



Basic Construction Training Manual for Trainers

Heini Müller

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Impessum

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References of sketches

1. Elementary course on Building Construction and Materials
SATA
2. Brick work Manual
Laurie Baker
3. Building Construction Manual
SKAT
4. Joints in Masonry
Module MM13
Habitat Polytech, Richmar

Foreword

The devastating earthquake of January 26, 2001 caused tremendous damage to the lives and property of the population living in the northern and northwestern districts of Gujarat. In the wake of this humanitarian tragedy a large number of local, national and international organisations engaged in relief and rehabilitation operations.

A diverse range of strategies was adopted to meet the urgent needs of the suffering population to rehabilitate their lives and reconstruct their houses. In line with its principles, Swiss Red Cross promoted a process-oriented and community-centred approach, taking into consideration the actual needs of the people and the specific conditions of the area. Accordingly, the rural villagers, especially women, were identified as a pro-active force building on their own strength rather than becoming passive recipients of external aid.

After a participatory assessment in three remote villages Antarnesh, Bakutra and Gadsai of Patan district, Swiss Red Cross decided to contribute to the rehabilitation of the lives of nine hundred families, through providing them with new, earthquake save houses, kitchens, toilets and water harvesting systems, called Naya Ghar (New housing). This infrastructure-focused improvement was mainly seen under the aspect of securing people's livelihood by creating employment opportunities in the building sector.

The following complementary organisations were engaged in the Swiss Red Cross and Swiss Solidarity supported Naya Ghar' Project:

- SEWA, (Self-employed Women's Association) with its wide network of more than 500'000 members in Gujarat was selected as the main local project implementing partner organisation.
- DA (Development Alternatives), an India based NGO, in cooperation with Skat Consulting from Switzerland, were selected to ensuring the practicability and quality of the construction work.

The earthquake unfortunately proved that local construction techniques and skill did not prevent houses from collapsing during the incident. This clearly indicated the urgent need to improve on both, construction technologies and especially on construction skill.

For this reason the „Basic Construction Training Manual for Trainers“ has been developed by Skat in close cooperation with field based SEWA construction engineers to ensure that their needs and expectations are met. This Training Manual is the summary of basic practical construction know-how that is of crucial importance to transfer appropriate and new skills to local masons, supervisors and SEWA members in building earthquake resistant houses. It will help construction trainers to pass on relevant skills in constructing houses and improving infrastructure in a practical manner, and offers a wide range of essential information.

Beside the Swiss Red Cross and Swiss Solidarity supported Naya Ghar Project, this „Basic Construction Training Manual for Trainers“ will also serve other SEWA construction related projects. All partners actively involved in the creation and application of this Training Manual hope that through it the new skills acquired by local masons, supervisors and SEWA members will lead to an better building standard and quality, preventing further loss of lives and property in this earthquake prone part of India.

Peter Eppler
Programme Coordinator
Swiss Red Cross

General Introduction

When Gujarat has been hit by the horrifying earthquake in January 2001, international help for the reconstruction of houses and creation of livelihood was soon at hand and warmly welcomed by the needy one.

The concerned government authorities and non-governmental organisations launched reconstruction activities with an astonishing swiftness. The resulting focus of construction activities in Gujarat was demanding a huge number of skilled construction manpower that was regrettably not always easy at hand.

This **Basic Construction Training Manual for Trainers** is tailor made for the specific capacity building / training needs of SEWA for the earthquake reconstruction programme that is, financed by the Swiss Solidarity Fond and implemented in partnership with Swiss Red Cross and technically coached by Skat_consulting.

This manual is specifically focussing on the practical implementation level and provides a wide range of essential information as well as dos and don'ts for trainers to communicate to masons and supervisors during theoretical and on the job trainings. It also contains photos and sketches / drawings that add clarity to the context. These photos and sketches have been collected from various reference sources and are therefore, not of uniform character in its present form.

This manual is divided into five separate modules. **Module one** explains the overall and essential parts of a building. **Module two** provides information about the quality benchmark and testing methods of building materials that are most commonly used in housing construction in Gujarat. **Module three** describes the skilled working principles for; Mortar, Concreting, Brick masonry, Stone masonry, Curing, Plastering and Flooring. **Module four** describes essential working safety measures to avoid occupational accidents. And finally, **Module five** provides a list of literature where useful information regarding earthquake save house designing and construction principles are described.

The merit of this manual lies in the modular structured documentation of information from a practitioner for practitioners that allows the design of various combination of required practical training.

A very tiny fraction of active masons in Gujarat have received formal masonry training. Practical construction skill and information are transferred in an informal way. Because of this system, some practices that are actually wrong have now become "good practice standard" and therefore some present construction qualities are not up to professional quality standards in Gujarat.

There is a genuine need and high demand for formal building construction training by masons. SEWA has recognised this as a high priority and expressed the necessity of professional and practical construction training material for their construction related programmes. This **Basic Construction Training Manual for Trainers** is the resulting outcome of their expression.

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MODULE 5

Basic Building Parts



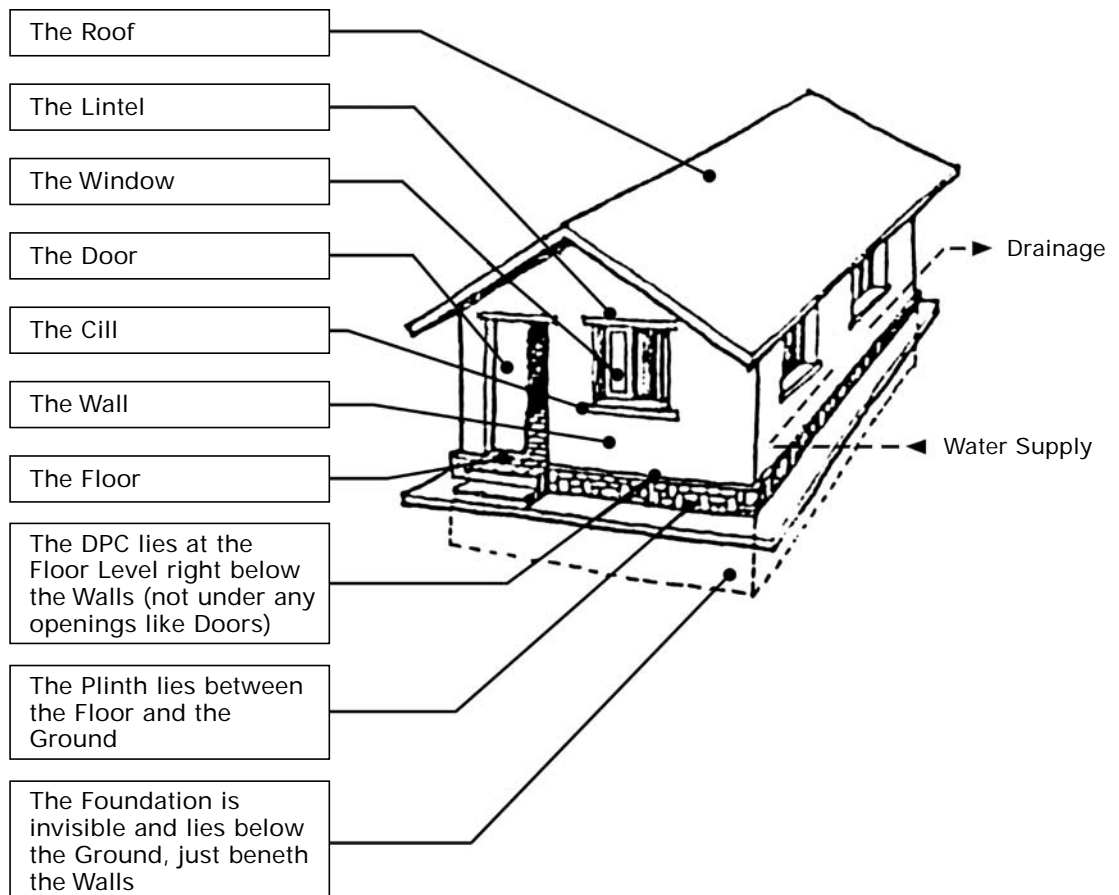
Various parts of a building (Floor, wall, openings, roof, stair)

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1. Building

A building provides shelter against natural elements such as rain, sunshine and wind. It also provides security and privacy. A building consists of the following basic parts:



1.1. Foundation

A foundation is necessary to evenly distribute the entire building load on the soil in such a manner that no damaging settlements take place. Hence, the foundations need to be constructed on good/solid ground



Steel reinforcement placing
in foundation excavation

1.2 Plinth

A plinth is normally constructed just above the ground level and immediately after the foundation. It raises the floor above the ground level and herewith prevents surface water from entering the building.



Plinth construction height up to ground floor level

1.3 Damp proof course (DPC)

Damp proof course is a layer of water proofing material such as asphalt or waterproof cement. Walls are constructed above the damp proof course.

Damp proof course prevents surface water from rising into the walls.

Dampness reduces the strength of the walls and creates unhealthy living conditions. Also it affects the paint and plaster and increasing the cost of maintenance

Damp proofing layer is not required where a plinth beam is constructed, because the plinth beam already performs like a DPC.



Typical DPC type where no concrete plinth has been constructed

1.4 Plinth beam

A plinth beam is constructed depending upon the type of the structure of the building and nature of the soil. It provides additional stability in regard to settlements of the building and earthquake damages.



Completed plinth beam of a building

1.5 Floor

This is the surface on which we do most of our activities. Floorings is laid over the filling of the plinth and on subsequent floors.

Flooring can be done with different materials, but care must be given that the ground below the floor is well compacted. Flooring is done to prevent dampness from rising to the top and to have a firm platform that can be kept hygienic and clean.



Floor construction section, levelling sand, brick layer, cement cover and finishing work

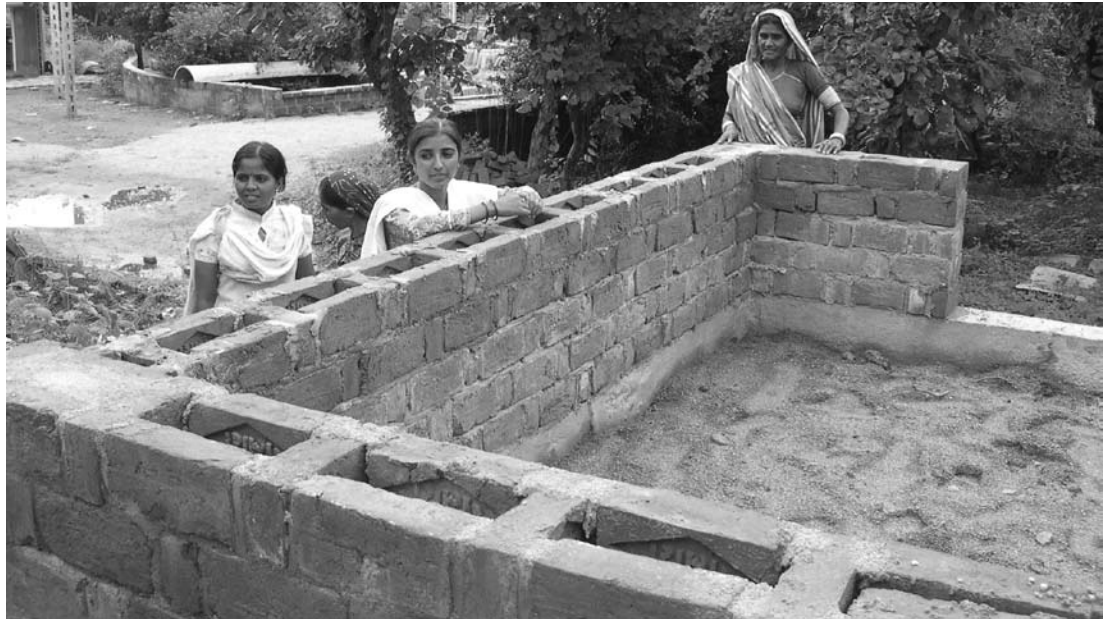
1.6 Walls

Walls are the vertical elements on which the roof finally rests. They can be made of different materials like bricks, stones, mud, concrete blocks, laterite blocks etc.

If the walls are very long, columns can be provided to carry the roof.

Walls provide privacy and enclosure. Walls also provide security and protection against natural elements such as wind, rain and sunshine.

Openings are to be provided in wall for access and ventilation.



Ongoing brick wall (Rat Trap Bond) construction

1.7 Openings

Openings are normally provided in the walls as door, windows and ventilators.

Doors provide access; windows and ventilators provide light and ventilation.



Building with many windows providing desired ventilation and light

Lintels are constructed just above the openings. It is normally a stone slab or a concrete slab.

Sill is the part of the wall that is just below the window.

Lintels are constructed to hold up the walls above the openings.

In earthquake prone areas a continuous lintel beam is provided all over the walls.



Continuous sill (direct bellow window) and lintel (direct above window)

1.8 Stairs

A stair is a sequence of steps and it is provided to afford the means of ascent and descent between the floors and landings.

The apartment or room of a building in which stair is located is called staircase.

The space or opening occupied by the stair is called a stairway.

There are different kind of stairs are used in buildings, like RCC stair, wooden stair, metal stair, brick stair etc.



External stair construction, provides safe access to roof area

1.9 Roof

The roof provides protection for the building and the people living in it. The roof rests on the walls and requires proper anchoring so that wind and other mechanical impact cannot destroy it. A roof can have different shapes but it is always either flat or sloping.

Roof is typically made of RCC, stone slab, tiles etc.



Clay tile covered roofs for rural housing scheme

1.10 Surfaces / Finishes

External finishes are the outer most layer of protection, which protect the structure from weathering.

Internal finishes are the layers given on internal faces. They give durability and pleasing appearance to the inside.



Wall plastering and decorative structure design

2. Service facilities

2.1 Water supply

Water supply facility is done to provide and distribute clean water inside the building.

This can be done through a network of pipes. Usually pipes used are of PVC or GI pipes.

2.2 Drainage and sewerage

This is provided to collect and carry the wastewater away from the building.

2.3 Garbage disposal

Garbage should be collected and disposed for creating hygienic living conditions.

2.4 Electricity

Electrical connections are done to provide power supply for various needs inside the building.

Building Material and Quality Standards



Building material compilation at site (sand, grave, cement, concrete blocks)

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Raw materials for masonry works

The raw materials required for masonry work, together with the skill of the mason are decisive factors for the final quality of the masonry work. Therefore, it is important that the correct raw materials are used. Basic know-how about the different required raw materials is essential for masons as well as supervisors.

The following main raw materials for brick masonry are needed:

- Bricks
 - Stones
 - Concrete blocks
 - Sand
 - Cement
 - Water
- } mortar

1. Bricks

Bricks must be of good quality and without visible cracks for a load-bearing wall. A hard ringing sound emitted when two bricks are struck together indicates that they have been burnt satisfactorily. Generally, the bricks should be true to size and shape, with straight edges and even surface, so as to facilitate laying them into position without using too much mortar. Inferior bricks are generally under-burnt and as a consequence are easily broken and are very porous. These are neither hard nor durable and are incapable of withstanding heavy loads.

Now all over the world, nearly all bricks are roughly the same shape and size – that is approx: **9 x 4-1/2 x 3** inches.

1.1 Classification of bricks

These are defined as suitable for general building work having no special claim to give an attractive appearance. The type in use for most areas in India is classified as Common Bricks.



