# AN INTRODUCTION TO CEMENT & CONCRETE


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AGGREGATES

"Aggregate" is the term used for the mixture of different sized stones that form the body of mortars and concrete. Ideally the stone should be graded so that the smaller sizes of stone fit exactly into the spaces between the larger ones and no gaps or holes are left in the mass of mortar or concrete.

Sand
Sand is a mass of finely crushed rock. It is either crushed naturally as seen on the sea shore, in river beds, or in deserts, or it is artificially produced in crusher plants near rock. Sand is classified according to the shape of its particles, which differs depending on where the sand came from originally (Figure 2). It is also graded according to the size of its grains.

Gravel
"Gravel" is the term commonly used for the larger sized stones of the aggregate. Originally, gravel meant an "all-in-one" aggregate, a mixture of sand and stones of all sizes which can sometimes be found all together in a natural deposit. The individual particles are rounded by the natural action of water and weather.

Broken Stones
These are the largest stones of the aggregate, they make up the bulk of concrete. They are found either in natural deposits or scattered on the ground surface; or they are artificially produced in crusher plants. The Rural Builder often must break up large stones with hammers, to make them a convenient size.

Note: These aggregates are the most common ones used. There are many other types of aggregates (chips, pebbles, rubble etc.), but as far as the Rural Builder is concerned they are of little importance.

QUALITY AND PROPERTIES OF AGGREGATES

Good mortar and concrete can never be made with poor materials. The cement, sand and stones must all be good quality and of the correct types. Sand and stone (fine and coarse aggregate) together make up more than four-fifths of the concrete mass, so there can be no doubt about their importance. It is not safe to take for granted that every load of sand or gravel brought to the site will be up to standard. Remember that aggregates are either dug from a pit or river bed or they are quarried, and although they may look the same there is a possibility of variation in the quality of different loads. Particle sizes, the shape and texture of the particles and their surface areas are all important factors in the strength and durability of the concrete or mortar.

Grading
A graded aggregate is one that is made up of stones or particles of different sizes; ranging from large to very small. It sometimes a load of sand will have too many coarse particles to make a good mortar, while another load will have too many fine particles. Depending on the job to be done, you might have to mix the two sands together in different proportions to get a suitable aggregate. If the sand contains too many bigger particles it may be necessary to sift these out before using the sand to make mortar, however it could work well for concrete.

The idea is to come up with a "well graded" aggregate; which means that the smaller grains will fit in between the larger ones, leaving only small spaces to be filled with the cement paste. The result will be a good workable mix of adequate strength, using the minimum amount of cement (see Figure 1).
Figure 1.

Classification Of Aggregates
For making concrete and mortar, the Rural Builder has two types of aggregate: the fine one which is sand and the coarse one which is broken stones. Both aggregates are classified according to their grain size and are each divided into two main groups:

<table>
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<th>from 0 - 1 mm</th>
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<td>Coarse sand</td>
<td>from 1 - 5 mm</td>
<td>Coarse broken stones</td>
<td>from 25 - 50 mm</td>
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Another classification is made according to the shape and texture of the single particles. Some sands and stones have particles which are rounded, with relatively smooth surfaces. This sort of aggregate is found mainly in river beds, along the shores of lakes and coasts, and in deserts. This weather and waterworn sand is called "river sand" or, because of its properties and workability, "soft sand" (Figure 2). The other type of sand has a fairly rough surface and it is found mainly in deposits close to hills and mountains. Artificially made sand, formed from crushed rock, also comes under this classification. It is known as "Pit sand" or "sharp sand" (Figure 2).

Whether the sand is soft river sand, or sharp pit sand; it will have various, grain sizes and is classified as fine or coarse, as in the table above.

Note: Sand dug from river beds is not necessarily "soft". Often it is a sharp sand or between soft and sharp, because the particles don't get exposed long enough to weather and water to become rounded and smooth.
An Important factor in the quality of an aggregate is its cleanliness. Clay, mud, or silt in the aggregate will weaken the concrete or mortar; while any rotting vegetable matter (organic impurities) like leaves, grass or roots may interfere with the setting of the cement.

