Rural Water Supply in Nepal: Concrete Course
Technical Training Manual No. 3

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CONCRETE COURSE

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C O N C R E T E   C O U R S E

1. General

1.1 Definition

Concrete is a mixture of:

- aggregates (sand, gravel)
- adhesive (cement)
- water

1.2 Types of concrete

There are many types of concrete which can be grouped, for example, according to the raw materials or to the quality.

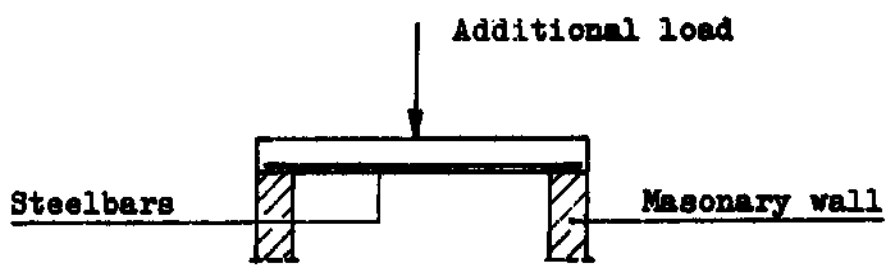
For our purpose we can seperate three different types of concrete, according to their use:

- lean concrete
- non-reinforced concrete
- reinforced concrete

As non-reinforced and reinforced concrete have the same mixture of aggregates, cement and water, the difference is explained as follows:

> Concrete alone has a very high compression strength but a low tensile strength. So concrete which is exposed to tensile stresses has to be strengthened with steelbars. These have a very high tensile strength.

Take for example a slab of a spring collection chamber:



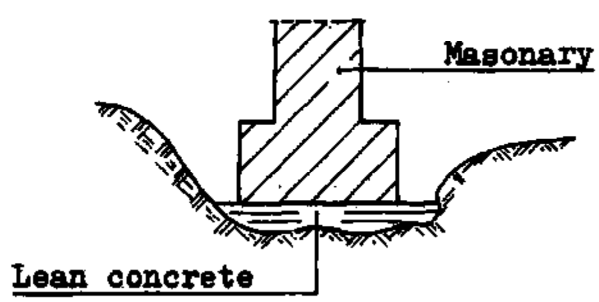
Due to dead load and additional loads such as people, earthfill, snow etc. the slab will get tensile stresses at the bottom. So in this place we must put some steel-bars into the concrete.

The number, diameter, length and position of the bars is a matter for the design engineer or the engineer - in - charge of the project.

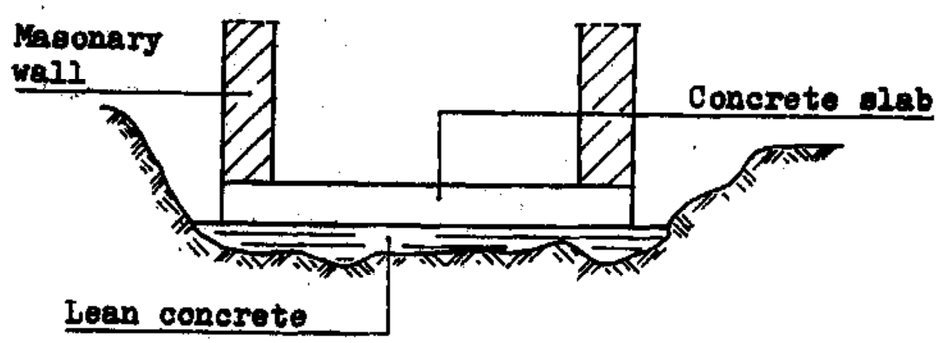
1.3 <u>Application of concrete</u>

I. <u>Lean concrete</u>: To make a clean and completely horizontal base for concrete and masonry constructions.

1. <u>Example</u>: Storage tank wall - foundation.

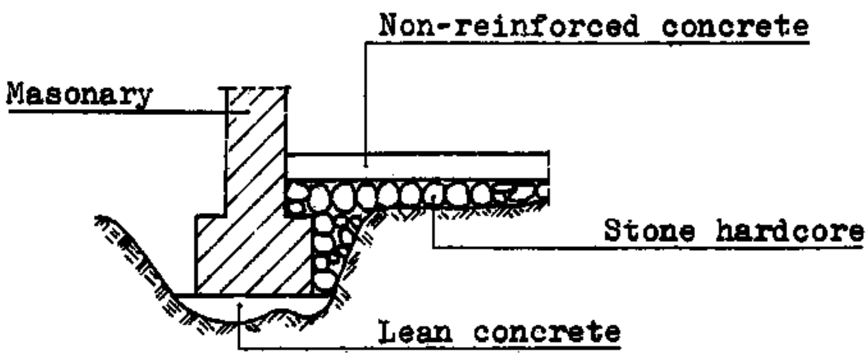


2. <u>Example</u>: Foundation of a spring collection chamber.