Piling up of common bricks at production site, ready for selling

1.1.1 Facing bricks

These bricks are thoroughly burned and uniform in colour, and having plane rectangular faces and sharp straight right angled edges. They are used in the exposed face of the brickwork without any plaster or surface treatment. The bricks must have sufficient resistance to penetration by rain and weathering agencies. In general they are selected from a number of bricks. Facing bricks are also used for "Rat Trap Bond" masonry walls.



Facing bricks (second quality) stored at construction site

1.1.2 Solid bricks

A solid brick is a brick with less holes or perforations of 25% of its volume, in which frogs do not exceed 20% of its volume.

1.1.3 Cavity bricks

A burnt clay hollow block or brick with holes larger than 20mm wide, which exceed 20% of its volume.

1.1.4 Special shaped bricks

These are usually solid bricks of various shapes suited to a particular construction.

1.2 Quality of bricks

Generally common bricks are grouped into 3 classes:

Description	Class 1	Class 2	Class 3
Water absorption	Max. 20%	Max 20%	Max 20%
Crushing strength	Min. 105 kg/cm ²	Min. 70 kg/cm ²	Min. 35 kg/cm ²

1.2.1 AA class

Bricks with crushing strength not less than 140 kg/cm^2 are graded as AA class.

1.2.2 Soaked bricks

The strength of a brick decreases by about 25% when soaked in water.

1.2.3 Structure

Brick when broken should be homogeneous in structure, compact and free from holes, cracks, fissures, air bubbles, lumps, pebbles and stones and particles of lime etc.

1.2.4 Shape and size

The brick should be rectangular with straight and sharp edges. All bricks should have the same dimensions and no broken corners or edges.

The size of the bricks varies slightly from region to region in India. Standard size is normally $230 \times 115 \times 70 \text{ mm}$ ($9 \times 4\text{-}1/2 \times 2\text{-}3/4 \text{ inch}$).

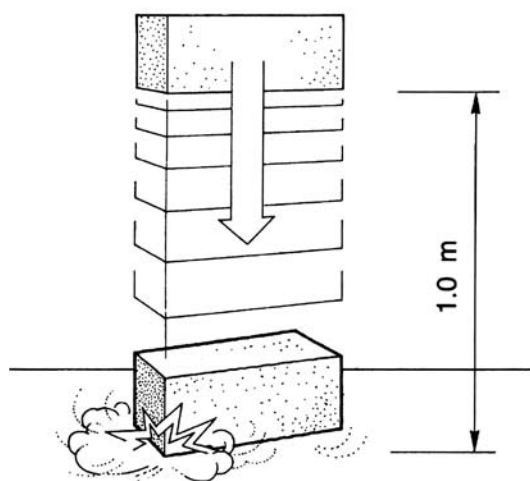
No dimension of a class 1 brick is allowed to vary more than 3 mm from the standard size.

1.2.5 Soundness

The quality of a brick is good if there is a clear ringing sound when two bricks are struck together.

1.2.6 Fall test

A brick should not break when dropped flat on hard ground from a height of about one meter.



1.2.7 Scratch test

A good burned brick has surface so hard that the fingernail cannot scratch it.

2. Stones

Building stones are derived from various types of rocks that are found in the crust of the earth. They are natural products and are used directly, except for their rough sizing and dressing, before being put in a structure.

Stones are or can be used in almost all parts of construction such as foundations, walls, floors, roofs, as well as for roads, dams etc.

As a rough guide, walls with well fitting stones laid in cement mortar have a strength of about 75% of an equivalent brick wall, and walls made of rough stones have a strength of about 50% of the equivalent brick wall.

Crushed and broken stones are used in making concrete and artificial stones such as concrete blocks.



All size bolder stone deposit



Sized stone deposit



All size bolder stone try masonry wall



Sized stone pillar construction

2.1 Classification of stones

Stones or rocks are divided into three main groups:

- Igneous (Granite)
- Sedimentary (Sand-stone Lime-stones)
- Metamorphic (Slates, Marble, Laterite)

2.2 Quality of building stone

The fundamental requirements of building stones are strength, density and durability combined with reasonable facility for working. A good building stone must be hard, tough, compact grained and uniform in texture and color.

Usually, crystalline and close-grained stones are durable.

2.2.1 Signs of good quality stones

- Colour:** Stones should have uniform colour. Red and brown shades and mottled colour indicate the presence of injurious material.
- Weight:** Basically, the heavier and compact grained stones are the stronger and durable they are.
- Water absorption:** A stone absorbing less water is stronger and more durable as it will have less action of rainwater.
- Appearance:** A good building stone should be free from decay, flaws, veins, cracks and sand-holes

2.2.2 Quality tests

There are several tests possible to define the quality of a stone. However, in the field there are basically three tests where one can define the suitable quality of a stone.

Hammer test

Take a hammer and check the stone for its sound. A hard ringing sound indicates that the stone is of good quality and has no major defect such as holes or cracks.

Visible test

Check the stone for any defects such as cracks, patches with soft materials, discoloring etc.

Porosity or absorption test

Weight a stone of reasonable size and place it for 24 hrs. into a water-bucket. A good building stone should not absorb more than 5% of its weight of water after 24hrs immersion.

3. Concrete blocks

Concrete blocks are nowadays very common and time proofed walling materials. Concrete blocks can be produced by hand and by machine. Hand made blocks are usually of lower quality, because machine made blocks are better compacted by a vibrator table. The specific use of a concrete block defines its size and the quality. Cement and coarse sand with small size aggregates are used with very low water/cement ratio.

Hollow blocks have better thermal properties than solid blocks of the same material and total thickness.

Hollow blocks have certain advantages over bricks, they are only about 1/3rd of the weight of the same number of bricks and they can be laid about four times rapidly and are of ample strength for all purposes for which ordinary bricks are used except under concentrated loads. They have the advantages of hollow walls as regards insulation against heat and sound.



Concrete hollow block (CHB) production yard



CHB wall construction used in earthquake resistant house design

3.1 Classification of concrete blocks

Concrete blocks are classified into two main groups;

- Solid blocks
- Hollow blocks

3.2 Quality of concrete blocks

The basic quality requirement of concrete blocks are; strength, uniform in size and to a certain degree water resistant. A good concrete block is produced and stored under a sunshade, has an appropriate mix ratio (not more than 1: 6 for hollow blocks and 1: 10 for solid blocks) contains clean raw materials (sand, aggregates and water) and fresh cement, is properly cured for 21 days and is handled with care up to the point of use for masonry work.

Description	Solid blocks	Hollow blocks (non load bearing walls)	Hollow blocks (load bearing walls)
Density	>1800 kg/cum	>1500 kg / cum	>1500 kg/cum
Crushing strength (after 28 days)	Min. 5 N/mm ²	Min.2.8 N/mms	Min. 3.5 N/mm ²

4. Sand and aggregates

Sand and aggregates are very essential building construction raw materials and deserve special attention.

4.1 Classification of sand and aggregates

Material retained on a 4.75 mm IS (Indian Standard) sieve is classified as coarse aggregate, and below that size as fine aggregate or sand. The material passing a 75-micron IS sieve is generally considered to be clay, fine silt or fine dust in an aggregate.

Sand, which contains 90% of particles of size greater than 0.06 mm and less than 0.2 mm, is fine sand.

Sand, which contains 90% of particles of size greater than 0.6 mm and less than 2 mm is coarse sand.

4.1.1 Coarse aggregate

There are mainly three sources from where coarse aggregates originate namely:

- Natural deposits
- Crushed stones
- Brick aggregates

4.1.2 Sand

There are mainly four types of sand namely:

- Pit sand
- Sea sand
- River sand
- Crushed sand



Pit sand deposit

4.2 Quality of sand and aggregates

The quality of the mortar is directly linked to the characteristics and condition of the sand. Sand and aggregates must be free from clay, loam, vegetables and any other organic material.

Clay or dirt coating on aggregates prevents adhesion of cement to aggregate, slows down the setting and hardening process and reduces the strength of the mortar.

Therefore, clay and silt content should not exceed 10%, otherwise the sand needs to be washed.

4.2.1 Sand storage

The sand should be stored preferably under a shade. The sand should be sufficiently protected, such that no impurity from animals, agricultural waste, children, trees, etc. is possible.

4.2.2 Testing the sand quality

There are two main sand quality-testing methods, namely:

Visible test

Check the sand for impurities such as organic materials (mud, leaves, roots etc.) Remove them before using the sand.

Clay and silt content test

The clay and silt content test can be in two ways:

Hand test

The sand sample is rubbed between damp hand. A clean sand will leave the hands only slightly stained. If the hands stay dirty, it indicates the presence of too much silt or clay.

Bottle test

Take a bottle and fill in the sand until it is half full. Fill in clean water until the bottle is three-quarters full. Shake up vigorously and leave it to settle for about one hour. Clean sand will settle immediately, silt and clay will settle slowly on top of the sand. The thickness of the clay and silt layer should not exceed one-tenth or 10% of the sand below.

This test is also called decantation test. This test is not applicable to crushed stone sands!!

Dirty sand should never be used in masonry because it will reduce the adhesive value of the mortar considerably.

4.2.3 Sea sand

Sea sand is unsuitable for mortar as it contains salts, which attract and retain moisture. In addition the salt content in the mortar will produce a whitish powder of efflorescence, which discolors the brickwork or masonry.

5. Cement

Cement is a mixture of 60 to 67% lime, 17 to 25% silica and 3 to 8% alumina, which are intimately mixed together with water to form into a slurry, which is subsequently heated, dried, calcined and ground to a very fine powder. A small proportion of gypsum is added before grinding in order to control the rate of setting.

5.1 Setting/Hardening

The terms setting and hardening have different meanings. Setting is the process which changes a fluid concrete to a solid but weak state. Hardening is the process by which the weak set concrete attains strength.

5.2 Hydration of cement

When water is added to cement, the cement hydrates and during the chemical reactions, which take place while the cement is setting, an increase in temperature occurs and a considerable quantity of heat is generated

5.3 Different types of cement

There are total five different kinds of cements. Cements are classified by their properties and chemical composition. The names of these five kinds of cements are:

- Ordinary Portland Cement
- Rapid hardening Cement
- Quick setting Cement
- Blast – furnace Slag Cement
- High Alumina Cement

5.4 Type and quality

For ordinary brick masonry work it is recommended to use ordinary Portland cement. In order to achieve a good mortar in strength and durability, it is essential that the following rules and regulations be followed:

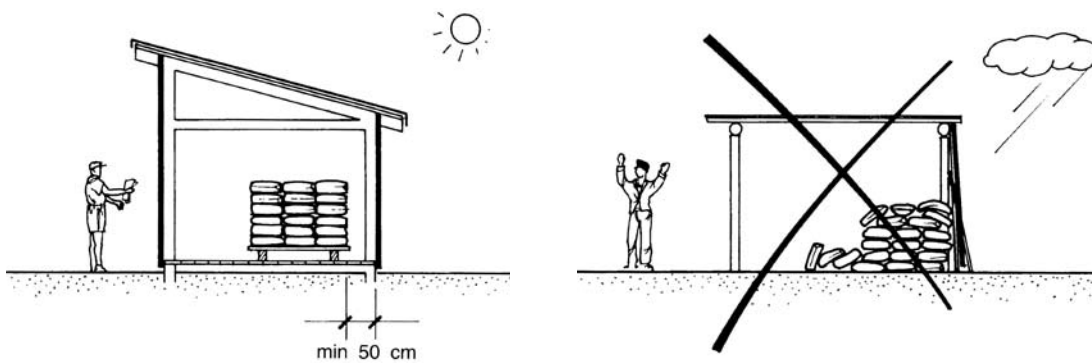
5.4.1 Cement storage

Cement can be safely stored in bags for a few months if kept in a dry room. Paper bags are better for storing than jute bags because paper bags perform better in regard to quality deterioration due to moisture. During the monsoon time, the cement storage plays an even more important role, since the relatively higher humidity accelerates the deterioration process of the cement.

Cement bags should be stored on a raised wooden platform (e.g. timber pallets) about 15 to 20 cm above the floor level and about 30 to 50 cm away from walls.

The cement stack should not be more than 10 bags high. The bags should be placed close together to reduce circulation of air.

A cement bag should never be opened until its immediate use for mixing.



5.4.2 Use of fresh cement

Ordinary Portland cement, which has been stored for over six months, should not be used for masonry work.

The average reduction of strength in a 1:2:4 mix as a result of storage is:

Fresh cement	strength	100%
Cement after 3 months,	strength reduced by	20%
Cement after 6 months,	strength reduced by	30%
Cement after 12 months,	strength reduced by	40%
Cement after 24 months;	strength reduced by	50%

5.5 Testing the cement quality

The indication of damaged cement is given by the presence of large lumps of set cement. These lumps of set cement should not be used, not even if screened again.

The freshness of cement can be tested as per following description:

Lump test:

Check the cement for any small or large lumps. Remove them.

Rubbing test:

When cement is rubbed between fingers and thumb it should feel like a smooth powder such as flour.

Setting test:

If you are uncertain about your cement quality you can make a simple setting test.

Make a stiff paste of neat cement and water and form it into a cake about 75 mm diameter and 12 to 15 mm thick. The cake should commence to set in about 30 to 60 minutes. In 18 to 24 hours the cake should have hardened sufficiently so that it does not effortlessly scratch the surface with a thumbnail.

6. Water

The workability of a mortar increases as the water content of the mix is increased. Water lubricates the mixture. However, increased water content will cause a decrease in strength, produce cracks (shrinkage) and decrease density.

Therefore, not only the quality, but equally important the quantity of the water is important for producing a good mortar and brick masonry work.

6.1 Type and quality

Almost any natural water that is drinkable and has no pronounced taste or odor can be used as mixing water for making cement mortar. Water suitable for making cement mortar, however, may not be fit for drinking.

6.1.1 Seawater

Seawater should not be used as mixing water for cement mortar.

6.1.2 Collected rainwater from roofs

Rainwater collected from roofs can be used for mixing mortar or concrete.

6.1.3 Oils

Various kinds of oil are occasionally present in mixing water. Water mixed with any kind of oil shall not be used for mixing mortar or concrete.

6.2 Water storage

Water should be stored where no contamination is possible. Water stored in clean drums or covered tanks is preferred. The age of the water, or the storage time does not affect the cement mortar quality in any way.

6.3 Testing the water quality

Water of questionable suitability can be used for making cement mortar cubes. The water in question should achieve the strength in 7 and 28 days equal to at least 90% of comparable specimens made with drinkable water.

Principles of Construction



Bad brick wall construction resulting into corner collapse / damage

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1. Principles of mortar

1.1 What is mortar?

Mortar may be defined as a material composed of fine aggregate and cement, which forms a hardened mass after mixing with water. It is used in the beds and side joints of masonry work, in order to bind the stones, bricks or blocks together and distribute the pressure throughout the block-work.

Mortar is further used also for plastering work, pointing work, flooring and topping work.

Good mortar used for masonry consists of cement, sand and water in the correct proportions. When the materials are freshly mixed, mortars have a plastic consistency, which could be easily worked with trowels to fill the joints in masonry or to render the surfaces of walls by plastering etc. By the virtue of the setting properties of the binding material used (cement, lime) they set and become hard subsequently.