- **The hand test for sand:** As a first test for cleanliness, simply pick up a little sand and rub it between your hands. If your palms stay clean, the sand is clean enough. If not, the sand may contain too much silt.

- **The silt test for sand:** You yourself can carry out a simple test to get an idea of the amount of silt in a natural sand (though not in an artificially crushed rock sand).

To test accurately you should have a measuring cylinder which is marked in milliliters, shown as "ml" usually up to 200 ml (Figure 3). First make a salt-water solution by putting one teaspoon of salt into 1/2 liter of water. Put this solution into the measuring cylinder, upto the 50 ml mark. Next pour in the sand until the level of the sand is up to the 100 ml mark. Add more salt water until the water reaches the 150 ml mark, cover the cylinder and shake it well. Stand the cylinder on a level surface and tap it gently until the top surface of the sand is level. Leave it to settle for 3 hours and then measure the height of the silt layer on top of the sand. This should be no more than about 6 ml, or about 6% of the total amount of sand.

**Note:** If the sand contains more than 6% silt, you would have to use more cement and the concrete would shrink more during the hardening process, causing cracks in the product.

If you have no measuring cylinder, you can use a 0.5 kg jam jar, though this may not be as quite accurate (Figure 4). Put about 5 cm of sand loosely into the jar and pour some salt water on to it until you have about 2.5 cm of water above the sand. Now cover and shake the jar, and leave it to stand for about 3 hours. You will see a layer of silt on top of the sand. Measure the depth of the layer, and measure the sand below it. There should be no more than about 3 mm of silt, or about 6% of the amount of sand.

- **Organic Impurities:** The Rural Builder can carry out a test for organic impurities using a glass jar. Put sand into the jar and fill up the rest of the jar with water. Cover and shake the jar and leave it standing for

![Figure 2.](image)
some minutes. If the water above the sand is brown or very dirty, the sand contains organic impurities and cannot be used.

Better sand can be found by simply removing the top layer of sand, about 5 cm deep, before taking sand from a dry river bed. This top layer consists mainly of excessive silt as well as organic impurities such as vegetable matter and cow dung. None of this is wanted, because it would cause problems with the concrete or mortar. If there is still too much fine or silty material, another source of sand should be found. If this is impractical, it is possible to remove the fine particles. This can be done by putting the sand in a container like a drum. Cover the sand with water, stir or agitate vigorously, let it stand for a minute, then pour off the liquid. A few such treatments will remove most of the fine and organic matter.

In very dry climates, the sand may be perfectly dry. Very dry sand will pack into a much smaller volume than sand that is moist. If 2 buckets of water are added to 20 buckets of bone dry sand, you can carry away about 27 buckets of damp sand. If your sand is completely dry, add some water to it.

*Remember*: Wherever your sand comes from it must be clean and suitably graded. If you use dirty sand, you may find that it mixes very nicely, but you will find problems before the job is finished. The impurities in it may affect the rate of setting and hardening of the concrete or mortar, and decrease the final strength of the work. The fine appearance of the just finished work may be spoiled by cracking and flaking as it dries.
BINDING MATERIALS

Lime
Lime is a very fine white powder, used in mixes for mortar, plaster and render. It is made from limestone or chalk which is burnt in a kiln and becomes quicklime. The quicklime is usually passed through a machine called a hydrator, where it combines with water and becomes hydrated lime. This is dried, crushed to a fine powder, then bagged and sold. Sometimes the lime is sold as quicklime, and the builder adds the water to it himself. This process is called "slaking" the lime or "running it to putty", and it is not described here. Slaked lime and hydrated lime are chemically the same, but slaked lime has more water in it.

Hydraulic lime is made from limestone or chalk containing clay. It hardens when combined with water; and it also hardens well in damp places or even under water. It is stronger than other lime, although weaker than Portland cement. Non-hydraulic lime comes from the purest limestone and chalk. It hardens by drying out and then slowly combining with the carbon dioxide in the air.

Portland Cement
Portland cement is a fine gray powder. Among the various kinds of cement it is the most commonly used as binding material. It is made of a mixture of chalk or limestone together with clay.