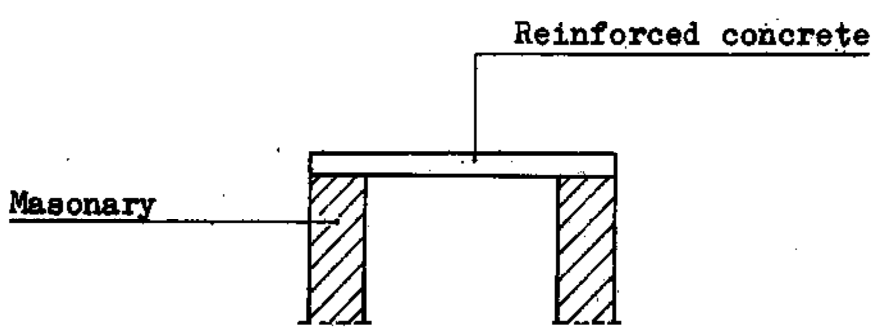
II. Non-reinforced concrete: To make foundations, floors small staircases, walls etc. All concrete constructions which are not exposed to high tensile stresses.

Example: Floor of a storage tank



III. Reinforced concrete: To make all kind of concrete constructions such as slabs, walls, bridges, etc.

Example: Slab of a spring collection chamber



Note: The decision to use reinforced or non-reinforced concrete is a matter for the engineer, and it should be shown on the site drawings.

2. Materials

2.1 The aggregates

2.1.1 Origin and extraction

Natural materials

Rubble sediments in rivers and lakes. Due to long transport in the rivers, gravel and sand are ground round,and bad materials have already been eliminated. They are also washed so that in many cases they are ready to be used for making concrete.

Crushed materials

Pieces of rocks and big stones broken in stone breakers or by hand.

This material must be washed and sorted out. It is important to remove all the dust which arises by crushing; stone with cracks should be eliminated. To obtain a high strength the crushed material should be mixed with river sand.

2.1.2 The form of grains

The compressive strength of each grain must be higher than the strength of the finished concrete. The ideal form of gravel is round for river gravel and cubic for crushed gravel. Do not use weather-worn stones,slate and flat stones.

2.1.3 Impurities

If aggregates are dirty and contain grass leaves, wood, humus, silt, clay etc, they have to be washed, but particular attention should be paid not to wash away the fine sand aggregates. Gravel and sand containing impurities cause heavy loss of strength in the finished concrete.

Simple methods for field tests:

Fist test

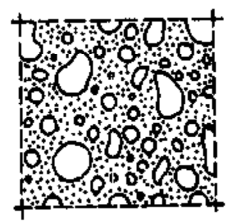
The hand filled with the aggregates to be tested is to clench and then to open again. If the material is clean it should not stick together in a lump. When the material is rubbed between the hands, they should remain almost clean.

Bottle test

A clear bottle filled up to 2/3 with material and the remaining space with water is to be shaked vigorously. After about 30 minutes of settlement, there should be no dirt or silt on top of the material.

2.1.4 Grading or gradation

In properly made concrete, each particle of aggregate is completely surrounded by cement paste. The better the distribution of the particle sizes, the better all spaces will be filled and the denser and stronger the finished concrete will be.



The most common composition is 3 parts gravel and 2 parts sand.

To find out the proper composition, it is recommended to make testing mixtures on site. The following table should give an idea of a good gradation.

Table of gradation

	Ø	Range of grains			
	mm	0-8	0-15	0-30	0-60
Dust	0.0-0.1	8-14	5-10	3-7	2-5
Fine sand	0.1-1	15-21	16-15	7-11	5-7
Medium sand	1-4	38-37	23-26	13-18	9-14
Coarse sand	4-8	39-28	24-21	16-15	9-10
Fine gravel	8-15		37-28	21-19	13-14
Medium gravel	15-30			40-30	22-20
Coarse gravel	30-60				40-30

Proportions in % of weight (dry aggregates)

2.2 Cement

2.2.1 Introduction

Cement is a product of minerals which are burnt and then pulverized. If water is added it becomes a binding paste which first sets (becomes firm) and then hardens for an indefinite period. The setting and hardening are brought about by chemical reaction between the cement and the water. This process is called hydration.