1.2 Type of mortars

Generally there are three common types of mortars in use for masonry and plastering work, namely:

- Cement mortar
- Lime mortar
- Cement – lime mortar

1.3 Cement mortar

Cement mortar is nowadays the most commonly used mortar for brick as well as stones or concrete block masonry work. It provides high strength properties. Mix proportion varies according to requirements of the masonry structure.

1.4 Lime mortar

This is a mixture of quicklime (burnt limestone) and sand in the proportion of 1 part lime and 3 parts sand, in addition to water. Lime mortar was once the principal material used for bedding and jointing bricks and stones. It is used less frequently now as it develops strength very slowly and is not easily available in the market.

1.5 Cement – lime mortar

This was the most usual general-purpose mortar comprising 1 part cement 2 parts lime and 9 parts sand. The addition of lime improves the workability and makes it easier to use. Cement – lime mortar is mainly used for internal work.

1.6 Mortar sand granulation

The sand used for every kind of mortar must be clean and free from clay and other organic matters.

For getting a proper mortar, the granulation of the sand needs to be correct. Sand without fines (below 0.5mm) gives a harsh mortar with a low compressive strength and a bad workability. Cement mortar gives the best result when the sand comprises of the following:

0	-	0.5 mm (60% 0-0.2 mm)	1 part
0.5	-	2 mm	1 part
2	-	4 mm	1 part

1.7 Mixing mortars

The sand is placed on a clean platform, the correct amount of cement is added to it, both, sand and cement are thoroughly mixed before water is added and the mass gradually worked up into a plastic condition. The general rule is that sand and cement are mixed dry together at least 3 times before water is added. This is important for achieving the proper plasticity.



Flatten the dry mix with a trowel, if properly mixed a uniform gray color is visible.



Add water only once a uniform gray color is visible.

1.7.1 Weight method

Mortar mixtures are also expressed in kg of cement per 1 m³ of cement mortar. For example PC 250 means that 250 kg of Portland Cement (PC), approx. 1000 liters of sand and 120 liters of water are used to obtain about 1 m³ mortar. This method is mainly used for large constructions in cities for bridges, hotel and shopping complexes etc.

1.7.2 Volumetric method

Usually on small and rural construction sites the more practical volume batching method is applied. The volumetric method is a very appropriate way to mix raw materials. Special care must be given to ensure that the workers measure each time the same volume.

1.8 Categorization of mortars and its mix ratio

Mortars are categorized in mainly three groups, namely:

Group 1

Highly stressed masonry incorporating height strength structural units as used in multistory load bearing buildings.

Group 1 batching

Cement	Sand
1	4
Bucket	Buckets

Group 2

Normal load bearing applications such as external house walls, parapets, and balustrades, retaining structures, freestanding garden walls and other walls exposed to severe dampness.

Group 2 batching

Cement	Sand
1	6
Bucket	Buckets

Group 3

Lightly stressed non-structural walls

Group 3 batching

Cement	Sand
1	8
Bucket	Buckets

1.9 Dos and don'ts**Dos:**

Use always-clean sand for mortar.

Why?

Contaminated sand (e.g. roots, leaves, plastic parts, saw dust, animal and human excreta etc) will not bind with cement, hence is weakening the mortar. Also sand with high percentage of clay or silt will weaken the mortar, because the clay or silt contains too many fines that needs to be covered by cement for proper binding, hence, the mortar becomes weak.



Sand deposit properly covered and protected from being contaminated

Dos:

Always use fresh and lump free cement for mortar

Why?

Old cement is losing its strength property. E.g. cement that has been stored for about 6 months is gaining 30% less strength than fresh cement. For good masonry work, strength is important as it influences the overall building quality.



Improperly stored cement results in loss of quality

Dos:

Always mix the dry ingredients (sand & cement) together before adding water.

Why?

Wet sand particles have the tendency to stick together and are therefore hindering that cement can cover them. This results in an un-uniform mix that is reducing the mortar quality, because each sand particle should ideally be fully covered with cement.

Further, adding water together with sand and cement in one go makes mixing the mortar extremely difficult for the laborers.

Dos:

Always protect the mortar-mixing place from wind, rain and sunshine.

Why?

Wind and sunshine is entraining the water from the mortar and is accelerating the hardening process before it is being used. This makes the mortar useless for any purpose. Rain is adding water and the mortar becomes unusable too.

Don'ts:

Do not use or re-use mortar that has already hardened. As cement mortar sets relatively quickly (approx. 30 minutes), it should never be mixed in huge quantities.

Why?

In hardened mortar, the hydration process of the cement has started and re-mixing it is destroying the bond between cement and sand. This bond cannot regain strength again by simply adding fresh water to the mortar.

2. Principles of concreting

2.1 What is concrete?

In its simplest form, concrete is a mixture of paste and aggregates. The paste, composed of portland cement and water, coats the surface of the fine and coarse aggregates. Through a chemical reaction called hydration, the paste hardens and gains strength to form the rock-like mass known as concrete. Within this process lies the key to a remarkable trait of concrete: it's plastic and malleable when newly mixed, strong and durable when hardened. These qualities explain why one material, concrete, can build skyscrapers, bridges, sidewalks and superhighways, houses and dams. The key to achieving a strong, durable concrete rests in the careful proportioning and mixing of the ingredients. A concrete mixture that does not have enough paste to fill all the voids between the aggregates will be difficult to place and will produce rough, honeycombed surfaces and porous concrete. A mixture with an excess of cement paste will be easy to place and will produce a smooth surface; however, the resulting concrete is likely to shrink more and be uneconomical.

A properly designed concrete mixture will possess the desired workability for the fresh concrete and the required durability and strength for the hardened concrete. Typically, a mix is about 10 to 15 percent cement, 60 to 75 percent aggregate and 15 to 20 percent water. Entrained air in many concrete mixes may also take up another 5 to 8 percent.

Portland cement's chemistry comes to life in the presence of water. Cement and water form a paste that coats each particle of stone and sand. Through a chemical reaction called hydration, the cement paste hardens and gains strength. The character of the concrete is determined by quality of the paste. The strength of the paste, in turn, depends on the ratio of water to cement. The water-cement ratio is the weight of the mixing water divided by the weight of the cement. High-quality concrete is produced by lowering the water-cement ratio as much as possible without sacrificing the workability of fresh concrete. Generally, using less water produces a higher quality concrete provided the concrete is properly placed, consolidated, and cured.

2.1.1 Other ingredients

Although most drinking water is suitable for use in concrete, aggregates are chosen carefully. Aggregates comprise 60 to 75 percent of the total volume of concrete. The type and size of the aggregate mixture depends on the thickness and purpose of the final concrete product. Almost any natural water that is drinkable and has no pronounced taste or odor may be used as mixing water for concrete. However, some waters that are not fit for drinking may be suitable for concrete. Excessive impurities in mixing water not only may affect setting time and concrete strength, but also may cause efflorescence, staining, corrosion of reinforcement, volume instability, and reduced durability.

Relatively thin building sections call for small coarse aggregate, though aggregates up to six inches (150 mm) in diameter have been used in large dams. A continuous gradation of particle sizes is desirable for efficient use of the paste. In addition, aggregates should be clean and free from any matter that might affect the quality of the concrete.

2.1.2 Hydration begins

Soon after the aggregates, water, and the cement are combined, the mixture starts to harden. All portland cements are hydraulic cements that set and harden through a chemical reaction with water. During this reaction, called hydration, a node forms on the surface of each cement particle. The node grows and expands until it links up with nodes from other cement particles or adheres to adjacent aggregates. The building up process results in progressive stiffening,

hardening, and strength development. Once the concrete is thoroughly mixed and workable it should be placed in forms before the mixture becomes too stiff. During placement, the concrete is consolidated to compact it within the forms and to eliminate potential flaws, such as honeycombs and air pockets. For slabs, concrete is left to stand until the surface moisture film disappears. After the film disappears from the surface, a wood or metal handfloat is used to smooth off the concrete. Floating produces a relatively even, but slightly rough, texture that has good slip resistance and is frequently used as a final finish for exterior slabs. If a smooth, hard, dense surface is required, floating is followed by steel troweling. Curing begins after the exposed surfaces of the concrete have hardened sufficiently to resist marring. Curing ensures the continued hydration of the cement and the strength gain of the concrete. Concrete surfaces are cured by sprinkling with water fog, or by using moisture-retaining fabrics such as burlap or cotton mats. Other curing methods prevent evaporation of the water by sealing the surface with plastic or special sprays (curing compounds). Special techniques are used for curing concrete during extremely cold or hot weather to protect the concrete. The longer the concrete is kept moist, the stronger and more durable it will become. The rate of hardening depends upon the composition and fineness of the cement, the mix proportions, and the moisture and temperature conditions. Most of the hydration and strength gain take place within the first month of concrete's life cycle, but hydration continues at a slower rate for many years. Concrete continues to get stronger as it gets older.

2.1.3 The forms of concrete

Concrete is produced in four basic forms, each with unique applications and properties. **Ready mixed concrete.** It's batched at local plants for delivery in the familiar trucks with revolving drums. **Precast concrete** products are cast in a factory setting. These products benefit from tight quality control achievable at a production plant. **Precast products** range from concrete bricks and paving stones to bridge girders, structural components, and panels for cladding. **Concrete masonry**, another type of manufactured concrete, may be best known for its conventional 8 × 8 × 16-inch block. Today's masonry units can be molded into a wealth of shapes, configurations, colors, and textures to serve an infinite spectrum of building applications and architectural needs. Cement-based materials represent products that defy the label of "concrete," yet share many of its qualities. Conventional materials in this category include mortar, grout, and terrazzo. Soil-cement and roller-compacted concrete—"cousins" of concrete—are used for pavements and dams. Other products in this category include flowable fill and cement-treated bases. A new generation of advanced products incorporates fibers and special aggregate to create roofing tiles, shake shingles, lap siding, and countertops. And an emerging market is the use of cement to treat and stabilize waste.

2.2 Functions and requirements of concrete ingredients

2.2.1 Functions of cement

- It fills up the voids in the fine and coarse aggregates.
- Make the concrete impermeable.
- It provides strength to concrete on setting and hardening.
- It binds the aggregates into a solid mass by virtue of its setting.
- Hardens when mixed with water.

2.2.2 Functions of sand

- Sand fills the voids existing in the coarse aggregates.
- It reduces shrinkage of concrete
- Sand helps in hardening of cement by allowing the water through its voids.

2.2.3 Coarse aggregate

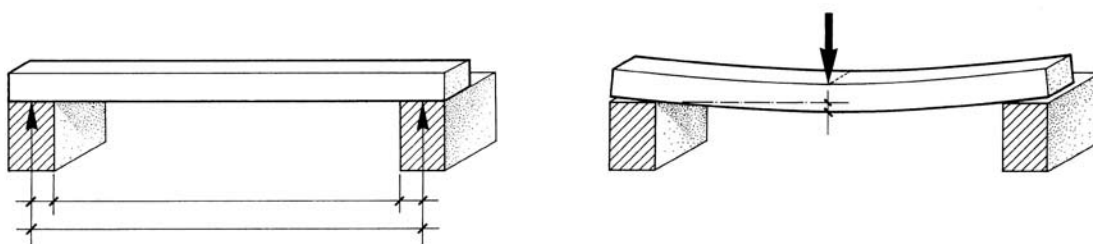
- It makes solid and hard mass of concrete with cement and sand.
- It reduces the cost of concrete, since it occupies more volume.

2.2.4 Water

- Water wets the surface of aggregates
- It facilitates the spreading of cement over the aggregates and makes the mix workable.
- It initiates the hydration process of the cement, subsequently starts the setting and hardening process
- It controls the heat generated by the hydration process of the cement

2.3 Reinforced concrete

Concrete can support heavy loads in compression, but its tensile strength is relatively low. (About one –tenth of the compressive) To compensate for the low tensile strength property of the concrete, steel bars with a very high tensile strength is combined with concrete.



By embedding steel bars in the concrete, advantage is taken of these properties to improve the load carrying capacity of the structure. The steel is placed in the concrete that is subjected to tension but also to avoid cracks due to shrinking.



2.4 Reinforcement

2.4.1 Type and characteristics of steel bars

Steel is a high strength material and for reinforced concrete work mild steel, medium tensile steel, high tensile steel and hard drawn steel is commonly used.

Different size of reinforcement & their weights:

Sr.No.	Size of Steel (dia in mm)	Weight per Rm.
1.	6	0.22 kg
2.	8	0.39 kg
3.	10	0.62 kg
4.	12	0.89 kg
5.	16	1.58 kg
6.	20	2.47 kg
7.	25	3.85 kg

The various forms in which steel is used as reinforcement in R.C.C. works are round bars, deformed bars, twisted bars, square bars and flats. Some times expanded metal fabrics made by welding steel wire in the form square mesh, are also used as reinforcement in slabs.

Mild steel and medium tensile steel bars of round sections are most commonly used in R.C.C. work. The diameters of round bars used in normal building work are 6, 8, 10, 12, 16, 18, 20, 22, 25 and 32 mm.

Deformed bars or high yield strength deformed bars are furnished with lugs, ribs or other form of surface deformations for the purpose of increasing their bond strength with concrete.

2.4.2 Categories & purpose of reinforcement

There are two main categories and purposes of reinforcement by steel.

The main reinforcement, to take care for the tension forces.

Distribution reinforcement, to spread the load and to keep the main reinforcement in position during casting.

2.4.3 Basic rules for steel reinforcement

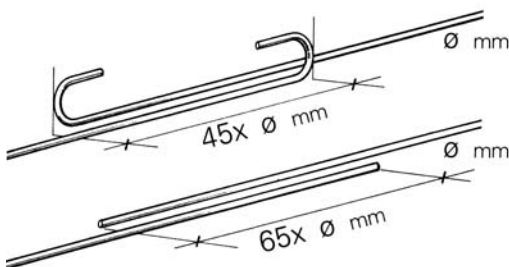
The main reinforcement should always be at the place where tension occurs. It should adequately covered by concrete to avoid corrosion of the reinforcement. Steel bars of plain surface (mild steel) need to be hooked at the ends to obtain better adhesion, and therefore create a greater strength for the structure. Hooking is not necessary for steel bars with ribbed surface (Tor-steel).

A proper bond between the steel rods and the concrete is the most important for reinforced concrete. The surface of the rod has to be clean. In order to provide a proper bond the rods have to be surrounded completely by the concrete. Therefore, the reinforced concrete has to be properly vibrated. Plain bars must have ends with hooks, which, should be anchored, in the pressure zone. Deformed bars with ribbed projections can have straight ends but then the anchorage has to be in the pressure zone of the structure.

If rods have to be overlapped the following rules show the minimum overlap length:

Rod with hook - 45 times diameter of the rod

Straight - 65 times diameter of the rod

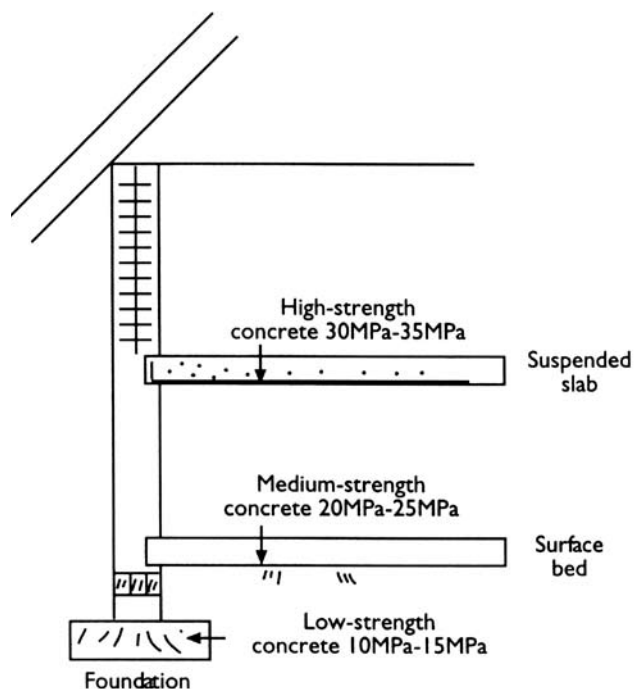


Important:

The proper placing of reinforcement for structures of high quality concrete requires a working drawing or reinforcement plan, containing all the necessary information. A structural engineer will make this reinforcement plan only.