The limestone or chalk and the clay, in appropriate proportions, are fed into a “wet grinding mill” and reduced to a creamy substance known as slurry. The slurry is pumped to a large cylindrical "kiln" which is about 90 m long and 3 m in diameter. The slurry enters the kiln at its upper end while pulverized (crushed) coal, gas or other fuel is blown in at the other end. The temperature inside the kiln at the lower end is very intense, approximately 1500 degrees C; gradually decreasing towards the top end. So the slurry as it moves down the kiln is first dried, then heated, and then finally burnt. it leaves the kiln in the form of very hard “clinkers” shaped like small balls and of a dark brown to black in color. The clinkers are ground up to an extremely fine gray powder, which is the cement. The cement is packed in paper bags of 50 kg capacity (in the US 94 pound, 42.6 kg sacks are used) which is about 35 liters of cement, however after leakage during transport this will probably be nearer 34 liters.

Storing Binding Materials
The quality of mortar and concrete depends on so many factors, but one of the most important of these is the cement. Cement must be stored properly, to prevent it from setting (hardening) before it is used. If the cement gets damp, it will become unusable. Everyone knows that cement should be kept dry, but they don't always realize that contact with damp air can do as much harm as direct contact with water. On all jobs where bagged cement is used, there should be a shed or room to store it.

- Storing in a shed: Make sure that the shed or room is water-tight and has a sound, dry floor. If the floor is not dry, make a platform out of boards set on blocks -and timber, to raise the bags off the ground (Figure 6). Stack the bags closely together to keep out air, and away from the walls so that they are not in contact with any dampness on the walls. In very large sheds it is better to cover the bags with plastic sheeting to keep out damp air, especially during the rainy season.

Check the bags from time to time for termites: these may damage the bags and with them the cement. Check also that the roof doesn't leak and that the walls are waterproof.

- Storing in the open: On some jobs, bags of cement may have to be stored in the open, with no more protection than a dry base and a covering of tarpaulins or plastic sheets. The sheeting must be properly overlapped to keep out the rain; and the top sheet should lay over all the ones below like a roof, so that the rain can run straight off without getting into the tarpaulin "tent" and wetting the cement.
Even if the cement is to be stored in the open for only an hour or so, there must be a dry platform raised about 35 cm above the ground for the bags to lie upon (Figure 5).

Whether the cement is stored indoors or out, arrange the bags so that the first batch brought in can be the first ones used, and the old bags don't get left at the bottom of the stack and never used. Prevent accidents by keeping the piles to a height of about 1.20 m, and never stack them more than 10 bags high.

Cement absorbs moisture during storage and will therefore lose strength. Lumps of cement power that should not be included in the mix.

<table>
<thead>
<tr>
<th>Storage Period</th>
<th>3 months</th>
<th>6 months</th>
<th>12 months</th>
<th>24 months</th>
</tr>
</thead>
<tbody>
<tr>
<td>Loss of Strength</td>
<td>20%</td>
<td>30%</td>
<td>40%</td>
<td>50%</td>
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</table>

**Remember:** The important thing with cement is to always KEEP IT DRY! Cement starts to set about 30 minutes after mixing or coming into contact with water or moisture.

![Figure 5](image)

**WATER**

The water used to prepare concrete must be clean, and free of organic matter. Water acceptable for drinking is preferable. Any clear, fresh water is acceptable. Salt water may be used if fresh water is not readily available, but it will reduce the strength of concrete about 15 percent. If you must use dirty or muddy water, let the water settle in a huge pan or tank to remove most of the dirt.

Enough water is needed so that the hydration reaction is completed and the maximum strength is gained. However, too much water leads to a reduction in strength.

**MORTAR**

Mortar consists of the body or aggregate, which is fine sand; and the binding material, which is cement mixed thoroughly with water. Mortar is used to bed blocks as well as for plastering. A good mortar should be easy to use and should harden fast enough that it does not cause delays in the construction. It must be strong enough, long lasting and weatherproof.
Types Of Mortar
The best mortar for a particular job is not necessarily the strongest one. Other properties like workability, plasticity or faster hardening can be more important, though the strength of the mortar must of course be sufficient for the job. The Mortar should neither be much stronger or much weaker than the blocks with which it is used.

