<ul style="list-style-type: none">- medium sand	acceptable after washing
lateritic soils	<ul style="list-style-type: none">- coarse sand with large, medium and fine grains		can not be used for water work because is water absorbant
Volcanic deposits	<ul style="list-style-type: none">- coarse and sharp edged grains- few medium grains	<ul style="list-style-type: none">- fine grains- very fine grains	acceptable only after adding fine grains

1-1-2- River sand

It is an alluvial material which is moving from one place to be deposited some where else according to the quantity of water in the stream or river.

The characteristics of the sand are not the same as the surrounding materials, but a mixture of local and foreign particles. The sand from very big river is the best because the weak particles (as laterite) are eliminated.

1-1-3- For the construction

The sand should be clean, there fore washed, but without removing the fine particles. The quality of the sand can be checked with the white bottle test. The granulation of the sand should be mixed between 0 to 5 mm diameter with the following proportions:

Diameter of sand grains	percent
0 to 0,5 mm	20 %
0,5 to 2 mm	35 %
2 to 5 mm	45 %

1-1-4- For pointing

The sand should be very clean (only river sand if possible). The granulation should be mixed between 0 to 3 mm diameter with the following proportions:

Diameter of sand grains	percent
0 to 0,5 mm	30 %
0,5 to 2 mm	50 %
2 to 3 mm	20 %

1-2- Cement

The cement should not be hard.

1-3- Water

The water should be clean and not polluted by:

- soil particles
- humus
- mudd
- dirt
- natural oil
- vegetable oil
- soap

1-4- Stones

1-4-1- Quality of the stones

The stones should be good, therefore the following stones cannot be used:

- surface stones
- stones with cracks
- weather-worn stones
- small stones (min. side 20 cm)
- plain stones (min. thickness 12 cm)

1-4-2- Dressing of stones

1-4-2-1 Surfaces of the stone

The following list gives the surfaces of a stone which needs to be cut and shaped.

- | | |
|----------------------|---|
| <u>Face</u> | This is the exposed surface of a stone in elevation |
| <u>Returned face</u> | This is the exposed surface to the side elevation. |
| <u>Bed</u> | This is the top or the bottom of a stone |
| <u>Joints</u> | Those are the surfaces prepared to meet surfaces of other stones. |

The stones are classified according to their different purposes:

- limestones
- cornerstones
- archstones

1-4-2-2- Limestones

Cut out the sides to form the beds and the joints.

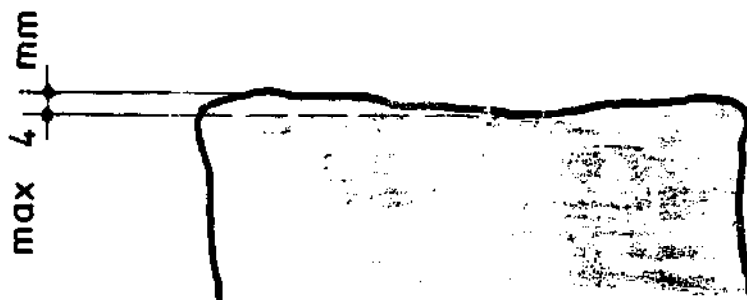
The beds should be as such that they can keep the stone when laid without support.

If the joints and the beds are shaped, the face can now be produced.

Lay the stone down with the intended face up and cut off the high parts with a chisel, or with a club hammer, to a plain surface. Use a straight edge to check the surface.

The maximum plain of the surface for a shaped stone should not be more than 4 mm.

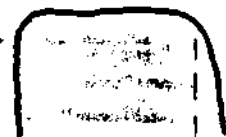
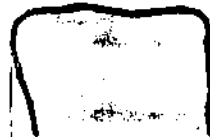
CROSS SECTION



The form of the stone should be as near as possible to a square stone .

CROSS SECTIONS

Correct stones

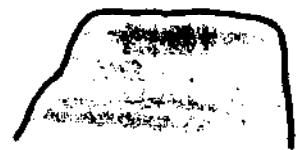


3 cm

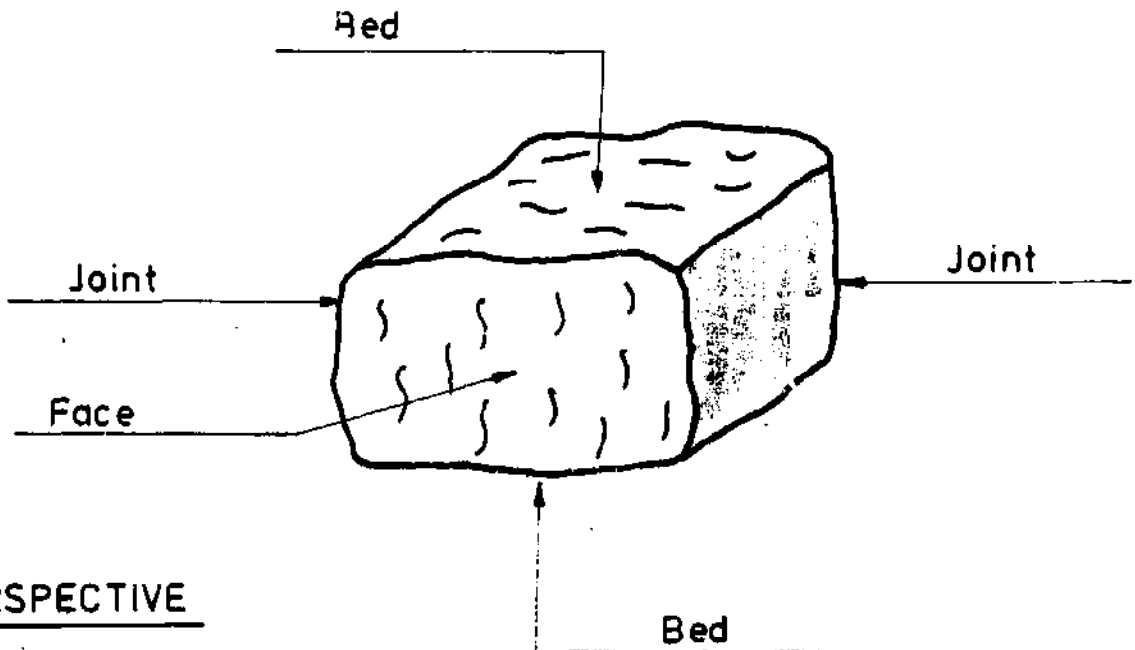
Maximum of

3 cm

Wrong stones



Example of a limestone .