2.5 Type of concrete

The strength of the concrete depends on mix proportions and should suit the work being done. Different applications require different strengths of concrete. Three different strength categories with typical applications are outlined below



2.5.1 High strength concrete (M 300 – M350)

High strength concrete should be used for suspended structural beams and slabs, precast items (stairs) and heavy-duty floors.

2.5.2 Medium strength concrete (M 200 – M250)

Medium strength concrete is suitable for reinforced foundations and slabs, light duty house floors, paths, steps, driveways and garage doors.

2.5.3 Low strength concrete (M100 – M150)

Low strength concrete is suitable for unreinforced foundations for houses and freestanding walls.

2.5.4 Mixing proportion of concrete

Concrete Type	Proportion of Cement	Proportion of Sand	Proportion of Aggregates
M100	1	4	6
M150	1	4	4
M250	1	3	3
M350	1	2	2

2.6. Cover in concrete

An appropriate concrete cover of the steel reinforcement is absolutely essential to protect the steel members from weathering effects. As soon as air contacts the steel members inside the concrete, the oxidation process starts, leading to rusting and eventually disintegration of the affected part. This can lead to serious consequences such as the collapse of a beam or slab.

Minimum requirement of cover in concrete members:

Members	Minimum reinforcement cover
Slab	150 mm
Beam	25 mm
Column, Foundation	40 mm

2.7 Requirements of concrete

2.7.1 Strength

The concrete must be strong enough to bear the imposed stresses safely in each with the required factor of safety. It will be uneconomical making the concrete stronger than desired, but at the same time its minimum strength must be ensured.

2.7.2 Workability

The concrete mix used should be such that it can be easily mixed, placed, compacted and finished at surface with minimum of effort i.e. the concrete should be workable.

2.8 Factors influencing concrete quality

2.8.1 Cement

The cement quality is a very important factor that influences the basic requirement of the concrete. Cement must be fresh and free from any lumps. The grading of the cement is important too. A high grade cement, e.g. Grade 53 is gaining more rapid strength than a Grade 33 cement. However, after 90 days, both type of cement will have approx. gained the same final strength.

2.8.2 Water – Cement ratio

The ratio of minimum quantity of water to the weight of cement, required to obtain the desired consistency and workability of concrete mix is called: water cement ratio. Concrete strength decreases with the increases in water cement ratio. This is because the added water once evaporated leaves behind very very small voids. The more voids there are in a concrete, the weaker it becomes.

2.8.3 Raw materials

The sand and aggregate must be free of leaves, grass and other foreign matters. Sand should be fairly coarse with particle sizes ranging from fine dust up to about 5mm.

Clean aggregate with sizes of 26,5 mm, 19 mm, 13,2 mm or 9,2 mm can be used for concrete. Aggregate size of 26.5 mm can be used for thick section such as foundations, deep suspended

slabs and industrial floors thicker than 120 mm. 19 mm aggregates can be used for floors, paths and driveways. Aggregates 13,2 mm or 9,5 mm can be used for thin concrete section such as thin suspended slabs, precast items with section thickness ranging from 40 mm to 50 mm.

2.8.4 Fineness of fine aggregate

Concrete strength decreases with increases in fineness of fine aggregate. This is because the fines require a lot of cement for a total coverage, resulting into a leaner overall mix.

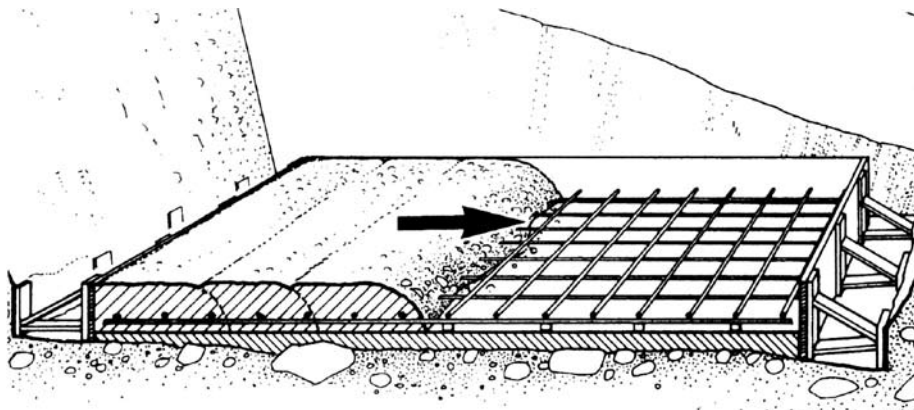
2.8.5 Placing the concrete

Concrete after mixing must be placed in the defined position and compacted before the initial setting of cement starts.

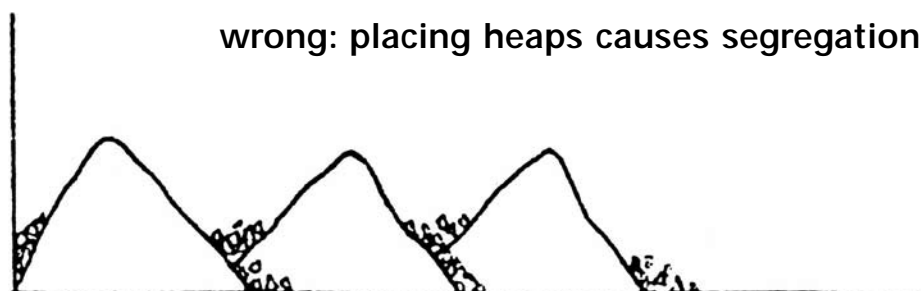
Before placing of concrete starts, it must be ensured that the forms are rigidly braced, true to their position, oiled, cleaned and dried of any standing water.

Special care must be taken that before placing the concrete that the steel reinforcement is properly distanced from the formwork to ensure appropriate coverage of the steel members.

Place the concrete as close to its final position as possible. If concrete is placed on the ground, the soil should be thoroughly damp, but without any standing water when the concrete is placed. Work the concrete right into the corners and along the edges on the form or hole with a spade or a trowel.

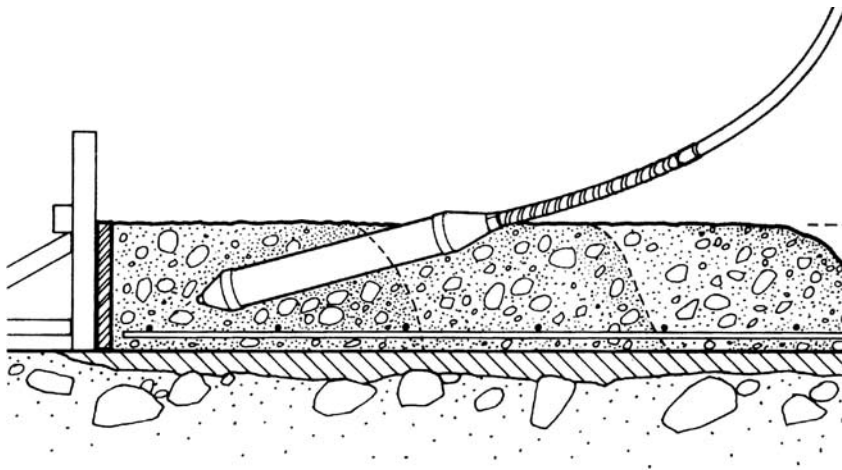


Concrete should never be dropped from a height, as it will cause segregation.



2.8.6 Compaction

It is extremely important that the concrete is thoroughly compacted immediately after placing in to the forms. Not properly compacted concrete results into so called "honey comb" spots that expose the steel reinforcement to air and resulting in rusting. Besides, not properly compacted concrete has a reduced bearing capacity and is overall weakening the casted structure. A vibrator needle can achieve best compaction.



2.8.7 Curing

After concrete is placed, a satisfactory moisture content and temperature (between 50°F and 75°F) must be maintained, a process called curing. Adequate curing is vital to quality concrete. Curing has a strong influence on the properties of hardened concrete such as durability, strength, watertightness, abrasion resistance, volume stability, and resistance to freezing and thawing and deicer salts. Exposed slab surfaces are especially sensitive to curing. Surface strength development can be reduced significantly when curing is defective. Curing the concrete aids the chemical reaction called hydration. Most freshly mixed concrete contains considerably more water than is required for complete hydration of the cement; however, any appreciable loss of water by evaporation or otherwise will delay or prevent hydration. If temperatures are favorable, hydration is relatively rapid the first few days after concrete is placed; retaining water during this period is important. Good curing means evaporation should be prevented or reduced

2.8.8 Effect of aging

Basically if all rules and regulation for concreting are properly followed, concrete gains strength by aging. However, the rate of increase in strength decreases with time.

2.9 Mixing of concrete

Mixing of concrete is usually made by hand for small quantities or by machine for big quantities.

2.9.1 Hand mixing

Hand mixing is adopted where in smaller quantities of aggregates is involved or the involvement or procuring of mixing machines is out of reach. Mixing shall always be done on watertight platform in order to avoid cement water seepage.

Procedure for proper hand mixing:

- Spread the measured quantity of sand in a layer of about 10 cm on the mixing platform.
- Place the cement on top of the sand and mix the two thoroughly together until they form an even color.
- Pile the mixture into a heap and make a hollow in the middle.
- Pour in water slowly in small quantities and mix until a smooth paste is formed.
- Add now the correct amount of aggregate and mix until every aggregate is properly coated.

2.9.2 Machine mixing

Machine mixing is required for large quantities of concrete work and for good workability for placing the concrete in a short time and with no wastage.

Concrete having coarse aggregates is mixed in concrete mixers.

Procedure for machine mixing:

- Measure the quantities of each ingredient
- First add the aggregates and some amount of water, then the cement, then the sand
- Mix and add more water until the right consistency is reached
- Empty the mixer completely when discharging each batch.
- Clean the concrete mixer thoroughly on completion.

2.10 Dos and don'ts

Dos:

Always calculate exactly how much finished concrete is required for the job to do and ascertain how much cement sand, coarse aggregate and water will be required

Why?

Even a good guess can go wrong. While guessing the amount of material required it can happen that you order too much, resulting into unnecessary expenses. It might also happen that you order too less and organizing immediately the remaining material might prove to be difficult or even impossible, resulting into unnecessary expenses and loss of quality.

Dos:

Use always-clean sand and aggregates for concrete.

Why?

Contaminated sand and aggregate (e.g. roots, leaves, plastic parts, saw dust, animal and human excreta etc. will not bind with cement, hence is weakening the concrete. Also sand and aggregate with high percentage of clay or silt will weaken the concrete, because the clay or silt contains too many fines that needs to be covered by cement for proper binding, hence, the concrete becomes weak.



Dogs will contaminate concrete raw material, therefore proper protection is required

Dos:

Always use fresh and lump free cement for concrete

Why?

Old cement is losing its strength property. E.g. cement that has been stored for about 6 months is gaining 30% less strength than fresh cement. For good concrete work, strength is important as it influences the overall building quality.

Dos:

Always mix the dry ingredients (sand & cement) together before adding water.

Why?

Wet sand particles have the tendency to stick together and are therefore hindering that cement can cover them. This results in an un-uniform mix that is reducing the concrete quality, because each sand and aggregate particle should ideally be fully covered with cement.

Further, adding water together with sand, aggregate and cement in one go makes mixing the concrete extremely difficult for the laborers.

Dos:

Always protect the concrete-mixing place from wind, rain and sunshine.

Why?

Wind and sunshine is entraining the water from the concrete and is accelerating the hardening process before it is being used. This makes the concrete useless for any purpose. Rain is adding water and the concrete is becoming too wet, resulting in a weak final strength.

Dos

Use the concrete mix within a maximum of 1 hr. after wet mixing and do never retempering by mixing in additional water

Why?

In concrete that is older than 1 hr., the hydration process of the cement has started and re-mixing it is destroying the bond between cement and sand/aggregates. This bond cannot regain strength again by simply adding fresh water to the concrete.

Dos:

Use always-proper quantity measuring boxes.

Why?

Using empty cement bags, or other means does not always ensure that the correct amount of raw material is being added. This inaccuracy could lead into a leaner or richer mix than designed, either reducing the concrete quality or adding extra costs.

Dos:

Always make a final check of the formwork before placing the concrete into the form.

Why?

During placing of the reinforcement some supporting pools or bracing might have been dislocated. If now concrete is pored into the framework, side shuttering or even slab shuttering might collapse. This is the worst-case scenario, but unfortunately it still happens too often, sometimes even killing people.

Don'ts

Do not make concrete work if the outside temperature is crossing 40 degree Celsius.

Why?

The direct sunshine temperature at 40 degree Celsius is nearly 50 degree Celsius. Hence, the water evaporation of the freshly placed concrete will happen immediately, causing serious shrinkage cracks and hindering a proper and controlled hardening of the concrete. This will finally seriously weaken the concrete work quality.

However, if it is unavoidable to stop concreting work, then the following precautions can be taken:

- Cooling down the aggregates by water sprinkling
- Providing a shade at the casting side
- Placing immediately plastic on the casted concrete

Don'ts

Do not store the steel bars direct on the ground.

Why?

The steel bars might get dirty and covered with mud. If the mud will not be properly washed away before concrete casting, the binding of the steel bar with the concrete is reduced, resulting in a weak structure.



Steel bars properly stored at construction site.

Don'ts

Do not clean the rust of the steel bars.

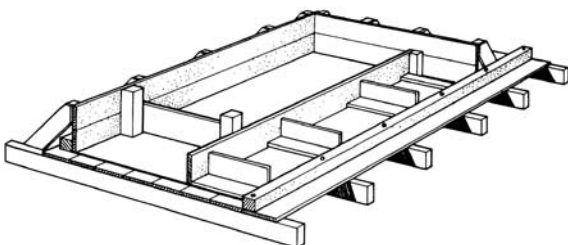
Why?

An alkaline environment, cement, surrounds the steel bars. The alkalinity of the cement will clean the rust in a very short time, provided no air is accessing the steel bars.

2.11 Form work

Most structural concrete is made by casting concrete into previously made boxes that are called forms or shuttering. Usually wall, column, beam and slab forms are built by joining wooden boards edge on edge. Sometimes plywood may be nailed on since it is tighter and more wrap resistant. In certain cases metal forms are used, e.g. when a large number of equal structural members (pre-cast elements) have to be erected or when the parts should be very exact in measurements.

The most suitable material for formwork is wood, in particular boards, rails, batten and planks. All this timber is available in various quality and dimension. Hardwood should not be used for parts where nailing is necessary. Boards of less quality and boards of rough surface do not last very long as shuttering. Using plastic or metal sheets can extend the reuse.