- **Cement Mortar:** This sets quickly and develops great strength. It is used in proportions of one part cement to three parts sand (1:3), which makes quite a strong and workable mix; down to a 1:2 mix, a lean mix which will be rather harsh and difficult to use.

- **Lime Mortar:** This is usually very workable and does not easily lose water to the blocks, but it is weaker than cement mortar and hardens slower. Lime mortars are nowadays largely replaced by cement mortars or combinations of lime and cement.

- **Cement-Lime Mortar:** This combines the properties of cement and lime to give a workable and strong mortar. The cement makes the mortar stronger, denser, and faster setting; while the lime makes the mortar workable and reduces the shrinkage during drying, because it retains the water better.

In some areas, lime is not always available, so in this book we will concentrate on cement mortars.

Selecting The Right Kind Of Sand
Sand for plaster, mortar and renderings must always be chosen with care. The sand used to make mortar for block laying should be well graded, sharp and must not be too fine if a strong mortar is needed (e.g. for footings). The more fine particles the sand contains, the better its workability in the mix, but more cement paste will be needed to cover the surfaces of the particles. This means that in order to improve the workability while maintaining the same strength, more cement must be added which results in higher costs. The Rural Builder is always faced with this problem and it takes a lot of experience to be able to find a good compromise.

If the sand is found to be too sharp so that it makes a mortar with poor workability, we suggest replacing about 1/3 of it with fine soft sand; but don't replace more than about ½ unless you add more cement. We can do this because the common mix proportion of our mortar is 1:6, while the sandcrete blocks are mixed in a proportion of 1:8 (cement:sand). When the fine sand is added, the strength of the mortar is reduced to about the same as the strength of the blocks, which is acceptable.

- **Remember:** A good mortar should:
  a. be easy to work with
  b. harden fast enough not to delay the construction
  c. stick well to the blocks
  d. be long lasting and weatherproof
  e. if possible, be as strong as the blocks.
Mixing The Mortar
Mixing is one of the most important stages in the process of making mortar because the workability and strength of mortar depend so much on the way it is mixed and on the amount of water added to the mix.

- What Water Does: Water in the mix does two things: it makes the mortar workable and it combines chemically with the cement to cause hardening. However, only about half the water is required for the chemical reaction and the rest will remain or evaporate slowly as the mortar hardens, leaving small holes or "voids" in the cement. Obviously, the more water there is in the mix, the greater will be the number of voids and the weaker the mortar.

- Three Times Dry: The sand and cement is measured on one end of the mixing platform. With two men facing each other across the pile and working their shovels together, turn the whole heap over once to form a pile at the other end of the slab (Figures 7). This turning must be repeated twice and results in a so-called "dry mix".

The correct method for turning over is to slide the shovel along the top of the platform, pick up a load and spill the load over the top of the new pile. The main point is that each shovelful runs evenly down the sides of the cone. This is the best and easiest way of mixing dry mortar and all other motions should be eliminated. When the dry mix is a uniform colour throughout, it is considered to be well mixed.

- Three Times Wet: Form the heap of dry mix into a crater or pool, with the sides drawn out towards the edges of the mixing platform. There should be no mixture left in the centre of the pool.

Now gently pour about 3/4 of the total required water into the crater. Turn the shovel over and with the edge scraping along the platform, push some of the dry mix into the pool in such a way that it spreads out, without separating the sand and cement. Handle the shovel carefully so that no water can escape by breaking through the ring (Figure 7). When all of the dry mix has been heaped up in the centre of the platform, it should have taken up all the free water and have a rather stiff consistency (earth- moist). Now make a second pool, add the remaining water and repeat the rest of the mixing procedure. This will result in a mortar of a plastic consistency. To make sure the mixing is thoroughly done, turn the mortar over a third time.
**Figure 7.**

*Note:* If you want to improve the workability of the mortar by adding water, remember that this will also decrease its strength. You are therefore strongly advised to add both cement and water in equal quantities (for example ½ bucket of water plus ½ bucket of cement).