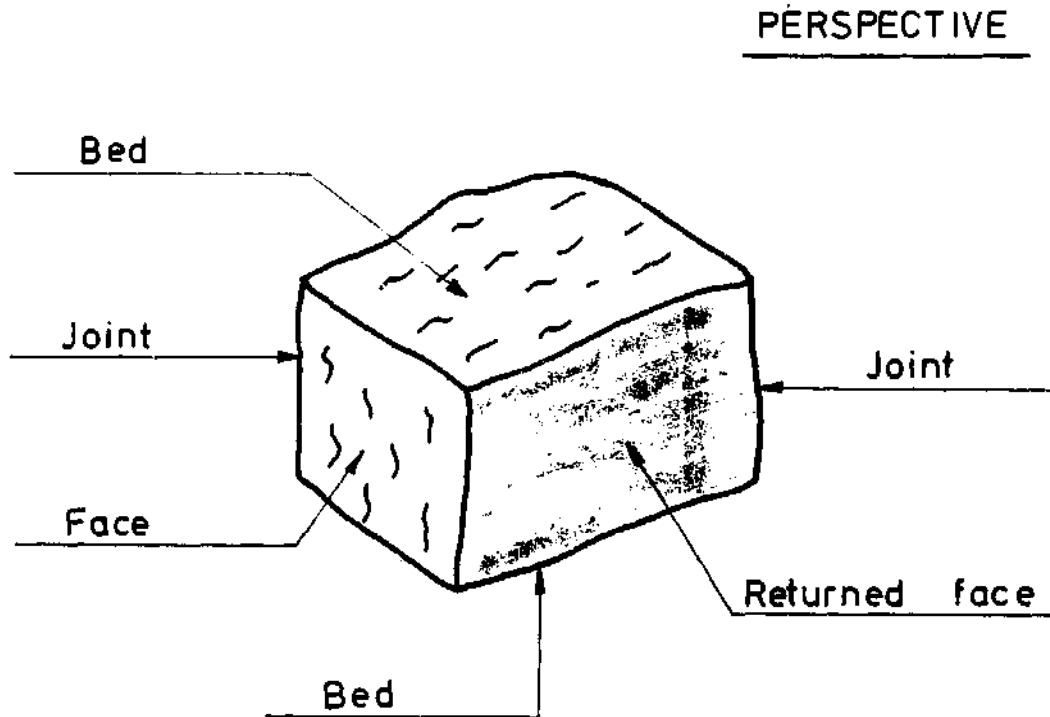


PERSPECTIVE

1-4-2-3- Cornerstones

They are the stones placed at the external angle of a building and prepared to bond with other stones in the wall in each directions. The corner stones are very important and must have good arrises. The two faces of a cornerstone must be squared to each other.

Example of a cornerstone



Preparation of a cornerstone

Select one stone which approach to a cube. Cut first the beds and the joints and give particular attention to the returned face. If the joints and the beds are well prepared, lay the stone with the intended face up, shape it and make sure that it is straight by using the straight edge.

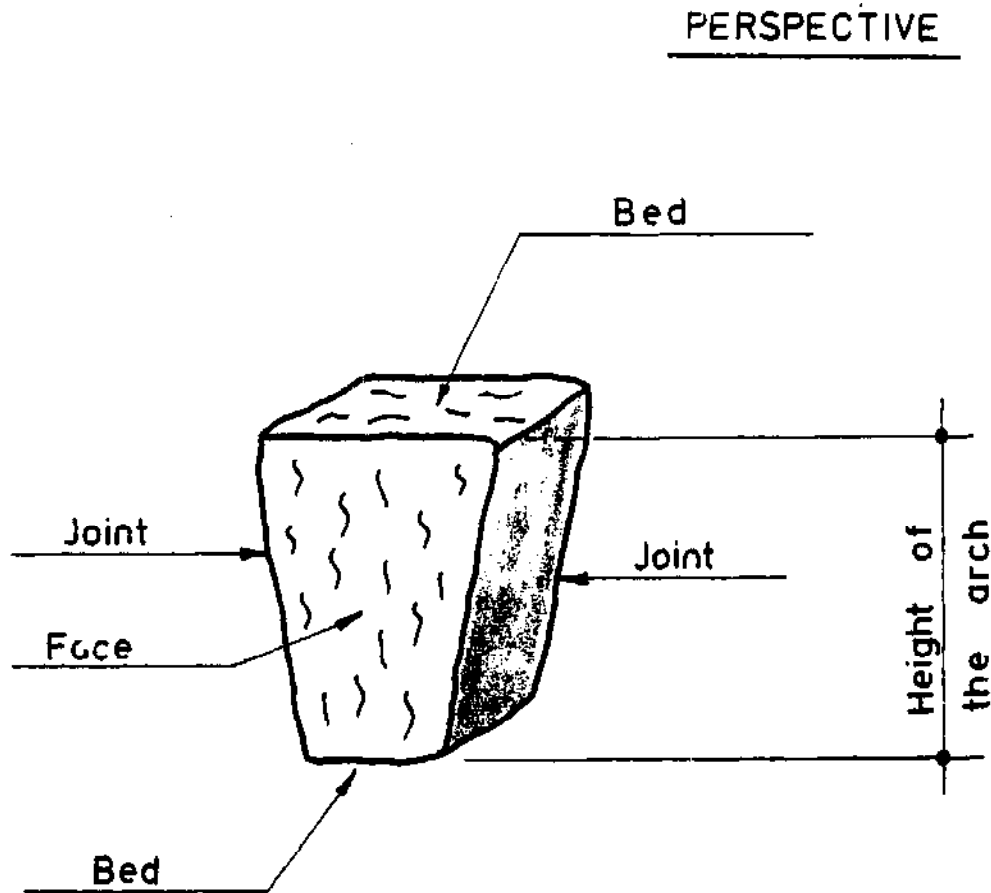
Then shape the returned face by chiseling and squaring it to the face.

Care must be taken not to damage the arrises.

1-4-2-4- Archstones

Unlike the cornerstones the archstone is shaped like a wedge and is more difficult to shape than any other stone, because it has to be shaped to specific measurements and dimensions according to the arch size.

Example of an archstone



Preparation of an archstone

Select a good stone, which by size approach to the desired stone. First cut out the beds to the required height of the arch. Then cut the joints and form the wedge by giving special attention to the dimensions required. Finally cut out and shape the face. Check the face with a straight edge.

1-4-3 Quantity for dressing

For indication the following table shown the number in quantity of stones to be shaped in one working day by a mason.

Type of stones	Hard stones black-blue	White stones
<u>LINESTONES</u> 1 face shaped	45 to 60	60 to 75
1 face + 2 beds shaped	15 to 17	17 to 20
<u>CORNERSTONES</u> 1 face + 1 return face + 2 beds shaped	9 to 12	11 to 15
<u>ARCH STONES</u> All faces shaped	6 to 9	9 to 11

1-5- Mortar

1-5-1- Generalities

Mortar may be defined as a material composed of fine aggregate and cementing materials which form a hardened mass after mixing with a suitable proportion of water.

Good mortar is necessary for good workmanship and good performance. It must bind the masonry units into a strong wall.

The strength of the bond depends on various factors:

- The amount of adhesive used
- The type and quality of sand
- The rate of suction of the masonry units
- The surface texture of the mortar binding area
- The water retentivity of the mortar
- The quality of the workmanship.

1-5-2- Mixing place

For a precise building construction, it is necessary to build only one mixing slab.

For big projects the mixing slab should be in concrete and placed in the way that it can serve easily all places of the job site.

For small projects the mixing slab should be transportable to reach the maximum near of the construction.

1-5-3- Mixtures Quantities

Proportions table

Part of building	sand	cement
Foundation of construction under water level	4	1
Normal foundation	5	1
Heavy construction	4	1
Pressured walls	4	1
Other walls	5	1
Normal pointing	4	1
Exposed pointing (steps, water channels, floors, spillway, dams)	3	1

The above quantities are valid for a good construction sand as described before.

The best way will be to do different mixtures (sand - cement) with the available sand for each job site. Those mixtures will be set in cube - elements, 4 cm by 4 cm by 16 cm, which will be tested with hammer, not before 28 days after mixing. The mixture which presents the best resistance will be chosen.