All form work material (planks, boards, steel etc.) and elements formwork (moulds) are sprinkled with water before placing concrete. After striking or dismantling, the formwork is cleaned and eventually oiled as well as properly stored and protected from sun and rain. This will guarantee the use of many times.

Form work for pre-cast products like cover slabs, fence posts, well and culvert rings, and element form work for standard structures like stand posts should be made of quality timber or steel. The use of GI sheets as additional reinforcement for timber formwork is very suitable because nailing of sideboards or batten is still possible

2.12 Removal of the 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.

Under ordinary circumstances, forms for various types for construction be removed after intervals as follows:

Side forms on beams, lintels, walls, columns	1 to 2 days
Slabs, lintels, beams	
Clear span 3 m and below	8 to 14 days
Clear span 3 – 6m	16 to 14 days
Clear span more than 6m	24 to 35 days
Cantilever constructions	as long as possible but min. 35 days (because of creeping of the concrete)

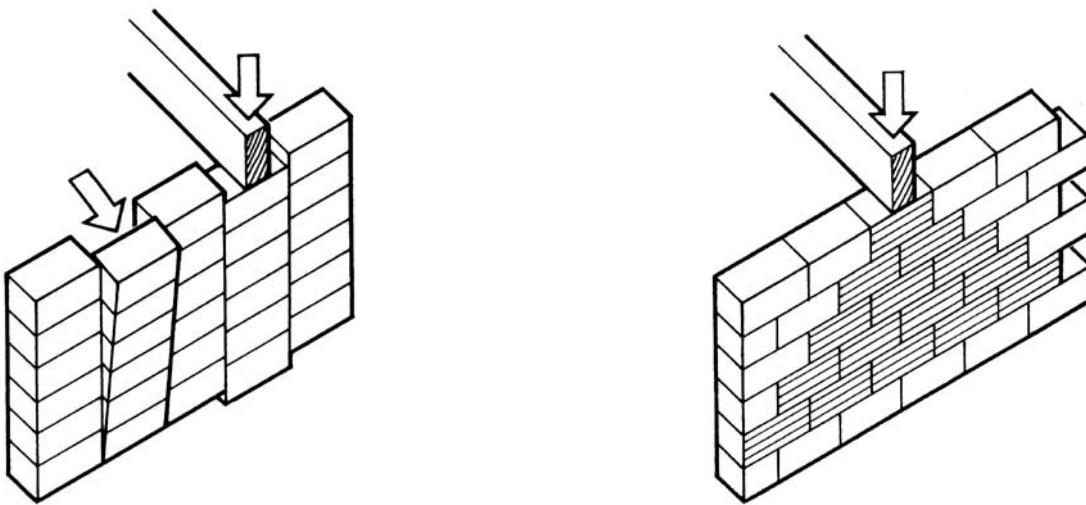
3. Principles of brick masonry

The craft of the bricklayer is concerned with embedding bricks in mortar and suitably arranging them so that the mass, called brickwork conforms to certain requirements such as strength and appearance. Strength depends a great deal upon the bond.

There are many rules for bonding and they are mainly related to the different bonds such as the English bond, the Flemish bond or the Rat Trap bond.

Bonding means the arrangements of bricks in such a way that no vertical joint of one course is exactly over the one below. This means that the brick is laid in such a way that it overlaps and breaks the joint below.

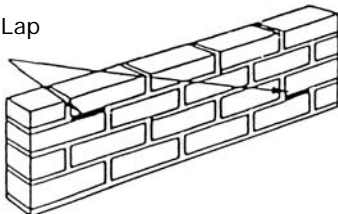
An un-bonded wall, with its continuous vertical joints, has little strength and stability and such joints in general must be avoided.



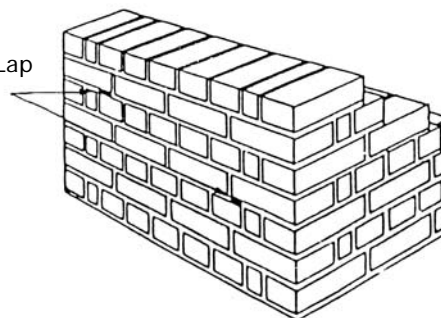
3.1 Brick overlap between layers

The amount of lap is generally half of the length of a brick. The minimum lap is $\frac{1}{4}$ of the length of a brick

Half Lap



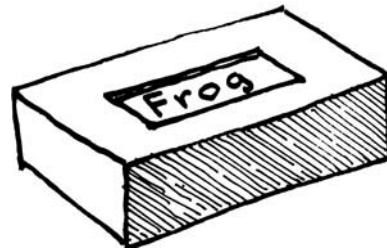
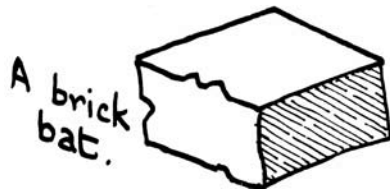
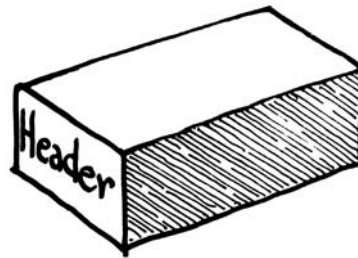
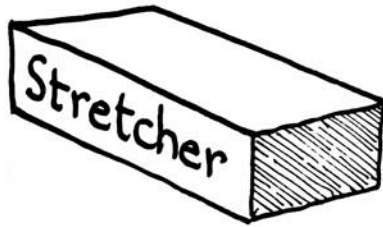
Quarter Lap



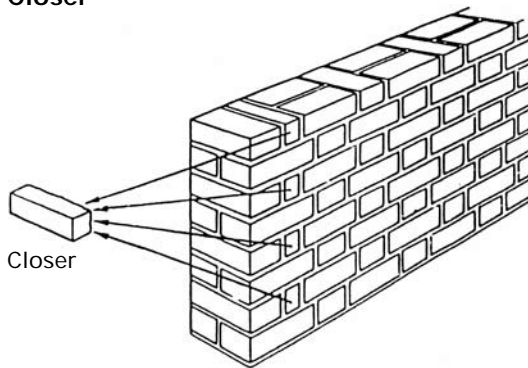
3.2 Size of bricks

Uniformity in the size of bricks is essential. The correct size of a brick for a proper bonding should be twice its width plus the thickness of one vertical joint.

3.2.1 Names of parts of a brick

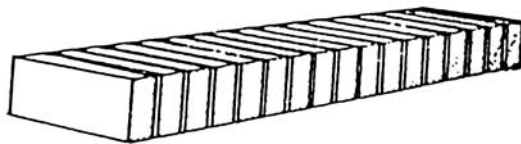


Closer



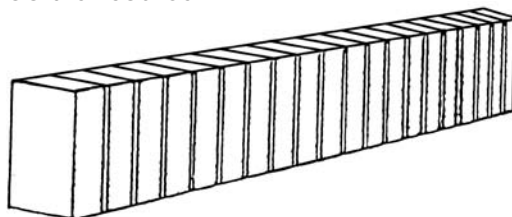
Proper overlap is obtained by using closers. They are also called Queen closer.

Rowlock course



Rowlock course: Bricks are laid on their edge, normally used for window sills and lintels

Soldier course



Soldier course: Bricks are laid on their end, normally used over windows and for special effects

3.3 Rules for joints

Basically, the mortar joints are the weakest as well as the most expensive part of the masonry. Therefore, care must be taken to be as economically as possible with all type of joints so not to make the masonry wall unnecessary weak and expensive.

3.3.1 Horizontal joints

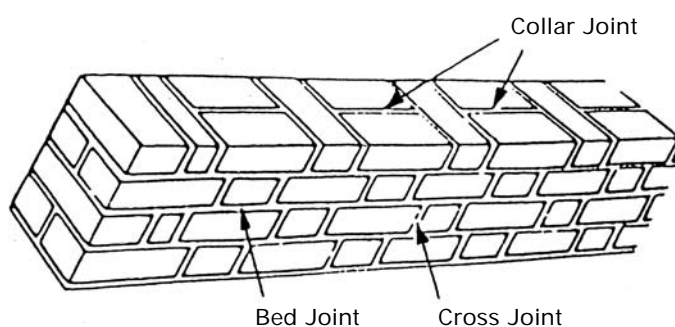
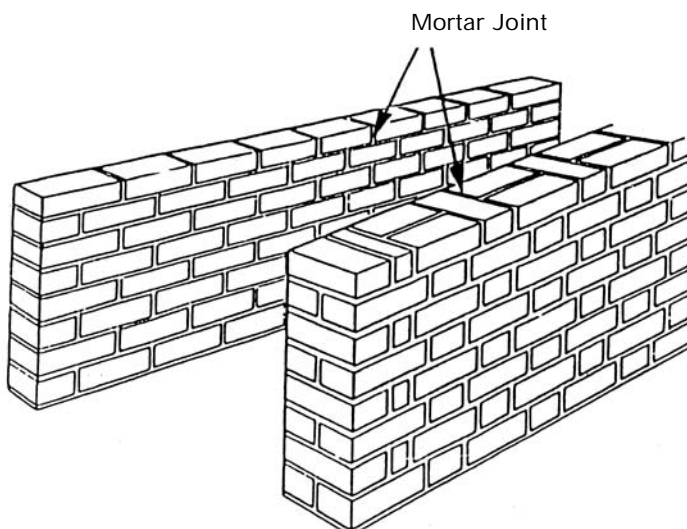
For horizontal joints "Bed joint" a thickness of 12 mm is recommended for brickwork to ensure:

- Leveling of the brick in the mortar bed
- Placing the brick completely in the mortar
- No uneven or incomplete support of the bricks due to stones in the mortar

If the horizontal joints are too thick (more than 15 mm) the result is a waste of expensive mortar (cement) as well as weakening of the structure.

3.3.2 Vertical joints

For vertical joints "Cross joint and Collar joint" a thickness of 10 mm is recommended for brickwork. The reduction of approx. 2 mm to the horizontal joints is possible because the contact area is much smaller at the side than at the bottom. Care must be taken to ensure that the entire vertical joint is filled with mortar; otherwise the brick masonry wall is prone to leakages.



3.4 Selection of bricks

Where good and bad quality of bricks is supplied in one truck load, it is advisable to select first of all the good quality out of the supplied bricks. This is especially important where bricks are used for constructing load bearing walls and foundations. Bad quality bricks should generally not be used for wall construction purpose. However, if it is unavoidable to use bad quality of bricks, then it should be used in the Flemish double bond brick wall as center fillers.

3.5 Brick cuttings

Before one is cutting a brick it is advisable to look just around and confirm that there is no cut brick already there. Otherwise, use first the cut bricks available.

In order to avoid too much wastage, only good bricks (without crack) should be cut. The mason needs to check each brick (sound test with a hammer) and must reject bricks that are faulty.

The correct size to be cut should be marked on the brick. A brick-cutting hammer is the most appropriate tool to cut a brick, avoid cutting bricks with a trowel. The trowel is not meant for this work.

3.6 Brick soaking

Before a brick is placed for masonry work, it needs to be thoroughly soaked in water. The minimum watering time is 6 hours. Dipping the brick into a water bucket just before placing it will not be good enough. Essentially, the soaking of bricks is done for two reasons:

Dust

The surface of the brick is always covered with a lot of dust, sometimes-even dirt. If this dust or dirt layer is not properly removed, the binding between the brick and the mortar will not be effective, hence the entire brick masonry wall will be weakened and the appearance of cracks will be very likely.

Soakage of Water by Brick

Further, a dry and porous brick will immediately consume away the water from the mortar. It is however exactly this water which is required for ensuring the proper hardening and controlled setting of the cement. If the cement does not have enough moisture to ensure a proper hydration process the final mortar strength will be considerably reduced and the masonry wall weakened in general.

3.7 Maximum brick wall height per day

The maximum brick wall height per day should not exceed more than 12 to 14 layers. Because the added weight by each new brick layer (course) needs to be carried by the mortar. The mortar however needs time to harden and to be able to carry more those 12 to 14 layers per day without developing cracks under this heavy load. These cracks usually cannot be seen; still they are there and will reduce the total strength of the masonry wall.

3.8 Curing

A brick wall needs to be cured for at least 7 days. Several times a day, water needs to be poured over the brick wall. The walls are mostly very much exposed to wind and sunshine and the water (moisture) of the wall will be dried out very quick. However, to gain the appropriate bearing strength, the mortar needs certain moisture content for hardening. Therefore, all brick masonry needs regular curing for at least 7 days.

3.9 Pointing

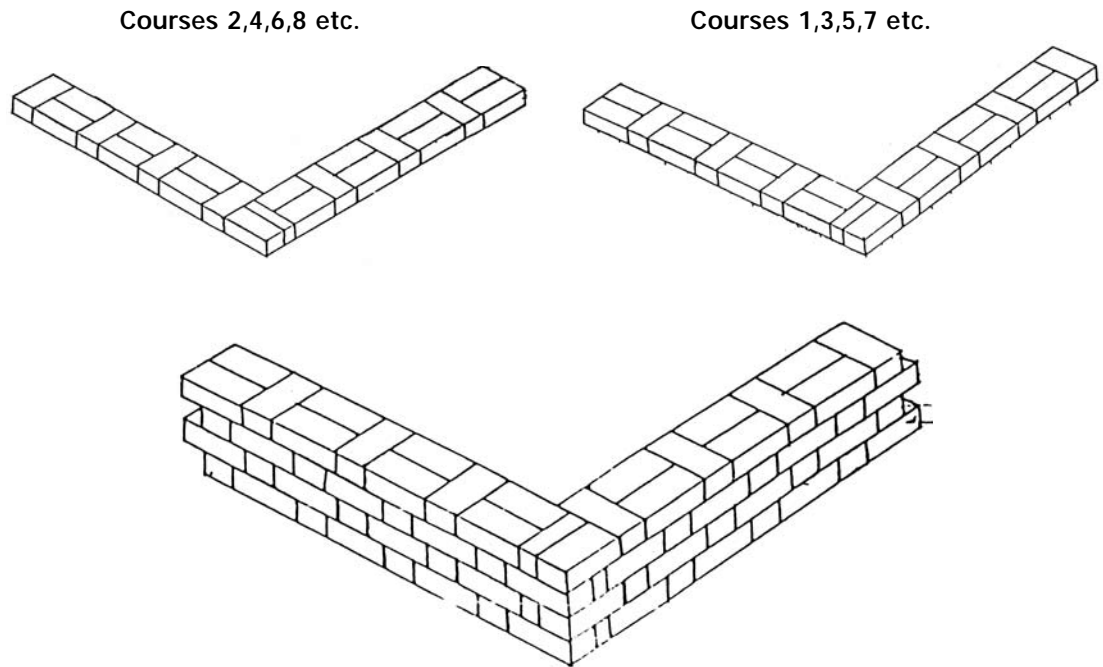
The main reasons for pointing the surface of block or brickwork joints are to increase its weather resistance and to give a neat looking finish to the work.

Pointing can be carried out as construction of the brickwork proceeds, using ordinary mortar in which the bricks are bedded.