*Remember:* Ready mixed mortar starts setting after only 30 minutes, never prepare more mortar than you can use within this time. It is certainly better to mix smaller amounts more often than to allow mortar to spoil; or to do the work very quickly (and sloppily) in order to get rid of the mortar. Always cover freshly mixed mortar with empty cement bags to keep it from drying out. Never mix mortar on the ground.

**CONCRETE**

To concrete something means to form it into a mass, or to solidify it.

As far as building is concerned, the term concrete means an artificial stone made by mixing sand, stone, Portland cement and water. This mixture, cast into a form of the desired shape and size, hardens into a stone-like mass: the concrete.

There are basically three materials we start with to make concrete:

- *The aggregate*, which is made up of the fine and coarse aggregates together, i.e. the sand and broken stones. The aggregate makes up the main mass of the concrete; its function is mostly just to add bulk.
- *The water.*
- *The binding material*, which is usually Portland cement.

When the three materials are mixed together, the cement and water combine chemically to make a cement paste, which surrounds the particles of the aggregate and holds them together.
Cement Paste
The cement paste component of concrete is what causes it to harden, the aggregate simply remains passive (inactive). Thus the cement paste must completely cover the surface of every single particle of the aggregate. This means that each stone, no matter whether tiny or big, must be covered all over by a thin layer of cement paste. This is achieved by mixing all three components very thoroughly and in the correct proportions. The cement paste fills up all the spaces between the particles of the aggregate and bonds them firmly together as it hardens.

The hardening process requires a certain amount of water; how much depends on how much cement is added to the mix. After it is set, the hardened cement paste cannot be dissolved again (except by the use of certain acids). An undesirable further reaction of the cement paste is the drying shrinkage as it hardens. Because of the evaporation of the extra water, the volume of the concrete is gradually reduced. The concrete shrinks and develops cracks. This reaction can be effectively reduced, if not prevented, by correct curing; as will be discussed later. Also to prevent cracking, large areas that are covered with concrete; such as floors, should be divided up into bays.

Properties Of Concrete
Concrete has many properties, but most of them are of little interest to the Rural Builder. Therefore here we only deal with the three most important properties:

- **Compression strength**
- **Tensile strength**
- **Protection against corrosion.**

- *Compression Strength*: It is commonly known that concrete becomes very hard and can withstand enormous pressures; a property which is called compression strength. This compression strength depends mainly on the properties and quality of the cement paste and the aggregate.

If the aggregate consists of a soft or weak material, the concrete will be weak also. About the only simple test is to break some of the stones with a hammer. If the effort required to break the majority of stones is greater than the effort required to break a piece of concrete of about the same size, the aggregate will make strong concrete. If the stone breaks easily, the concrete made of these stones will be no stronger than the stones themselves.

If the aggregate is so dirty that there is no direct contact between the surface of the particles and the cement paste, the concrete will again be weak.

Provided that all the rules for producing a good concrete are observed, the strength of the concrete can be controlled by choosing the mix proportions. For example, a mix proportion of 1:10 is weaker than a 1:3 mix. This is because in a 1:10 mix the particles of aggregate are not completely coated with cement paste, but in the 1:3 mix they are fully embedded in it.

If not enough water was added to the mix, the cement paste remains too dry and stiff and the concrete will be weak. If too much water was added, making the cement paste too thin, the concrete will again be weak. Therefore the Rural Builder must always carefully follow the correct concrete recipe.

- *Tensile Strength*: The tensile strength of a material means its capability of being stretched to a certain extent without breaking. Although concrete becomes very hard, its tensile strength is very limited. It is so low that in practice, the tensile strength of concrete is regarded as being nonexistent. This is why sometimes concrete members of a structure must be reinforced by steel bars embedded in them.
Some types of wood, while they are softer and have a much lower compression strength than concrete, have a far higher tensile strength because of their fiber structure. The wood fibers act in a way like the reinforcement iron embedded in concrete.

Wood is a good building material because of its tensile strength. However, Its flexibility makes it subject to bending under loads. Because of this problem, short-span constructions are chosen; or, among other possibilities, reinforced concrete can be used instead of wood.