1-5-4- Preparation



- Mixing of the sand and cement as dry mixture
- Adding of water to the dry mixture for quantities to be used within half an hour only.
- Protection of the mortar against rain and sun.
- The consistency of the mortar should be in the way that it does not flow out of the trowel.

- Remark

As the setting action commences soon after watering and mixing, the mortar should be used at once. Any subsequent disturbances will reduce the strength

Cement mortar should never be retempered if not used within 1½ hours after its watering and mixing.

1-6- Materials quantities for one finished cubic meter of stone masonry for different constructions

Building description			Cement in bags	sand in m ³	Uncut stones in m ³
<u>Stone masonry walls</u>					
Design	Height	Thickness			
	up to 1,5 m	45 to 30 cm	2,5 to 3	0,40	1,5
	More than 1,5 (max 3m)	70 to 30 cm	2 to 2,5	0,35	1,2 to 1,5
<u>Stone arches</u>					
<u>Length of spans</u>					
1,2 to 1,8 m			2,5	0,40	2
1,8 to 2,5 m			3	0,40	2,5

2- Tools

The mixing slab and the showels should be cleaned before mixing the mortar.

The trowel and the straight edge should be washed before using for masonry work.

Every evening all the tools should be carefully washed.

3- Construction

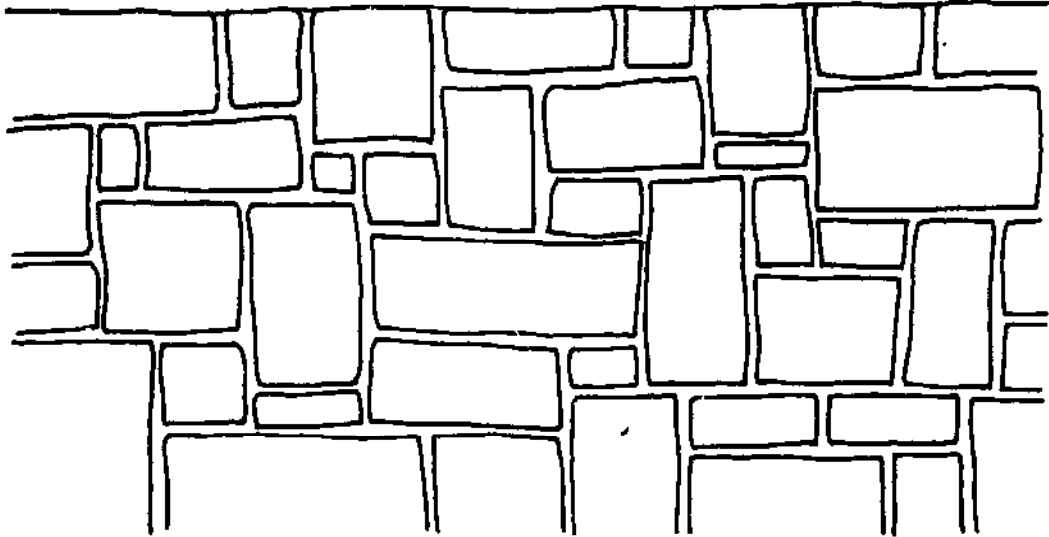
3-1- Generalities

The classification of stone masonry construction varies according to the kind of Stones used, the surface finish and the type of bonding.

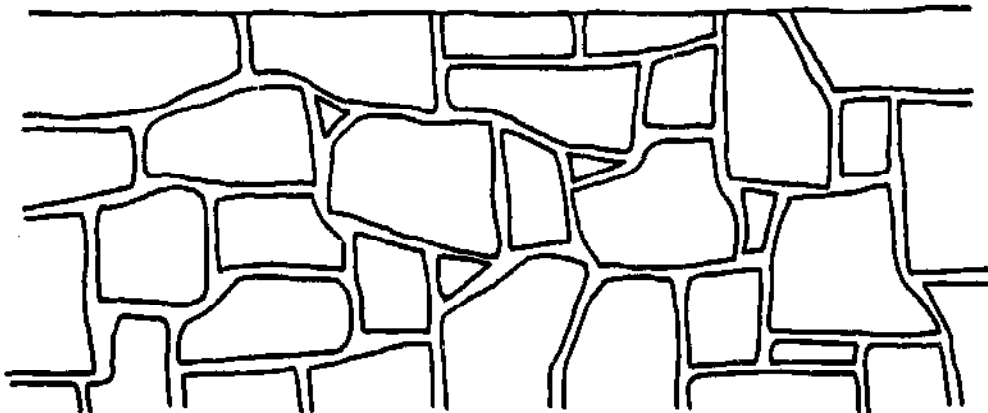
For water work the best masonry work will be a squared uncoursed masonry with various size of stones.

As we know it is difficult to find squared stones, so we also can use the uncoursed rubble masonry (unsquared) with well shaped stones.