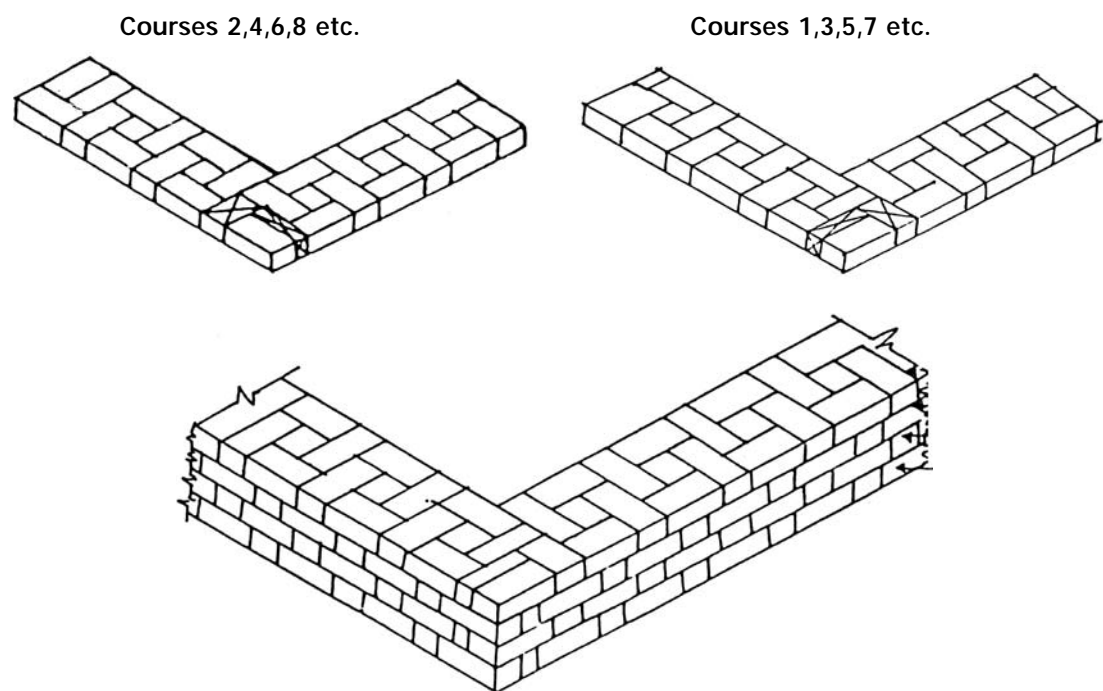
Another method is to finish the masonry work first and then make the pointing work with a 1:2 cement mortar later. The joints must be raked out to the depth of about 1 to 1.5 cm., brushed, washed and filled with a 1:2 cement mortar.

3.10 Most common bonds

3.10.1 Flemish bond (One brick thick)

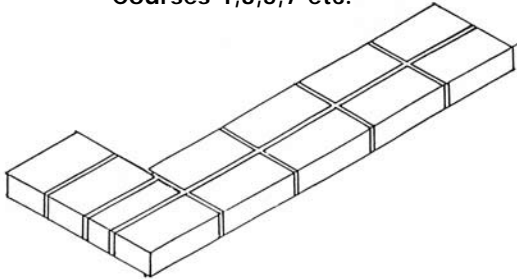


3.10.2 Flemish bond (One and half brick thick)

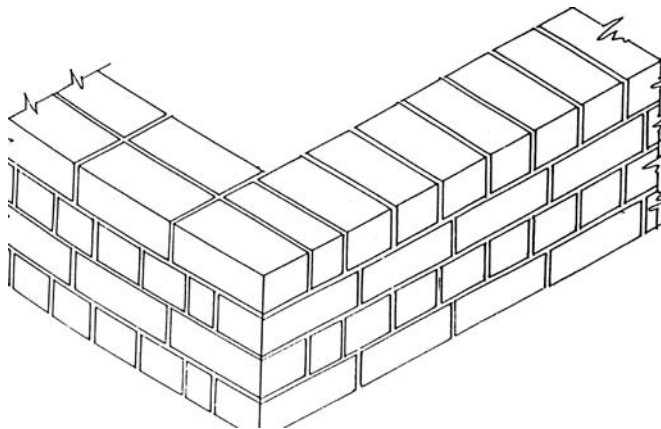
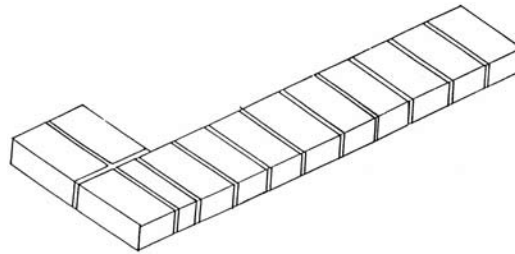


3.10.3 English bond (One brick thick)

Courses 1,3,5,7 etc.

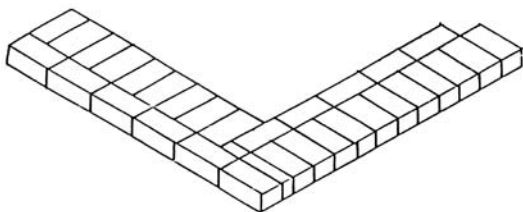


Courses 2,4,6,8 etc.

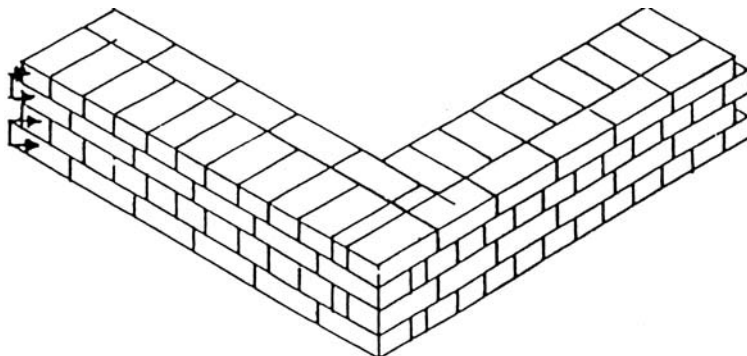
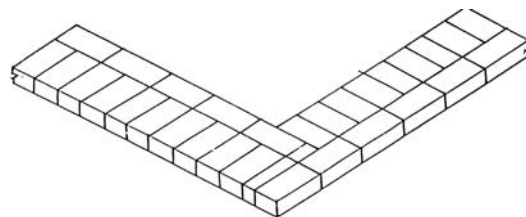


3.10.4 English bond (One and half brick thick)

Courses 2,4,6,8 etc.



Courses 1,3,5,7 etc.



3.10.5 Rat trap bond

Rat trap bond masonry is a cost effective application of brick masonry that has been popularized in India by the Architect Laurie Baker in the last 20-30 years. In rat trap wall, the bricks are placed on edge, thereby leaving a cavity of 4" between the two leaves in case of a 10" thick wall. The bricks are placed alternate headers and stretchers as in Flemish bond. The rate trap masonry reduces cost by reducing the consumption of bricks and cement mortar for the same cubic meter of brickwork.

Where to use Rat Trap Bonded brick masonry ?

Where good quality of bricks is available. Bricks used in a rat trap masonry wall need a minimum compressive strength of more than 35 kg per square centimeters and the other properties as per IS 1905-1987.

Advantages

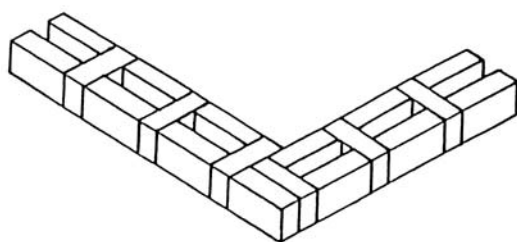
- Compared to a 10" thick solid brick wall, consumption of brick is reduced by 25% in rat trap.
- Due to reduction in number of bricks, the consumption of cement mortar is also reduced.
- Stability of wall is not affected as the excess material is eliminated from around the center line.
- Acts as a good thermal insulator due to the cavity in the wall.
- Plastering of the outside face is not needed as well as inside plaster is minimized since both surfaces are fair faced.

Limitations

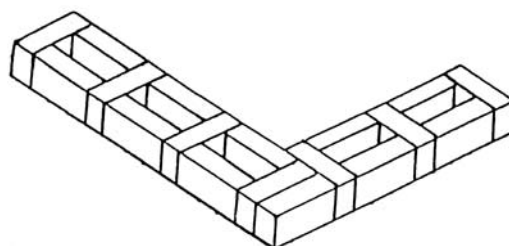
- Not a good sound insulator.

The rat-trap bond is a masonry technique that reduces brick and mortar consumption. Bricks are placed with a 3" cavity between two leaves of brick-on-edge. The cavity provides for thermal insulation.

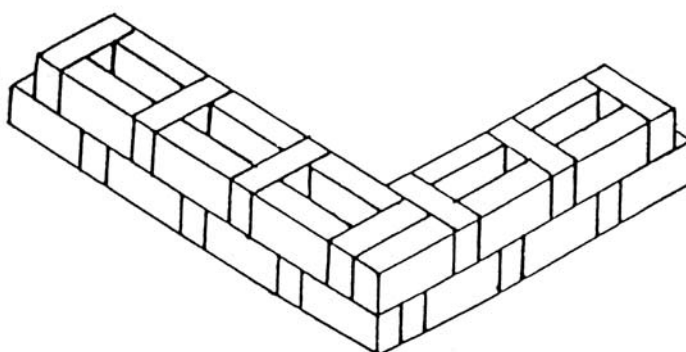
Rat trap bond

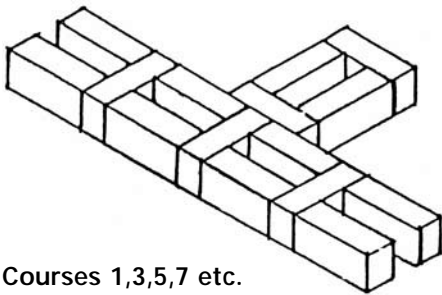


Courses 2,4,6,8 etc.

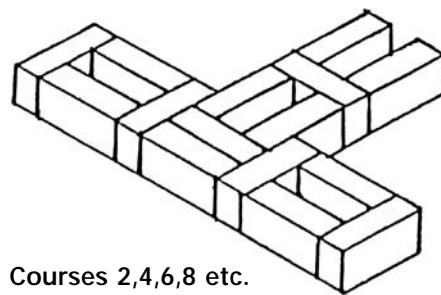


Courses 1,3,5,7 etc.

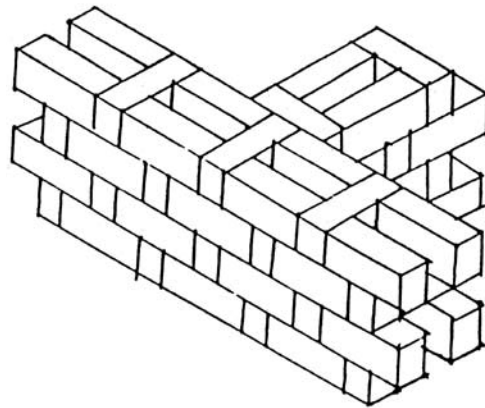


Rat trap bond T-Junction

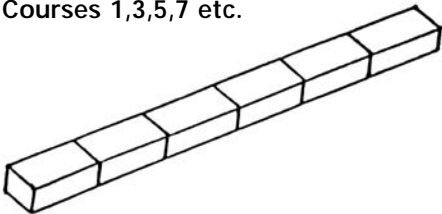
Courses 1,3,5,7 etc.



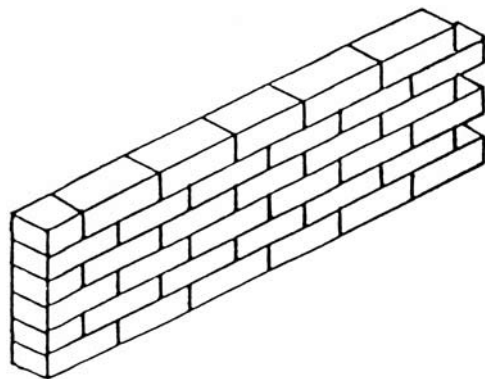
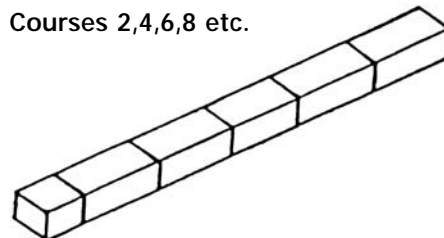
Courses 2,4,6,8 etc.

**3.10.6 Stretcher bond**

Courses 1,3,5,7 etc.



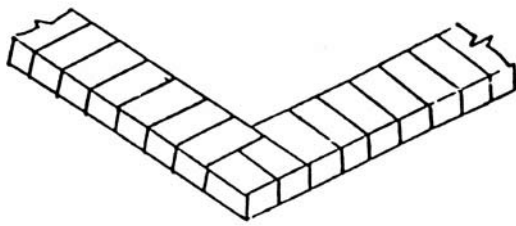
Courses 2,4,6,8 etc.



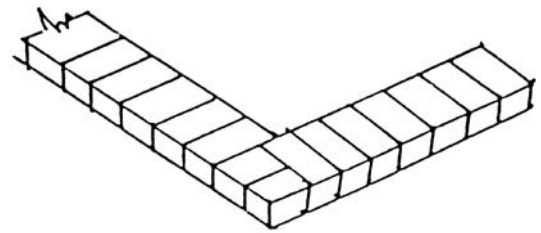
All bricks are placed as stretchers.
 Alternate layers start with a half bat.
 All joints break at the center of the brick below

Stretcher walls are generally used in half brick walls like partition or compound walls etc.

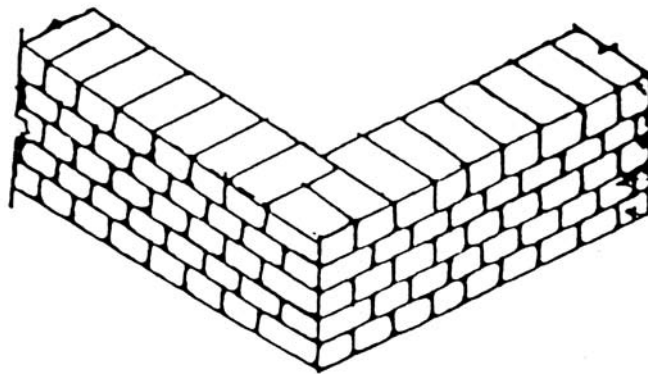
3.10.7 Header bond



Courses 1,3,5,7 etc.



Courses 2,4,6,8 etc.



All bricks are placed as headers.

Overlap is achieved by laying a three quarter bat in alternative course at the corners

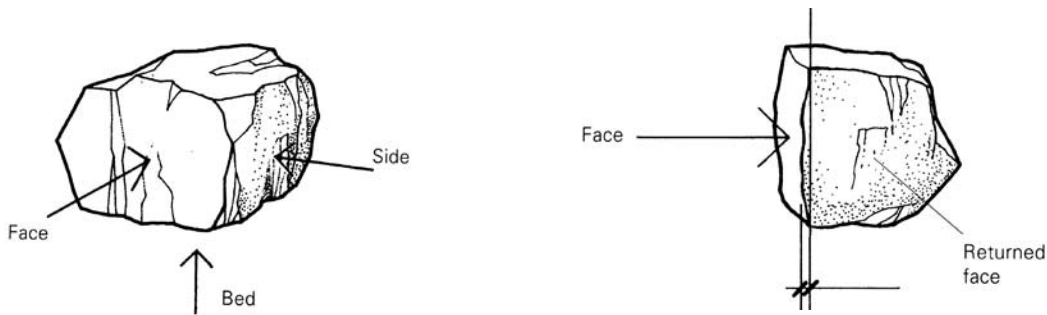
Header bond walls are generally used for footings in foundation and walls curved in plan.