- Protection Against Corrosion: Corrosion means a wearing away, a slow destruction caused by a reaction with air, water or chemicals. Reinforcement iron which is left unprotected and exposed to air and humidity will eventually start to corrode on the surface and become rusty. If this process is not halted in time, the rust goes into the bar and it becomes too weak to be used.

In order to maintain the strength of steel-reinforced concrete, the steel has to be protected from rust. This is partly done by the hardened cement paste and partly by structural means. Ideally, the hardened cement paste hermetically seals the iron so that direct contact with air and humidity is cut off. Even slight rust stains on the iron cannot do any harm because the cement paste protects it against further corrosion.

The protection will not be enough however, unless the builder observes the following rules:

- The reinforcement bars must be completely covered by concrete which is well compacted and without voids.
- The concrete cover must be sufficiently thick, and without cracks.

In most cases ordinary Portland cement is used and the mix proportion should be no less than 1: 5 for reinforced concrete. Apart from these, all the other rules for producing a good concrete must be observed.

*Note*: Quality concrete is not a brand. It does not have a trademark on it to say "This is quality concrete". Sometimes the concrete does not even look different from poor concrete, but it is different. This depends not only on the mix proportion, but on the awareness and skill of the builder.

**THE SLUMP TEST**

A "slump cone" is a simple device for testing a concrete mixture to see that it has the right proportion of materials. The equipment can be constructed from:

Heavy galvanized iron sheet: 35.5 cm x 63.5 cm (14 1/8” x 25 ½”)
4 x iron strap: 3 mm x 2-5 cm x 7.5 cm (1/8” x 1” x 3”)
16 x iron rivets: 3 mm in diameter and 6 mm long
Wooden dowel: 16 mm in diameter and 61 cm long

See Figure 8.

To perform the test:

- Dampen the slump cone and set it on a flat, moist, non-absorbent surface. Stand on the clips at the bottom of the cone to hold it down.
- Fill the cone in three layers approximately equal in volume. Because the diameter at the bottom of the cone is large, the first layer should fill the cone to about one-fourth its height.
- Stroke each layer 25 times with the wooden dowel.
- After the top layer has been stroked with the dowel, smooth the surface of the concrete so the cone is filled exactly.
- Carefully lift the cone off the concrete.
- Place the empty cone along side the concrete. Measure the difference between the height of the cone and the eight of the concrete. This difference is the slump.

Figure 8.

Suggested slumps for various types of construction are:

- Reinforced wags and footings: 5 cm to 13 cm (2" to 5")
- Un-reinforced walls and footings: 2.5 cm to 10 cm (1" to 4")
- Thin reinforced walls columns and slabs: 7.5 cm to 15 cm (3 to 6")
- Pavements, walkways, culverts, drainage structures, and heavy mass concrete: 2.5 cm to 7.5 cm (1" to 3")

Correcting the mixture:

If the slump is not within the desired range, or if the mixture is obviously either too fluid or too stiff, the proportions of the mixture must be changed. To make the mixture more fluid and increase the slump, increase the proportion of water and cement without changing the water/cement ratio. To make the mixture stiffer and decrease the slump, increase the proportion of the aggregates without changing the fine aggregate-coarse aggregate ratio. Do not add just water to make the mix more fluid; this will weaken the concrete.

**PLACING CONCRETE IN MOULD**

To make strong structures, it is important to place fresh concrete in the moulds correctly. The wet concrete mix should not be handled roughly when it is being carried to the forms and put in the moulds. It is very easy, through joggling or throwing, to separate the fine aggregate from the coarse aggregate. Do
not let concrete drop freely for a distance greater than 90 to 120 cm (3’ to 4’). Concrete is strongest when the various sizes of aggregates and cement paste are well mixed. The concrete mix should be firmly tamped into place with a thin iron rod (about 2 cm or 3/4” in diameter), a wooden pole, or a shovel.