SQUARED UNCOURSED MASONRY



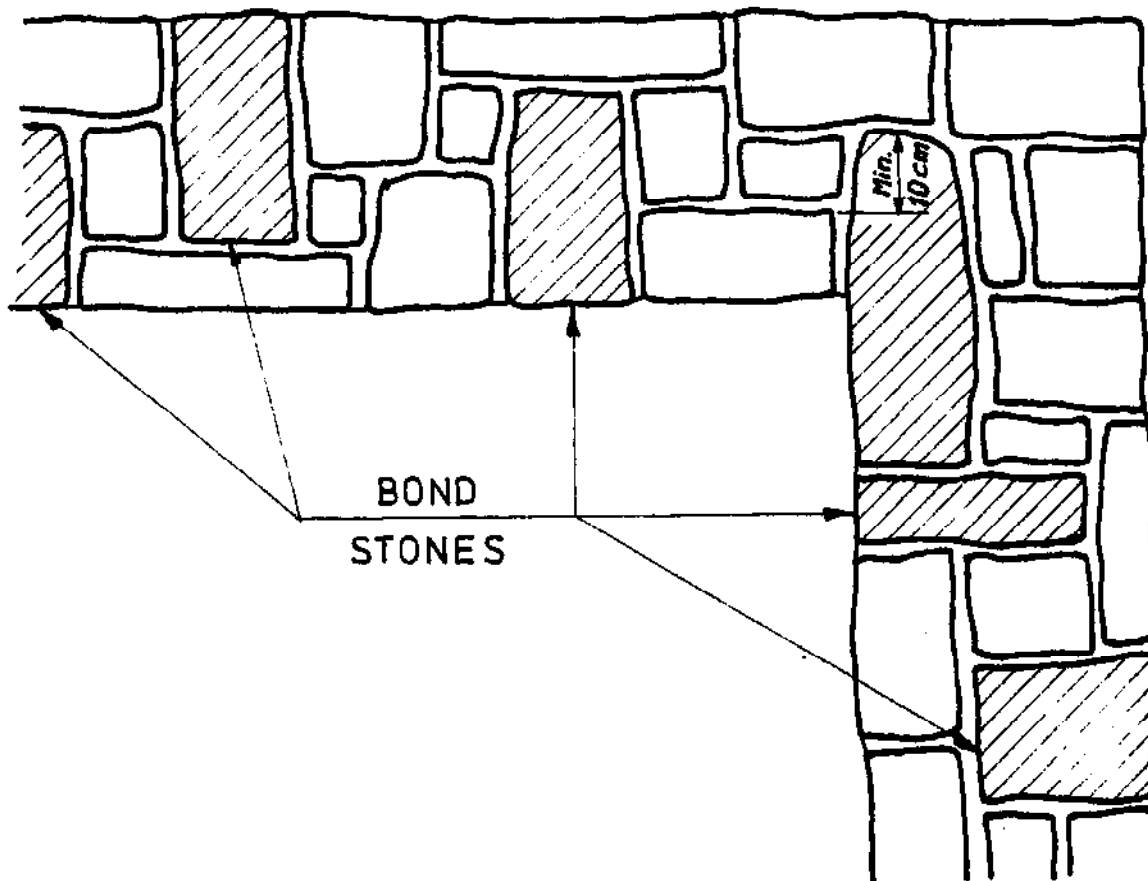
UNCOURSED RUBBLE MASONRY



3-2- Conditions for a good construction in stone masonry

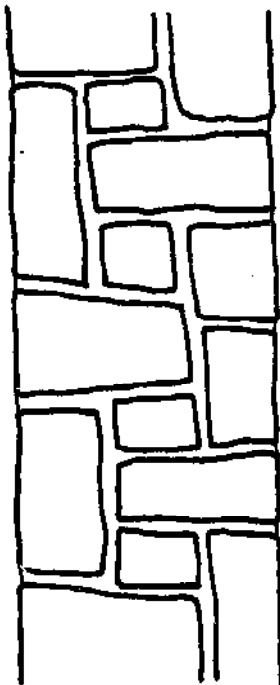
- a - The normal procedure need two masons working one at each face of the wall.
- b - All the stones (especially the dirty) should be brushed with hard iron brushes.
- c - All the stones should be washed before use.
- d - All the stones have to be wet before laying them into mortar to insure a good connection with the mortar in the wall.
- e - Never used stones with cracks.
- f - The bottom (or footing course) should be laid with largest and straight stones since the stability of the wall depends largely on the bearing of stones on the ground.
- g - First the corners of the walls should be built up to a height of about one meter, making sure that outer and inner faces are plumbed and squared.
- h - The corners must be of large stones, that will bond the two walls together in the best to resist of strain. The binding of stones should require special attention.

TOP VIEW

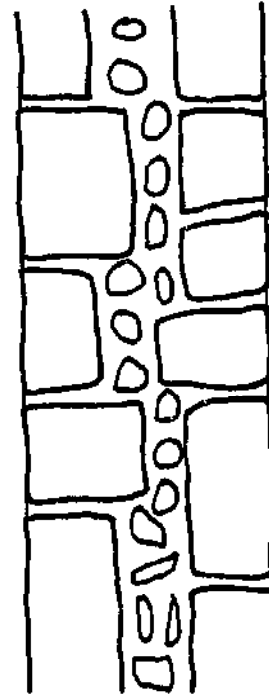


- i - When the corners are up, the building can continue by fixing two lines in and out side the wall to guide the masons during laying of stones. The lines are 2 mm away from the face of the wall. The stones should be checked for alignment with straight edge and spirit level.
- j - Broken pieces of stones (spalls) can be slipped under the shaped stones to help for a good bed seating. The wall should NOT be built by forming the outer parts in good masonry and then filling the middle part with mortar and spalls (see "wrong" drawing below).

CROSS SECTIONS



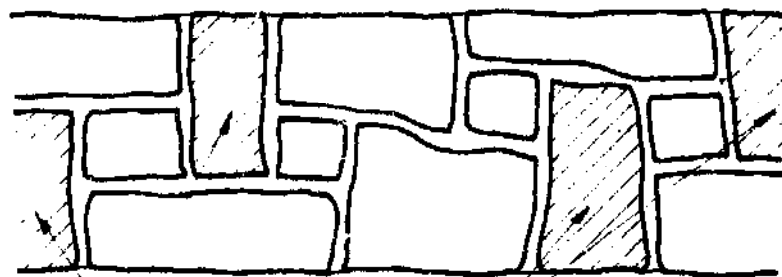
Correct



Wrong

- k - Special attention should be paid to the bondstones. They should be crossing on the two plans, vertical and horizontal. The lap (or difference) should not be less than 10 cm. For water work the stone masonry should never be laid in courses. (very important)

TOP VIEW



Horizontal
bond stones

- l - A long stone needs a uniform bedding. If the stone is too long, it should be broken and laid as two stones.
- m - It should never be a stone crossing all the wall face to face.
- n - Spread the mortar, force the stone to its bed with power, maintain a perfect face alignment on the wall. The joint in mortar between two stones should not be bigger than 2 cm to 2,5 cm and never less than 1 cm to 1,5 cm.
- o - Two stones can never touch each other.
- p - After building up the wall stages, at the end of the day, all new erected masonry should be cover by wet paper or any similar wet materials, to prevent the construction (especially the joints) against rain or too fast drying by sun and air.
- q - A masonry work should be wet for at least 3 or 4 days after completion.
Water should be spilled on it.

3-3- Special attention to the bonding

In stone masonry for water work it is important to secure a good vertical and horizontal bonding.

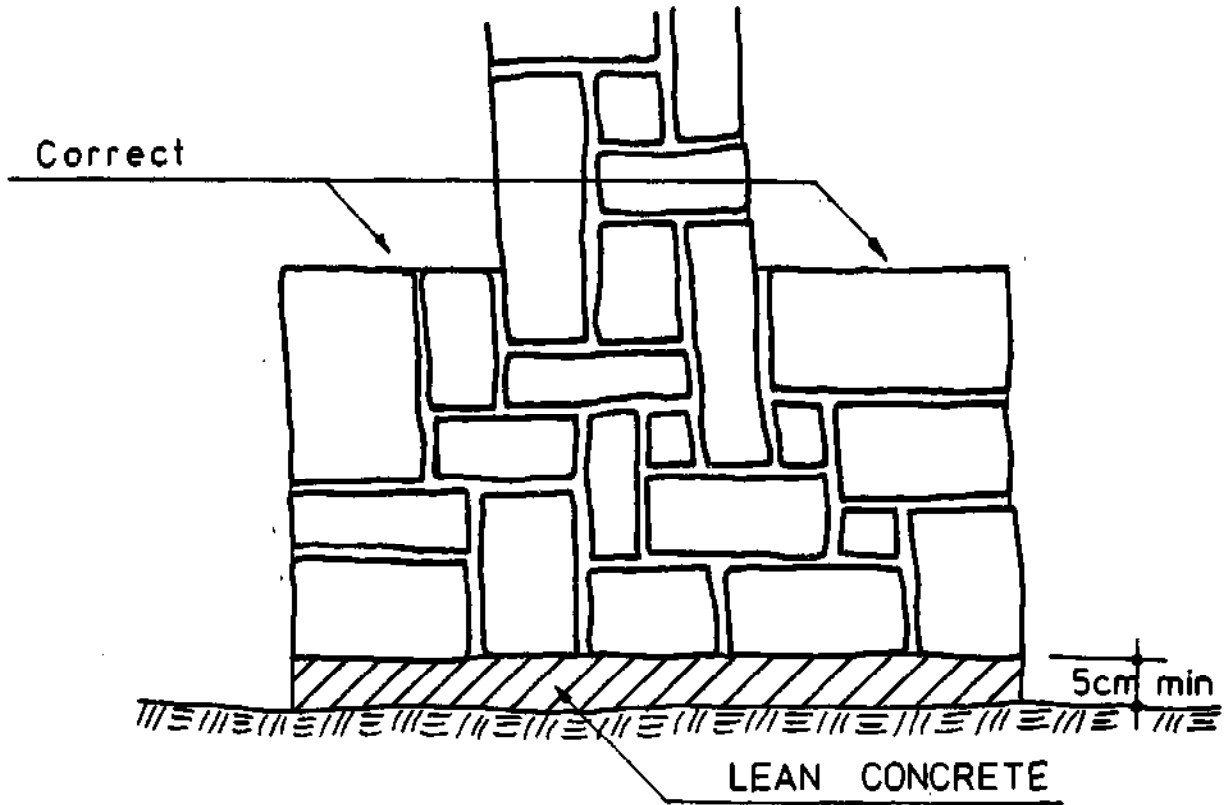
In bonding the following rules should be strictly observed:

- a - Bondstones should extend about $2/3$ of the wall thickness.
- b - The lap should not be less than 10 cm.
- c - The largest stones should be used for the lowest part of the wall.
- d - It should not be continuous joints, vertical or horizontal.

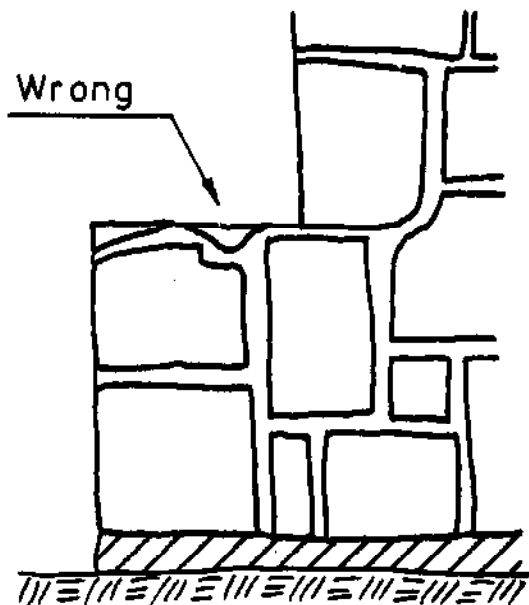
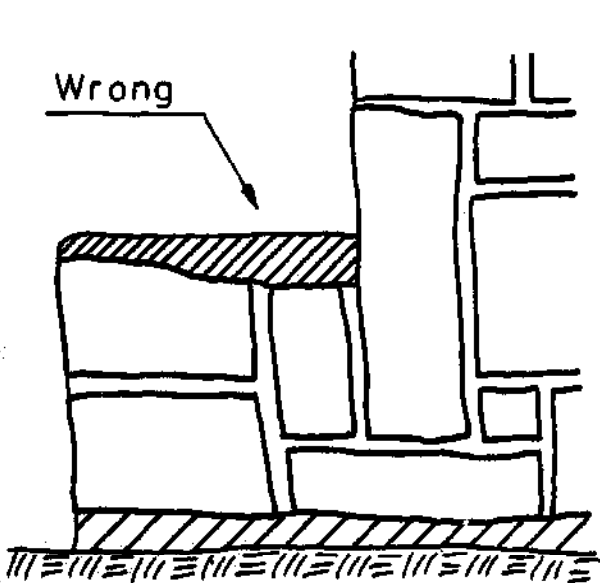
3-4- Details of stone masonry foundation

- a - A foundation should start on a firm, uniform strong sub-soil. It should not be started on grass, black fertile soil, filled up material and mud.
- b - Under any foundation there should be a layer of lean concrete (min 5 cm) before starting with the masonry.
- c - A minimum depth of 40 cm of foundation should be built in the actual ground in place. Backfilling should appear after and cannot be taken for the minimum depth of foundation.
- d - All differences of level in a stone masonry foundation should be erected vertically.
- e - If the foundation is wider than the wall, the top of the foundation should be made with big shaped stones without topping coat.

CROSS SECTION



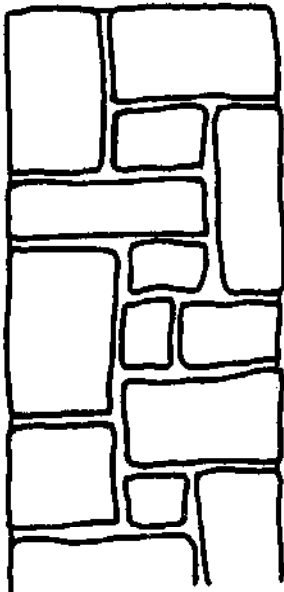
CROSS SECTIONS



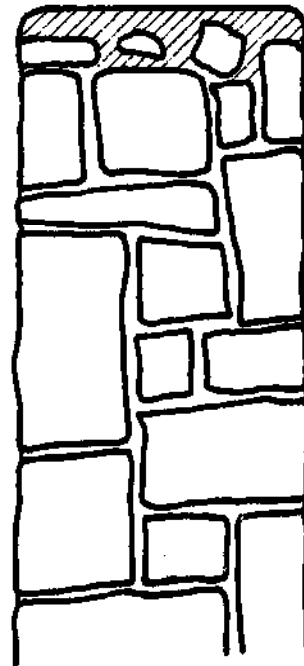
3-5- Details of stone masonry walls

- a - The maximum thickness of the bottom of a stone masonry wall should be 60 to 70 cm because wider walls cannot be constructed with two lines.
- b - The minimum thickness of a stone masonry wall should be 30 cm.
- c - The height of walls should be reduced in area of black soil or swampy places.
- d - The top of a normal stone masonry wall should be built with shaped stones with good pointing.
Never should it be with topping coat.
(see drawings below)