4. Principles of stone masonry

Evidently for building purpose, a good stone should possess strength, durability, cheapness and fine appearance. The strength of a stone under compression and cross strain is an important factor for the weight of the masonry. Floor loads must be supported, resulting in considerable pressure on the lower course. Therefore, for a given load, the lower the compressive strength of the stone, the thicker the wall should be for safe loading.

4.1 Stone surfaces

For the proper shaping of stones, it is important to know the different surfaces of the stone.



Face	This is the exposed surface of a stone in elevation.
Returned face	This is the exposed face to the side elevation e.g. a corner stone.
Bed	This is the top or the bottom of a stone. The lower surface on which the stone rests and the upper surface which supports the stone immediately above.
Joint (Side)	These are the surfaces prepared to meet other surfaces, (e.g. Limestone).

To shape or dress a good stone is not a problem if a man takes the pains to do it.

The stonemason should hammer, dress, shape or cut inequalities which prevents the stone from facing up with the rest of the wall, or that will interfere with the bedding or fitting of the next course. Always select the stones making sure that they have no cracks, which could lead to unexpected breaking off.

In shaping and dressing we classify the different shapes of the stones according to their purposes.

Line stones

Corner stones

Arch stones

4.2 Rules for stone shaping

Stone shaping must be made by a very experienced stonemason to avoid unnecessary wastage. He needs to have a good feeling to assess the potential use of each stone. Since stone handling and cutting is quite an accident prone activity, it is important that basic safety rules are followed such as:

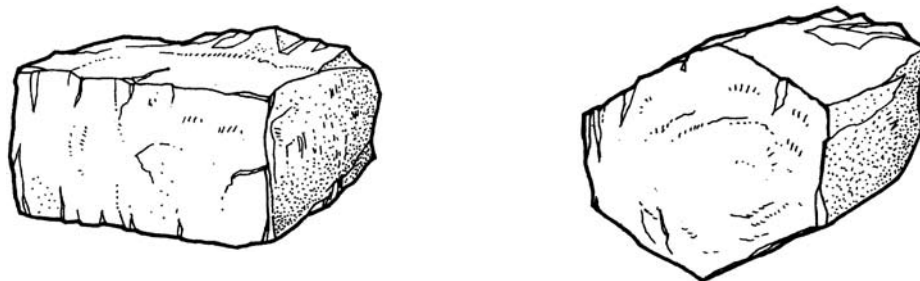
- Workers shaping stones should always use eye protection glasses and wear good shoes.
- All the stones should be of a size and weight that can be carried by one person only.

The following general stone cutting and shaping rules are relevant

- Select the stone and then choose the way you want to shape it.
- Cut it first roughly on all sides, if possible according to its natural shape.
- No angle of the face to side surface should be more than 90 degrees.
- Dress the face straight and check it with a square or a straight edge.
- Select the stones, which could be used as corners and shape the reverse face.

4.2.1 Line stones

Cut out the sides to form the beds and the joints. The beds should be such that they can keep the stone when laid without supports. 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, bush hammer etc. to a plain surface. Use a straight edge to check the surface.



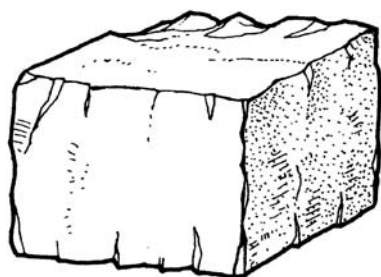
4.2.2 Cornerstones

Cornerstones are the stones placed at the external angle of a building and prepared to bond with other stones in the wall in each direction. In any building good corners are essential therefore good cornerstones must be used for easy plumbing.

A good cornerstone must have good arises and the two faces must be squared to each other.

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 a straight edge.

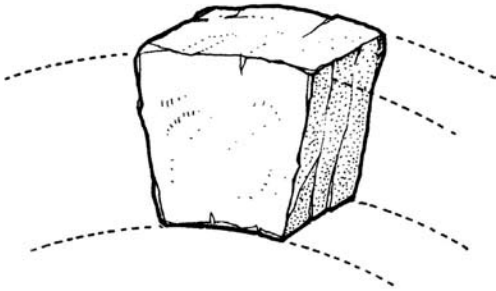
Then shape the returned face by chiseling and squaring it to the face. Care must be taken not to damage the arises.



4.2.3 Arch stones

Unlike the cornerstone the arch stone 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.

First cut out the beds to the required height of the arch. Then cut the joints and form the wedge, giving special attention to the dimensions required. Finally cut out and shape the face, checking it with a straight edge.



4.3 Unsquared rubble masonry

Stone masonry may be classified in various ways, as for instance, according to the kind of stones used, surface finished, bonding etc.

Rubble masonry is composed of unsquared stones. They are found in a quarry or are dug and broken out of the field, the irregularities being made up by filling with mortar, as the stones are set. The quarried variety is preferable because they approach more nearly a rectangular shape and is better for stonework because their faces are sharper and form a better hold for the cement than the weather worn and smoother surfaces of fieldstones. However, fieldstones are much used in the building of houses.

There are three kinds of rubble masonry known as:

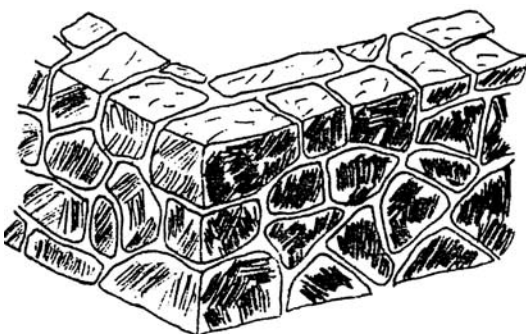
- Uncoursed rubble
- Random coursed rubble
- Coursed rubble

4.3.1 Uncoursed rubble

This kind of masonry covers all kinds and all sizes of stones in which faces, joints and beds are roughly shaped.

No special attention is given to the level of the courses.

With a good surface finish (joint finish, flash joints) an attractive wall will result.



4.3.2 Random coursed rubble

In this kind of rubble masonry all the stones, which are used, beds, joints and faces are well shaped. In laying the stones special attention is needed to bring each course to as near a level as possible.

The difference of uncoursed and random coursed rubble can be seen in the surface finish.

In random coursed rubble smaller stones are used than in uncoursed rubble.



4.3.3 Coursed rubble

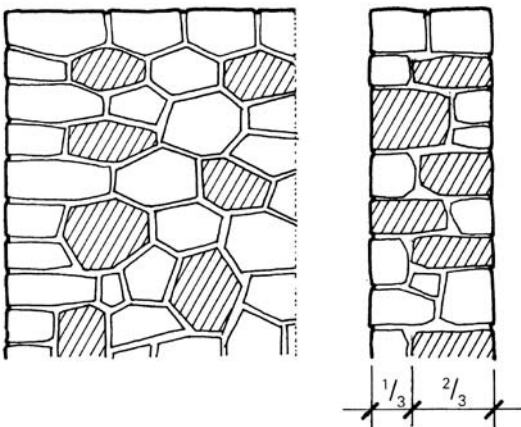
In coursed rubble particular attention is given by shaping the stones. The faces are roughly squared and the height of all the stones should be nearly the same. Special attention by laying of the stones is given to the bond stones, the height of each course and a proper alignment.



4.4 How to build with shaped stones

- The normal procedure to build a stone wall is such that it involves two masons working one at each face of the wall.
- The bottom or footing course should be laid with the largest, straightest stones since the stability of the wall depends largely on the bearing of stones on the ground.
- First the corners of the wall are built up to a height of about 1m, making sure that outer and inner faces are plumbed and squared.
- The corners must be of large stones that will bond the two walls together in the best manner to resist strain. Additional strength may be given to the wall by the addition of galvanized iron or wire bonds, especially if small stones are used.
- When the corners are up, the building can now continue by fixing two lines (rope) in and outside the wall. The purpose of those lines is to guide the masons during laying, and they should be 2 mm away from the face of the wall. The shaped line stones are then laid in a mortar-bed to the line and then checked for alignment.

- Instead of shaping a stone's bed, which does not bed firmly, "spalls" or pieces broken off in trimming can be slipped under the stone. It is easier than the painful labour involved in handling, trimming and correct setting. Though contrary to the best practice, if these spalls are correctly used and set in mortar so as to actually support and hold the stones that they can not move or be displaced, it simplifies the making of a rubble wall and proves much satisfaction for an ordinary building.
- After a thorough check small stones (spalls) are laid into the interior cavities and filled with mortar to tie the two faces (lines) together. These interior cavities are known as hearting.
- Bond stones (trough stones) should cover the thickness of the wall at frequent intervals of not over 1.50 m. Their ends should be dressed to conform to the wall on either side.



Minimum length of a bond stone is $\frac{1}{3}$ of the wall thickness



Bond stones or through stones provide stability to the masonry wall



Bad example, stone wall construction without bond stones



Bad example, stone wall construction with too many small stones and no proper bonds

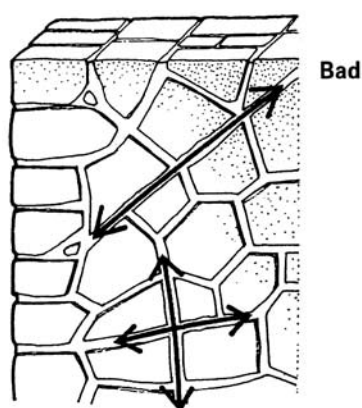
- Dirty stones must be brushed (iron brush) and washed clean before laying them into mortar because the dirt prevents adhesion between the stone and mortar.
- The stones should be wet before laying them into mortar.
- Use up all sizes and shapes of stones to the best advantage and the least cutting by sorting and placing them at the same time preserving the strength and the quality of the wall, and bring each to as near a level as possible.
- A lone stone needs uniform bedding. If it is too long, break it and lay it as two stones.

- Spread the mortar, force the stone to its bed without its touching the stone underneath, and maintain a perfect alignment with the face of the wall. The thickness of the joint between two stones is equal a flat hand (2 – 2.5 cm).
- After building up the wall in stages, cover it with cement bags or plastic to protect the mortar against sun and rain.

4.5 Bonding

In stonework too it is important to secure a proper bonding. In bonding the following rules should be strictly observed:

- Headers should extend not less than $\frac{2}{3}$ the thickness of the wall.
- The vertical joints of each course should break with the joints of the course below.



- The largest stones should be used for the lowest courses!
- Stratified stones should be laid on their natural beds (Sandstones).

4.6 Curing

The walls are mostly very much exposed to wind and sunshine and the water (moisture) of the wall will be dried out very quick. However, to gain the appropriate bearing strength, the mortar needs certain moisture content for hardening. Therefore, a stone masonry wall needs to be cured for at least 7 days. Several times a day, water needs to be sprinkled over the stone masonry wall.

4.7 Pointing

The main reasons for pointing the surface of the stone masonry wall or joints are to increase its weather resistance and to give a neat looking finish to the work.

Pointing can be carried out as construction of the stone masonry work proceeds, using ordinary mortar in which the stones are bedded.

Another method is to finish the stone masonry work first and then make the pointing work with a 1:2 cement mortar later. The joints must be raked out to the depth of about 1 to 1.5 cm., brushed, washed and filled with a 1:2 cement mortar.

4.8 Dos and don'ts

Dos

Use mortar in stone masonry as economical as possible.

Why?

Mortar is expensive and is also the weakest part in the stone masonry wall.

Don't

Do not build up a stone masonry wall higher than 1.00 m per day

Why?

The heavy weight of the stone needs to be carried by the lowest mortar joint. If the mortar is not properly hardened, it will develop cracks if the weight becomes too much, resulting in a weak masonry wall

Don't

Do not partly lift up the stone after placing into the mortar bed for final adjustments with small stones or additional mortar.

Why?

While partly lifting up the stone and placing additional mortar or small stone pieces a gap will be created between the stone and the mortar bed resulting in a very weak stone masonry bonding. The correct procedure is to remove the entire stone and place additional mortar so that the entire stone be is again covered in mortar.

Don't

Do not level at the end of the day the stone masonry wall with mortar.

Why?

The next morning new mortar will be placed on top of the old mortar. This old mortar is anyway not properly cured and most likely very weak. Hence, this joint becomes a weak spot in the stone masonry wall.



Don't

Do not allow anyone to stand on the fresh wall

Why?

A person standing or much worse, working on top of a stone masonry wall will disturb the mortar joints while moving. This will create cracks as well as gaps between the stones and the mortar, resulting in a very weak stone masonry wall.

5. Principles of curing

5.1 What is curing?

Curing must be made with every building material, construction part or product that is using cement as part of the raw material. This is because Cement requires water to initiate the hydration process and to control the internal temperature generated by this process in order to obtain optimal hardening and strength of the cement. This internal temperature controlling with water is called curing.

Uncontrolled hydration process initiated temperatures will lead to overheating of cement and a very substantial loss of hardness and final strength of the cement product such as concrete, mortar etc.

Good curing means evaporation should be prevented or reduced

5.2 Type of curing

There are generally 3 main type of curing used in the construction sector, namely:

- Water curing
- Vapor curing
- Steam curing

5.2.1 Water curing

Water curing is the most commonly used practice. It is the system that is most appropriate for house construction and does not require any special infrastructure or skill.

However, water curing requires a lot of water, which is not always easy at hand and might be even expensive.



Water tank curing method. Cement products are only partly immersed into water, resulting into loss of quality

In order to economize on water it is important that all measures are taken to prevent water evaporation of cement products. E.g. concrete must be protected from direct sunshine and winds to prevent rapid water evaporation. Methods such as covering the concrete with wet, earth, sand, sawdust, grass and leaves are inexpensive, still quite effective.

Further, plastic, jute bags, hessian clothes too are common used material to prevent rapid water evaporation of cement products. Wood forms left in place also furnish good protection if they are loosened and flooded with water at frequent intervals.

Is of paramount importance that the entire cement product (concrete, stone masonry, brick masonry, plaster work, cement flooring work etc.) is kept wet and that it does never fully dry out, otherwise the final strength of the cement product will suffer. If the hydration process has prematurely ended due to overheating (no curing), sprinkling water onto the fully dried out cement product will not reactivate the hydration process, the loss in strength will be permanent.

In water curing, the cement product must be kept fully wet for at least 7 days. After 7 days, the cement product should be regularly sprinkled with water for additional 14 days.

5.2.2 Vapor curing

Vapor curing is done where water is scarce and cement based prefabricated elements such as toilet slabs, tiles, stairs, beams etc are mass-produced. Vapor curing reduces the curing time compared with simple water curing of about 50 to 60%.

The principle of vapor curing is to keep the cement product in a humid and hot environment that allows the cement to gain strength in a much quicker way than with simple water curing.

To create this humid and hot environment a simple chamber with water retaining walls and floor needs to be constructed which is covered with plastic to allow the sunshine to heat the chamber up and prevents the water from evaporating. A floor water level of about 5 to 7 cm is to be maintained all the times to keep the vapor system principle working.