On the world market there are a lot of different adhesives available. But in Nepal, and also in other countries, only portland cement is used to date. Therefore the following chapters give a brief description of this portland cement.

2.2.2 Manufacture

The raw materials, limestone and clay, are extracted from quarries and crushed into pieces of the size of a fist. After this, the raw materials are mixed with hydraulic compound, granulated and burnt at a temperature of 1500°C. This burning produces a clinker which is cooled and pulverized into fine powder with a small amount of gypsum added to regulate the setting time. This powder is the finished portland cement.

2.2.3 Hydration

Hydration of the cement is divided into two processes: The setting stage and the hardening stage.

Setting

This chemical process which radiates heat, starts at a certain time after the water has been added and it lasts till the mass is solid. The time of beginning and the duration of this process varies mainly according to the temperature. At a temperature of 18°C the setting starts after about 2.5 hours and lasts 7 hours. If the temperature falls to 0°C, no setting process takes place. In the tropics, where temperatures of 30°C often occur, the same cement may change to a quick setting one.

During the setting time the material must not be disturbed, as this would diminish its strength considerably.

The setting time can be checked on site, by a very simple method:

> The concrete is scratched with a fingernail or a piece of soft wood.

If it flows together again, the setting has not yet started, if the scratch remains, the setting is in process, if no scratch can be seen on the concrete, the setting stage has finished and the hardening stage has already started.

Hardening

Theoretically portland cement never stops hardening and therefore the end of the process cannot really be determined.

For practical work it is sufficient to know how long it takes a structural part to attain the required strength.

2.2.4 Shrinkage

All adhesives, including portland cement, are subject to shrinking during the setting and the hardening process.

The shrinkage must be counteracted by keeping the mortar or the concrete wet.

2.2.5 Storage of cement

Cement should not be stored longer than three months. Otherwise the strength will be reduced to approximately 75% of the original value. If cement is allowed to absorb any moisture, it will set more slowly and the strength will be drastically in decreased.

In storing cement, especially sacked cement, the warehouse or shed should be as airtight as possible. All cracks in the roof and walls must be closed. The floor should be above ground to protect cement against dampness. Sacks should be stored close together to reduce the circulation of air, but at least 50 cm away from walls, and with not more than 10 bags per pile.

On smaller sites, where there is no shed or other building available, the sacks may be placed on a raised wood platform. A waterproof tarpauline should be placed over the pile to protect the cement against rain. The tarpaulin should extend over the edges of the platform. If the cement is hard due to moisture, it can not be used.

2.3 Water

The water must be clean. Drinking water is always suitable for making concrete. If it is not possible to use drinking water it must be certain that the water is not polluted by:

- soil particles
- mud
- dirt
- oil
- soap, etc

It is important to use only clean water for making concrete and mortar.

3. Making and handling of concrete

3.1 Mixture

3.1.1 The amount of aggregates

Experiments have shown that the portion of gravel and sand which is used in mixing 1 m3 finished concrete is not always the same. Normally 1400 liters of aggregates are needed to make 1 m3 of finished concrete.

3.1.2 The amount of cement

The amount of cement for a certain mixture is given in liters or kilograms.

1 bag of cement = 50 kg = 40 liters

For the different types of concrete we need the following amount of cement per m3:

lean concrete : 150 kg = 120 liters

non-reinforced)
reinforced) concrete : 300 kg = 240 liters

The quantity has to be increased if the aggregates do not correspond to the requirements described in chapter 2.1.4.

3.1.3 <u>Amount of water used in concrete</u>

The amount of water to be used depends on: the aggregates; on the consistency of concrete wanted; and on the amount of cement.

It should be noted that the total amount of water in a mixture is equal to the added water and the natural moisture of the aggregates.

The proportion of water to cement is called:

$$\text{water-cement ratio} = \frac{\text{water (in kg)}}{\text{cement (in kg)}}$$

The water-cement ratio has a direct influence on:

- workability
- density
- strength

The best results for density and strength are achieved by using a mixture with a water-cement ratio of:

0.4 for lean concrete
0.5 for non-reinforced and reinforced concrete

<u>Note</u>: Each litre of extra water used demolishes the effect of 2 to 3 kg cement.