CROSS SECTIONS



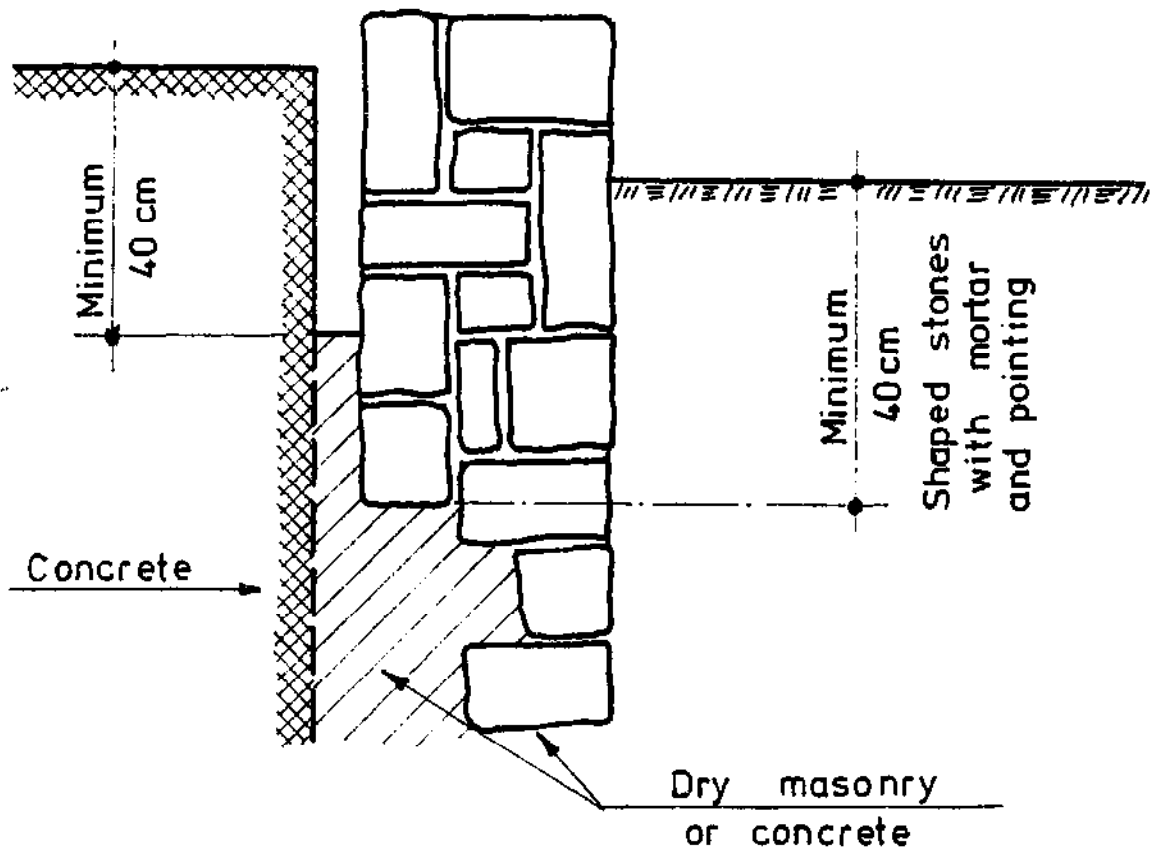
Correct



Wrong

- e - The top of dry stone masonry wall (protection or retaining wall) should be built with shaped stones on the two sides, with mortar and joints pointing as from at least 40 cm below the ground level (in place or future).

CROSS SECTION



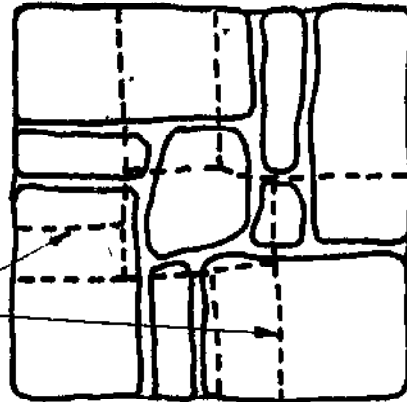
- f - For a bevel wall on the top of a chamber or at an entrance of a chamber, the wall can be reduced to 15 cm thick.

3-6- Details of stone masonry pillars

- a) For a single pillar the minimum dimensions should be 40 by 40 cm.
- b) A special attention should be paid to the cross jointing of the different courses.
- c) The cornerstones should be enough big to cover at one side more than the half of the pillar.

CROSS SECTION

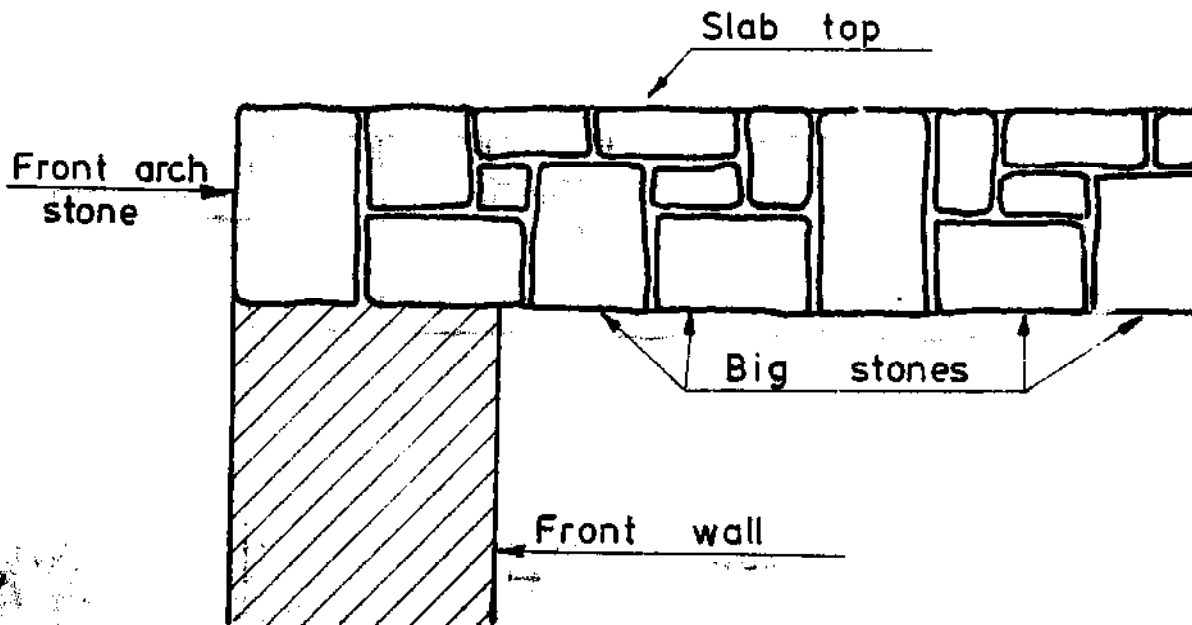
Next layer



3-7- Details of stone masonry arch

- a - The thickness of a stone arch cannot be less than 20 cm.
- b - The front arch stones each side of the building should be especially shaped precise according to the size of the arch (thickness) and to the angle of the arch rise.
- c - The front face arch stones should be built in the way that it will be started on the two sides to be finished together on the arch Key stone in the middle (coping stone).
- d - The top of the supporting walls should be built in the line of the arch, before starting to place the arch stones.
- e - The biggest stones should be used on the lowest part of the arch slab.

CROSS SECTION



f - The water level in the tank should be at least 20 cm lower than the line of the arch rise.