5.2.3 Steam curing

Steam curing is normally used in only very sophisticated industrial plants that produce mass cement based products. A steam curing system is expensive and requires a lot of energy to generate the required heat required for the steam.

However, steam cured products can be used after approx. 24 to 36 hrs. after production, providing a distinctive advantage over all other curing systems.

6. Principles of plastering

6.1 What is plastering?

Plastering is the process of covering rough surfaces of walls, columns, ceilings and other building components with thin coat of mortars to form a smooth durable surface. The coating of mortar is termed as plaster.

Plastering is done to achieve the following objects:

- To protect the external surfaces against penetration of rainwater and other atmospheric agencies.
- To give smooth surface in which dust and dirt cannot lodge.
- To give decorative effect.
- To protect surfaces against vermin.
- To conceal inferior materials or defective workmanship.

6.2 Requirements of good plaster

The plaster material should fulfill the following requirements:

- It should adhere to the background, and should remain adhered during all variations in seasons and other atmospheric conditions.
- It should be hard and durable.
- It should possess good workability.
- It should be possible to apply it during all weather conditions.
- It should be cost efficient.
- It should effectively check penetration of moisture.

6.3 Types of mortars for plastering

The selection of type of plaster depends upon the following factors:

- Availability of binding materials.
- Durability requirements.
- Finishing requirements.
- Atmospheric conditions and variations in weather.
- Location of surface (i.e. exposed surface or interior surfaces).

6.3.1 Cement mortar

Cement mortar is the best mortar for external plastering work since it is practically non-absorbent. It is also preferred to lime plaster in both rooms etc., and in damp climates. Cement mortar is much stronger than lime mortar. The mix proportion (i.e. cement:sand) may vary from 1:4 to 1:6. Sand used for plastering should be clean, coarse and angular.

Cement plaster is applied either in two coats or in three coats, the former being more common. For inferior work, single coat plaster is sometimes provided.

6.4 Number of coats of plaster

The background over which plastering is to be done depend upon the type of wall construction, such as random rubble (R.R.) masonry, coarsed rubble masonry, brick masonry

6.4.1 Background No. of Coats

Stone work	3 or 2
Brick work or hollow blocks	2 or 1
Concrete cast in situ	2 or 1

If plastering is done in single coat only, its thickness should not exceed 12 mm nor should it be less than 6 mm.

6.4.2 Two coat plaster

The following procedure is adopted:

- The background is prepared by raking the joint to a depth of 20 mm, cleaning the surface and well-watering it.
- If the surface to be plastered is very uneven, a preliminary coat is applied to fill up the hollows, before the first coat.
- The first coat or rendering coat of plaster is applied, the thickness being equal to the specified thickness of plaster less 2 to 3 mm. In order to maintain uniform thickness of plaster, 15 cm x 15 cm size. Two dots are so formed in vertical line, at a distance of about 2 m, and are plumbed by means of a plumb. A number of such vertical screeds are formed at suitable spacing. Cement mortar is then applied on the surface between the successive screeds and the surface is properly finished.
- Before rendering hardens, it is suitably worked to provide mechanical key for the final or finishing coat. The rendering coat is trowelled hard forcing mortar into joints and over the surface. The rendering coat is kept wet for at least 2 days, and then allowed to dry completely.
- The thickness of final or finishing coat may vary between 2 and 3 mm. Before applying the final coat, the rendering coat is damped evenly. The final coat is applied with wooden floats to a true even surface and finished with steel trowels. As far as possible, the finishing coat should be applied starting from top towards bottom and completed in one operation to eliminate joining marks.

6.4.3 Three coat plaster

The procedure for applying three-coat plaster is similar to the two-coat plaster except that an intermediate coat, known as floating coat is applied. The purpose of this coat of plaster is to bring the plaster to an even surface. The thickness of rendering coat, floating coat and finishing are kept 9 to 10 mm, 6 to 9 mm and 2 to 3 mm respectively. The rendering coat is made rough. The floating coat is applied about 4 to 7 days after applying the first coat. The finishing coat may be applied about 6 hours after the application of floating coat.

6.4.4. Single coat plaster

This is used only in inferior quality work. It is applied similarly as two-coat plaster except that the rendering coat, as applied for two-coat plaster, is finished off immediately after it has sufficiently hardened.

6.5 Preparation of background

For plastering new surfaces, all masonry joints should be raked to a depth of 10 mm in brick masonry and 15 mm in stone masonry for providing key to the plaster. All mortar droppings and dust, and laitance (in case of freshly laid concrete) should be removed with the help of stiff wire brush. Any unevenness is levelled before rendering is applied. For finish applied in three

coats, local projections should not be more than 10 mm proud of general surface and local depressions should not exceed 20 mm. For two-coat plaster, these limitations are 5 mm and 10 mm respectively. The surface should be washed with clean water and kept damp uniformly to produce optimum suction. In no case should the surface be kept so soaked that it causes the green mortar to slide off, or so dry that it causes strong suction which withdraws moisture from mortar and makes it weak, porous and friable. If plaster is to be applied on old surface, all dirt, scool, oil, paint etc. should be cleaned off. Loose and crumbling plaster layer should be removed to its full thickness and the surface of the background should be exposed and joints properly raked. The surface should be washed and kept damp to obtain optimum suction.

6.6 Recommended mortar mixes

	Situation	Composition of Mortar	I.S. Grading of Lime		
1	External Plaster in localities where rainfall is less than 500 Mm per year and where sub- Soil water is not within 2.5 m Below the ground surface:				
		(a) Below D.P.C.	1 cement 6 sand	-	
			1 cement 2 lime 9 sand	B or C	
			1 lime 2 sand	A	
			1 lime 1 sand 1 surkhi	B or C	
			1 lime 2 surkhi	B or C	
		(b) Above D.P.C.	1 cement 2 lime 9 sand	B or C	
			1 lime 2 sand	A	
			1 lime 1 surkhi sand	B or C	
			1 lime 2 surkhi	B or C	
2	External plaster in localities where rain fall is more than 1300 mm per year and where subsoil water is not within 2.5m below ground surface:				
		(a) Below D.P.C.	1 cement 4 sand	-	
			1 cement 1 lime 6 sand	B or C	
			1 lime 2 surkhi	B or C	
		(b) Above D.P.C.	1 cement 2 lime 9 sand	B or C	
			1 lime 2 sand	A	
			1 lime 1 sand 1 surkhi	B or C	
			1 lime 2 surkhi	B or C	
		3	External plaster in localities where the subsoil water is within 2.5 m of the ground		
				Below D.P.C.	1 cement 3 sand
4	Internal plaster in all localities	1 lime 2 sand	A		
		1 lime 1 surkhi 1 sand	B or C		
		1 lime 2 surkhi	B or C		
		1 cement 2 lime 9 sand	B or C		

Note: the ratio of lime varies with % purity of lime and these ratios may be suitably adjusted depending upon local practice.

6.7 Defects in plastering

The following defects may arise in plasterwork:

6.7.1 Blistering of plastered surface

This is the formation of small patches of plaster swelling out beyond the plastered surface, arising out of late slaking of lime particles in the plaster.

6.7.2 Cracking

Cracking consists of formation of cracks or fissures in the plaster work resulting from the following reasons:

- Imperfect preparation of background.
- Structural defects in building.
- Discontinuity of surface.
- Movements in the background due to its thermal expansion or rapid drying.
- Movements in the plaster surface itself, either due to expansion (in case of gypsum plaster) or shrinkage (in case of lime sand plaster).
- Excessive shrinkage due to application of thick coat.
- Faulty workmanship

6.7.3 Crazeing

It is the formation of a series of hair cracks on plastered surface, due to same reasons which cause cracking.

6.7.4 Efflorescence

It is the whitish crystalline substance that appears on the surface due to presence of salts in plaster-making materials as well as building materials like bricks, sand, cement etc. and even water. This gives a very bad appearance. It affects the adhesion of paint with wall surface. Efflorescence can be removed to some extent by dry brushing and washing the surface repeatedly.

6.7.5 Flaking

It is the formation of very loose mass of plastered surface, due to poor bond between successive coats.

6.7.6 Peeling

It is the complete dislocation of some portion of plastered surface, resulting in the formation of a patch. This also results from imperfect bond.

6.7.7 Popping

It is the formation of conical hole in the plastered surface due to presence of some particles, which expand on setting.

6.7.8 Rust stains

These are sometimes formed when plaster is applied on metal laths.

6.7.9 Uneven surface

This is obtained purely due to poor workmanship.

7. Flooring

7.1 What is flooring?

The layer that separates the ground from the floor finish is called the flooring.

7.2 Components of flooring

- Sub-floor (also called base)
- Floor Finish

7.2.1 Sub floor

This is the waterproofing layer

It prevents water from seeping up from the ground to the floor.

It also provides the solid bedding for the final finish. Thus, it must be

- Solid and hard, dense
- Waterproof
- Absolutely level

7.2.2 Floor finish

This is the visible and usable floor. Thus, it must be:

- Easy to clean
- Resistant to dampness
- Durable with long life
- Hard
- Easy to maintain

7.3 Types of floors

7.3.1 Brick bat floor

Materials used

- Brickbats as bedding layer (55mm)
- Sand in between brickbats
- Cement mortar (1:4) (20mm)
- Cement slurry finish



Laying bricks into a bed of sand



Filling the brick joints with wet sand



Cleaning the frog of the brick from wet sand for better binding



Placing the cement mortar



Prepare the floor top finish



Brick bat floor example completed

Advantages:

- Cheap
- Durable
- Easy to clean

Disadvantages:

- Not 100% waterproof
- Needs good workmanship
- Not very resistant to impacts.

7.3.2 Concrete floor

Materials used:

- Cement - 1
- Sand 2
- Aggregate 4
- Mortar of 1 : 2 Cement : Sand mix is used for the finishing coat.

The thickness of the floor is normally 1½" .

For the bedding layer, two alternatives can be used:

- Brickbats in 1 : 6 cement mortar (3")
- Lean Concrete Bed - 1 : 4 : 8 (3")

Notes:

- The aggregate would be a mix of 12 mm down and 6 mm down chips in ratio of 1 : 1, for the 1½" floor of 1 : 2 : 4 PCC.
- PVC/Glass strips are inserted to form grids of max. 1m × 1m. These strips are inserted in the Concrete Floor. The purpose is to make joints, to avoid large expanses of unjointed floors. This helps in avoiding cracks, which may otherwise form due to temperature variations.

Advantages of IPS Flooring:

- Reasonable Cost
- Very hard and durable
- No need to procure different materials
- Easy to clean and maintain
- Attractive colors can be added to give colored flooring, patterns etc.

Disadvantages:

- Surface cracks appear in areas of high temperature variation.

7.3.3 Other common types of floors

Type	Materials for Floor	Finishing	Where used Normally
Stone Slab Flooring (Rough)	Kota Stone Cuduppah Stone etc. (mainly sandstones)	Rough	Outdoors in Paving etc.
Stone Slab Flooring (Polished)	Sand Stones: Kota, Marble Cuduppah etc.	Polished	Indoors, cost ranges from Rs. 30 - Rs. 100/sft can be used in toilets etc.
Mosaic or Terrazzo	Marble/hand stone chips are used as aggregates in mix of 1 : 2, laid in base of 1 : 3 Cement sand mortar	Polish with carborundum stone and wax	Anywhere, mostly indoors
Ceramic Tiles	Ceramic tiles laid on 1 : 3 cement mortar	Pre-polished	Wet areas, and on toilet/kitchen dados.

Safety



Children using construction site as play ground

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Principles of safety

1. Introduction

**“Accidents do not happen,
accidents are made” .**

The main reasons for construction related accidents are carelessness, technical faults, inappropriate use of tools, wrong reaction of workers, abuse of alcohol, and most important no proper awareness about potential sources of accidents.

A construction site is the place where people come to work together mainly to earn money to support their families. A place where people come together for doing a living must be safe; no economical consideration justifies an accident. What a great tragedy for a family, if for the reason of a preventable working accident, no more income is available.

Knowing the sources of potential and predictable accidents means that we can prevent them. It is the duty of a construction supervisor to know the potential sources of accidents and to prevent them as far as possible.

2. Rules to prevent accidents:

2.1 General rules:

- Only professionals should make electrical installations.
- No electrical wires would be allowed to lie free on the ground.
- No person without a valid license should be allowed to drive a tractor, truck or any other vehicle at the construction site.
- No fire shall be made at the construction site.
- No ladder with structural default should be used. The supervisor is responsible to order for its repair and maintenance.
- Erect ladders in positions where people do not have to walk underneath them.
- When going up or down a ladder, always face the ladder.
- Do not leave discarded timber with nails sticking out. Shuttering timber must always be collected and stored in one place.
- Special care needs to be taken for scaffolding work. The scaffolding material needs to be strong and well fixed.



Scaffolding not properly protected from vehicles, workers at increased risk of serious accident



No proper working platform for wall painting made, workers at increased risk of serious accident

- Scaffoldings need to be checked every day by the supervisor.
- Floor openings and floor holes must be covered or protected by a guardrail.
- Proper access path with side railings (claiming stairs) needs to be constructed for carrying material from ground level to higher elevations.
- Always bend down or cover the ends of vertical steel bars that stick out of concrete.
- Weights more than 50 kg. should not be carried by one person alone.
- Lifting stones, cement and other heavy building materials must not be made with a bent back. Always lift the weight with a straight back.
- Prevent any material from falling down that could hurt people or could damage other materials or construction.

2.2 Storage

- Storage of explosive and health hazardous materials should not be allowed at the construction site.
- Bricks or blocks shall not be piled up higher than 1 m at the storage as well at the construction site.



Pavement blocks dangerously piled up, workers at increased risk of accident

- Material such as steel bars, timber, sand and cement should be stored in such a way, that access to the construction site is not blocked.

2.3 Conduct

- No alcohol consumption should be allowed at the construction site.

2.4 Working conditions

- For night work, proper lighting arrangements need to be in place.
- For stone cutting and chiselling works, the workers need to be instructed how to avoid eye injuries

2.4.1 Cleanliness, hygiene & resting place:

- A person shall be made officially responsible for the cleaning of the construction site.
- A toilet, separate for men and women must be provided for the construction workers.
- The construction site should be kept clean. Workers need to be instructed that the toilet must be used and that no urination etc. is allowed inside the construction.
- An official resting-place protected from rain and sunshine should be established at site.
- Clean drinking water should be provided at the resting-place as well as at the working place.
- Mothers who attend to their children should do so at the official resting place only.

Earthquake resistant construction practices



Remains of one story building collapsed during earthquake

Earthquake resistant buildings

A few selected Literature references

1. L&T Cement

Masonry construction by: Pradipta Banerji
RCC construction by: Shirish Patel

2. Gujarat State Disaster Management Authority: Series of Guidelines

- 2.1 Guidelines for Reconstruction and new Construction of Houses in Kachchh Earthquake affected areas of Gujarat (May 2001)
- 2.2 Guidelines for Reconstruction and new Construction of Houses in Kachchh Earthquake affected areas of Gujarat (June 2001)
- 2.3 Guidelines for Control an Quality of Construction in Earthquake affected areas of Gujarat (June 2001)

3. Shelter – A HUDCO - HSMI Publication

Special issue: World Disaster Reduction Day, October 13. 1999

4. Indian Practical Civil engineers, Handbook

5. BASIN Publications:

Earth Construction, CRATerre
Appropriate Building Material, Skat Consulting