Natural moisture of aggregates:

	Sand liters/m3	Gravel liters/m3
Dry season	25-30	5-10
Rain and sun mixed	70-80	25-35
Rainy season	160-170	70-80

3.1.4 Measuring the ingredients for hand mixing

The following table shows volume ratios.

	Type of concrete	
	Lean concrete	Non-reinforced and reinforced concrete
Cement : sand : gravel	1 : 4 : 7	1 : 2 : 3
Cement : sand + gravel	1 : 25	1 : 12

3.2 Mixing

3.2.1 Equipment

Hand mixing does not need much equipment but a lot of manpower.

A batch to be hand mixed should not be larger than about 0.5 m3. Concrete should never be mixed on soil. A platform has to be built, with boards, metal sheets, stones or concrete. It should be level to prevent water or fluid material from flowing off the platform.

3.2.2 Procedure of mixing

Measure the amount of aggregates used for the batch, put it onto the platform in a layer, and spread the cement over it. Mix together until it is uniform in colour.

For addition of water, the material is sprinkled gradually while it is turned over another 3 times, that is, until it is uniform in consistancy.

3.3 Transporting concrete

If mixed concrete is transported there is a tendency for the larger aggregate particles to segregate by settling to the bottom. To avoid this, ready mixed concrete should not be transported over long distances and if it has to be, the transport container should be adequate. There should be no leakage, so that none of the cement milk is able to flow off.

3.4 Casting concrete

3.4.1 Preparation of the formwork

Before any concrete is placed, the forms must be cleaned of all rubbish and carefully checked for strength, tightness and proper alignment. The forms should be wet the day before casting and again before the work starts. If this is not done, the boards will absorb a high amount of the cement,milk,which is necessary to bond the aggregates.

3.4.2 Placing of concrete

Concrete has to be placed in layers or strips of maximum 15 - 20 cm width.

Placing in layers
is correct

Placing heaps is wrong
(causes segregation)

Each layer has to be cast before the former layer has started setting.

3.4.3 Casting concrete inside standing water

The depth of the water should not exceed 20 cm, as this would demand a pump and a water tight formwork.

The amount of cement has to be increased by at least 50 kg/m3 finished concrete.

The concrete has to be consolidated immediately after placing.

It is not possible to cast concrete inside flowing water.

3.5 Consolidating concrete

3.5.1 Why consolidating ?

If concrete is simply poured into a form and left to harden without further treatment, the product will contain a number of defects:

- Large number of bubbles entrapped in the material.
- Inadequate coverage of coarse aggregates.
- Small or intricate form spaces are not completely filled.
- Reinforcing steel is not solidly bonded to the concrete.

3.5.2 Hand - vibrated concrete

The concrete layers should not be thicker than 15 to 20 centimeters. Those layers have to be stamped vigorously especially at the edges and the corners until the water rises up to the surface.

If the work is interrupted for more than 2 hours, the last layer has to be roughened before new casting can go on.

3.5.3 Consolidating with vibrator

Proper consolidating is only possible with vibrators. But these engines are heavy and expensive. From the transportation point of view therefore, it is not practical to use vibrators in the hilly regions of Nepal.

3.6 Curing concrete

3.6.1 Drying out

As mentioned in the chapter on cement, concrete hardens as a result of the hydration of the cement by water. Fresh concrete contains more than enough water to hydrate the cement completely, but if the concrete is not protected against drying out, the water, especially near the surface, will drop below the amount required for complete hydration.

3.6.2 Shrinkage

Rapid drying-out causes a decrease in volume, which starts at the surface of the concrete mass while the centre of the mass is still wet. This causes a surface tension which the fresh concrete is not able to absorb. The results are reticular cracks all over the surface.

The more water and cement are used the more the concrete shrinks.

3.6.3 Curing

The procedure called curing is designed to prevent surface evaporation of water during setting and hardening stages.

Curing starts as soon as possible without damaging the surface. Curing is brought about by keeping the concrete surface continuously wet. Depending upon the structure and the means available this may be done by:

- Sprinkling or flooding

- Covering with jute bags, grass and leaves which should be wet continuously. Min. coverage 5 cm.

Highly strained concrete should be kept moist for at least 14 days.

3.7 Removal of forms

Forms should be left in place until the concrete has hardened enough to hold its own weight and any other weight it may be carrying.

The surface must be hard enough to remain uninjured and unmarked when care is used in stripping the forms. The engineer in charge of the project should tell how long the formwork should remain in place.