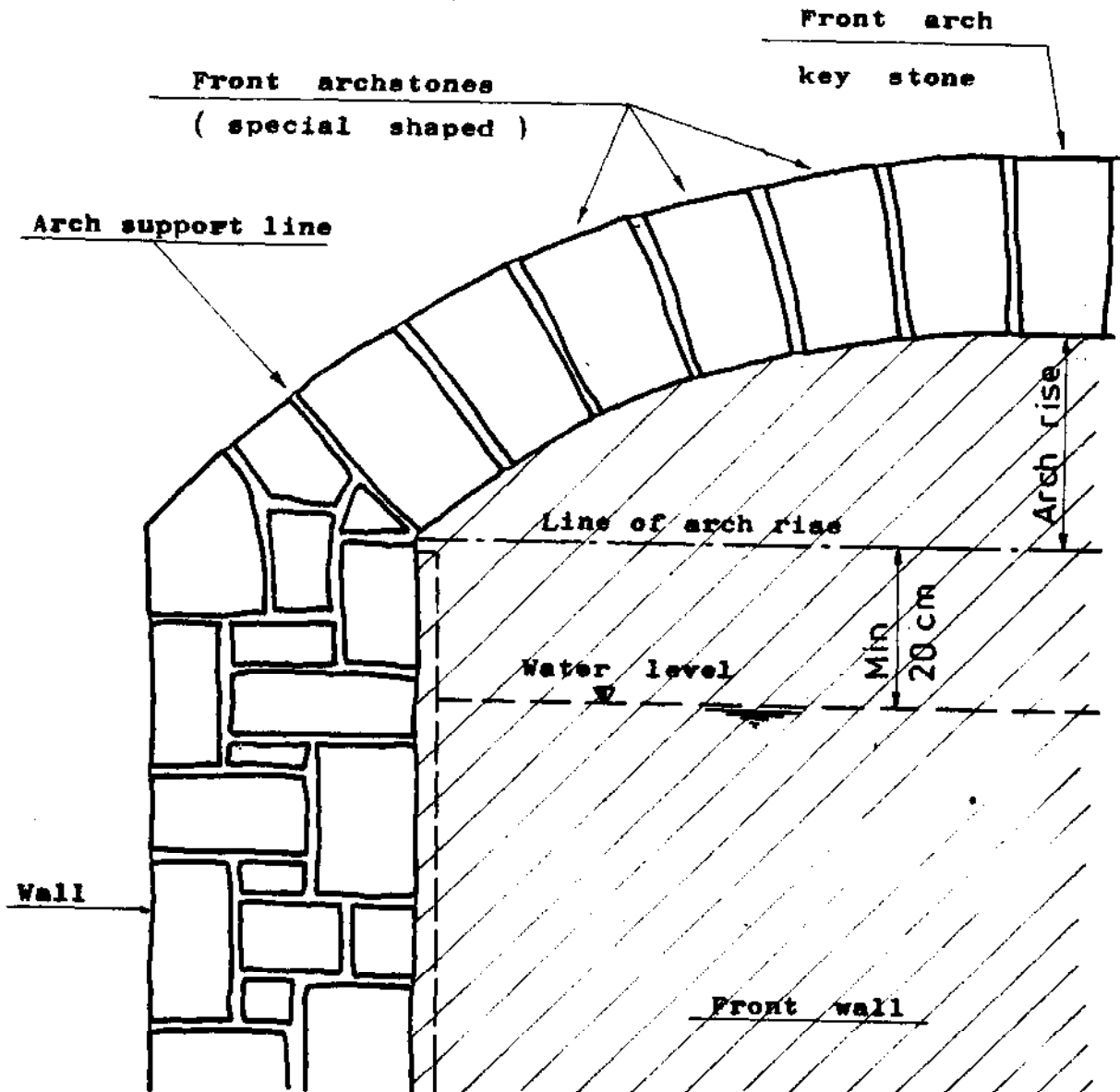
g - Table for the arch rise

Distance between the two walls	Arch rise	Arch slab thickness
1 m to 1 m 50	25 cm	20 cm
1 m 50 to 2 m	35 cm	25 cm
2 m to 2 m 50	45 cm	30 cm
2 m 50 to 3 m	55 cm	35 cm

h - A pre-fabricated formwork will be installed under the arch slab for the construction.

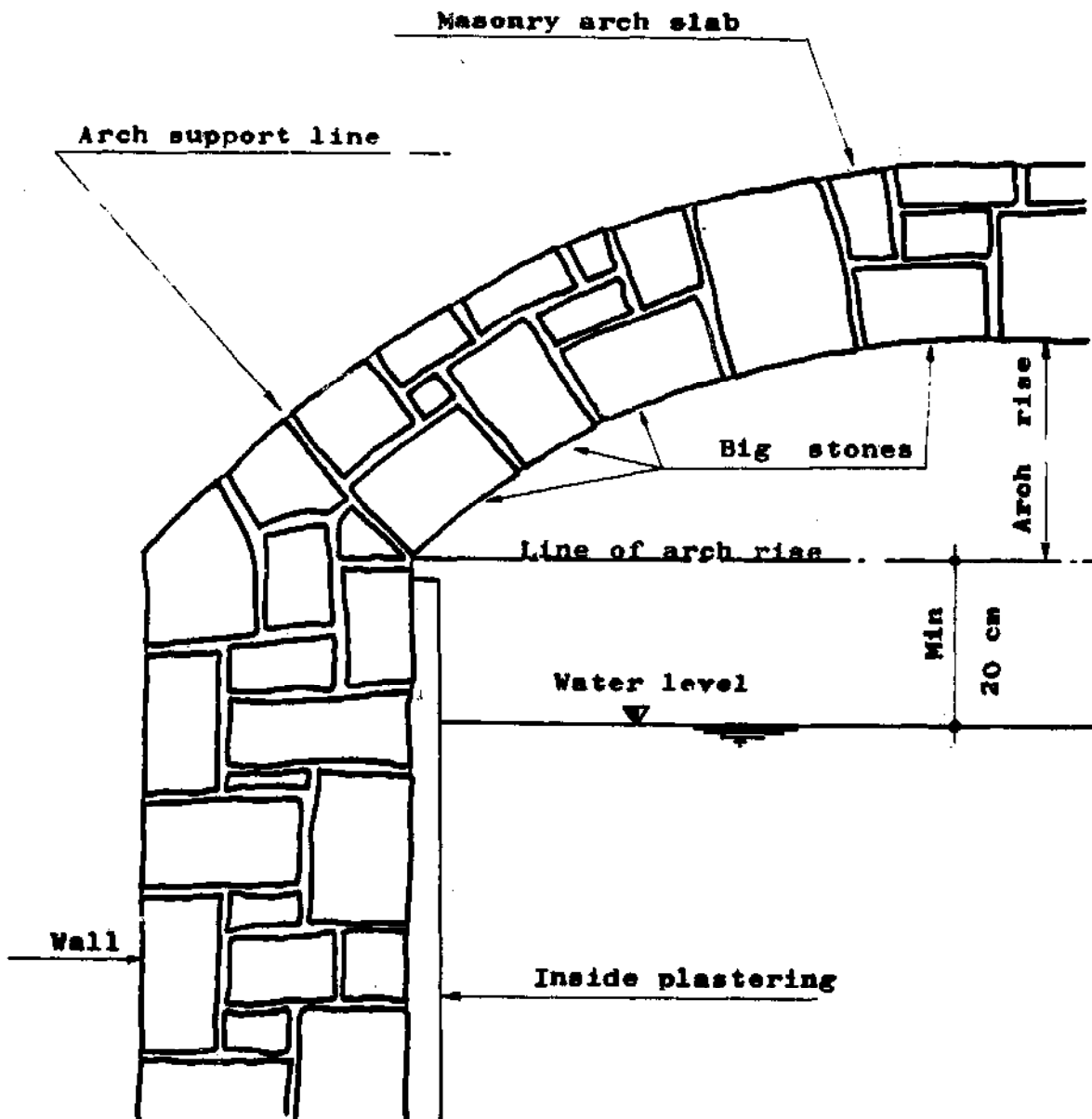
Example of an arch in stone masonry .

FRONT SECTION



Example of an arch in stone masonry .

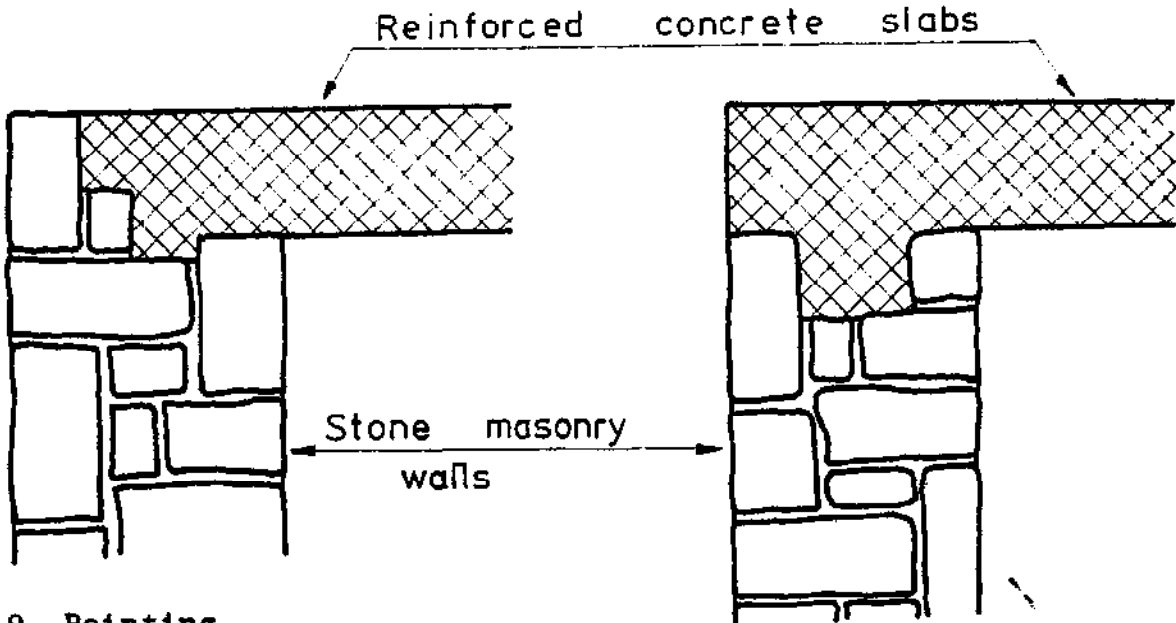
CROSS SECTION



3-8- Connection between stone masonry wall and concrete slab

- a - The joint between the wall and the slab should be washed before concreting, and never at all it should be paper between.
- b - The junction can be as follows:

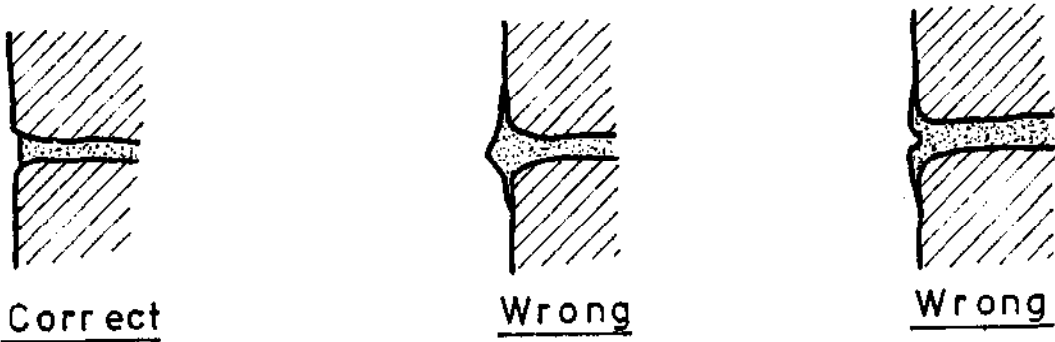
CROSS SECTIONS



3-9- Pointing

- a - The pointing should not be done on the face of the stone.

CROSS SECTIONS



- b - Before pointing, all joints should be brushed and wet by watering.

- c - The best time for pointing will be four days after completion of the stone masonry wall, part after part.
- d - The pointing should also be done for the inside walls with the same precautions.
- e - The pointing should be protected against sun and rain for at least one whole day.

4 - Inside storage tank plastering

4-1- Generalities

Plastering is the process of covering walls with a substance which still plastic when applied and which will later become hard. Plastering may be carried out in one, two, three or four coats, depending upon the required quality.

4-2- Preparations and precautions

To obtain a good connection between the stone masonry wall and the plastering, the following rules should be considered:

- a - All loose particles have to be removed.
- b - Dust should be wiped out.
- c - Moss and other organic specimens have to be eliminated (with iron brushes)
- d - The surface should be wet the day before and only moisty before the plastering takes place.
- e - Plastering should be strongly protected against sun and rain destruction.
- f - A hot wall cannot be plastered.

4-3- The different coats

For a waterproof construction the plastering should be made in four coats:

- spatterdash
- floating coat
- setting coat
- cement paste

In certain cases it can be necessary to applied a waterproof paint at the end.

4-4- Spatterdash

It is a wet, rich mixture of cement and cleaned sand.

Proportions: 1 cement for $1\frac{1}{2}$ sand

Thickness: 2 to 4 mm

Application: It is thrown with the trowel, hard onto the wall in two different times with a lap of 6 hours between the two. The first application, covering the whole surface, provides a key and reduces the suction of the next coat. The period in between allow the first application to set. The second application gives the first seal of the plastering.

Remarks

Do not use a straight edge, a patter or a finishing trowel. The spatterdash should remain rough. Before the next coat is applied the spatterdash should remain at least for twenty four hours (24).

4-5- Floating coat

It is a plastic mixture of cement and cleaned sand.

Proportions: 1 cement for 3 to 4 sand

Thickness: 2 cm (20 mm)

Application: The mixture (plastic consistence) is thrown onto the spatterdashed wall with the trowel and screeded with a straight edge only, to insure a good connection with the next coat.

Remarks

Do not use a patter or a finishing trowel. The finishing surface should not be too smooth. It is recommended to use screeds (small lintels with thickness of the coat) to insure a plumb and straight surface.

4-6- Setting coat

Setting coat or finishing coat is a mixture of cement and fine sieved sand. The sand grains should not exceed 2 mm.

Proportions: 1 cement for 2 to 3 sand

Thickness: 1 to 2 mm according to the size of the grains.
(Not thicker than the largest grain).

Application: Usually it is applied the day after floating coat in one operation all over the surface to be plastered. The consistence should be slurry. It is applied by putting the mixture on the patter and pressing it onto the wall, while moving it upwards in zig-zag motion.

Remarks

Application should start on a corner of the wall. Circular strokes must be used, always in the same direction, to produce an uniform surface. If the plaster becomes too dry, it should be lightly sprinkled with water to maintain the plasticity of the material as long as it is manipulated.

4-7- Cement paste

It is pure cement mixed with water.

Thickness: 1 to 2 mm

Application: The paste is trowelled on the wall with a finishing trowel up to a smooth finish, while sprinkling water if necessary.

Remarks: This cement paste should never be exposed to the sun or let it dry too quickly, because of shrinkage cracks. The cement paste should be kept wet for at least three days, by sprinkling water and use of paper or leaves. The best way will be to fill the tank with water as soon the cement paste starts to become enough hard.

4-8- The corners

It is very important to bench well all the corners, between walls and walls, between walls and floor. It is recommended to use a bottle.

4-9- Water proof paint

If a water proof paint is applied on the wall, it should be done in two coats.

The first coat to close all the pores of the plastering.

The second coat as a waterproof finishing.

A waterproof additive can also be mixed together with the cement for the plastering.

DIAGRAM OF THE BOTTOM WALL THICKNESS FOR STONE MASONRY BASINS AND STORAGE TANKS