CURING CONCRETE

When the moulds are filled, the hard work is done, but the process is not finished. The concrete must be protected until it reaches the required strength. Concrete begins to set about 30 minutes after water has been added and is firm after about 4 hours, although it may set much faster in hot and humid conditions. The concrete then continues to gain strength as it hardens, a process that takes at least a year.

<table>
<thead>
<tr>
<th>Time</th>
<th>3 days</th>
<th>7 days</th>
<th>28 days</th>
<th>3 months</th>
<th>6 months</th>
<th>1 year</th>
</tr>
</thead>
<tbody>
<tr>
<td>% of ultimate strength</td>
<td>20%</td>
<td>45%</td>
<td>60%</td>
<td>85%</td>
<td>95%</td>
<td>100%</td>
</tr>
</tbody>
</table>

The early stage of curing is extremely critical. Special steps should be taken to keep the concrete wet, once the concrete has set the addition of further water will not result in a loss of strength. In temperate climates, the mixture should be kept wet for at least 7 days; in tropical and subtropical climates, it should be kept wet for at least 11 days. Once concrete dries, it will stop hardening; after this happens, rewetting will NOT re-start the hardening process. Newly-laid concrete should be protected from the sun and from drying wind. Large areas such as floors or walls that are exposed to the sun or wind should be protected with some sort of covering. Protective covers often used are: canvas, empty cement bags, burlap, palm leaves, straw, and wet sand. The covering should also be kept wet so that it will not absorb water from the concrete.

Floors should be flooded with a few centimeters of water after pouring. After 1 day they can be drained so that a waterproofing coat can be laid however, it should be re-flooded once this layer has set. If a surface dries out it will crack and any loss of moisture will stop the hydration reaction and no further strength will develop.

Concrete is strong enough for light loads after 7 days. In most cases, moulds can be removed from standing structures like bridges and walls after 4 or 5 days, but if they are left in place they will help to keep the concrete from drying out. In small ground-supported structures such as street drains, the moulds can be removed within 6 hours of completion provided this is done carefully. Plans will usually say if forms should be left in place longer. Concrete is usually expected to reach the strength for which it was designed after 28 days. Concrete that is moist cured for a month is about twice as strong as concrete that cures in the open air.

QUICK-SEITING CONCRETE

Quick-setting concrete is often useful; for example, when repeated castings are needed from the same mold. A concrete mixture that contains calcium chloride as an accelerator will set about twice as fast as a mixture that does not. The mixed batch must be put into the moulds faster, but since quick-setting batches are usually small, this is not a problem. Calcium chloride does not lessen the strength of fully-cured concrete.

No more than 1 kg (2 pounds) of calcium chloride should be used per sack of cement. It should be used only if it is in its original containers, which should be moisture-proof bags or sacks or air-tight steel
drums. To add the calcium chloride, mix up a solution containing 1/2 kg per liter (1 pound per quart) of water. Use this solution as part of the mixing water at a ratio of 2 liters (2 quarts) per sack of cement (42.6 kg or 94 pounds). Solid (dry) calcium chloride must never be added to the concrete mix; only use it in solution.

**REINFORCEMENT STEEL**

To reinforce a material means to add something to it, in order to make it stronger. One of the strongest reinforcement materials available is steel or iron. In reinforced concrete, a concrete member is strengthened with steel bars or metal netting embedded in it.

**Types Of Reinforcement Steel**

There are various types of reinforcement steel; how they are used depends on the function, shape and dimensions of the reinforced concrete member as well as on the required strength. Reinforcement steel is classified according to its shape and surface texture. The most common reinforcement is single round bars which can have either a smooth or a ribbed surface (Figure 9).

- **Circular bars:** Round, smooth bars are called circular bars and are available in diameters ranging from 5 mm to 28 mm. The four sizes most often used in Rural Building have diameters of 6 mm (1/4"), 10 mm. (3/8"), 12 mm (1/2") and 18 mm (3/4").

- **Ribbed bars:** The round bars with a ribbed surface are called ribbed bars and are available in diameters ranging from 6 mm to 40 mm, if the bar is crossribbed. For obliquely ribbed bars, the diameters range from 6 mm to 28 mm.

The standard length of reinforcement bars is 9 m.

- **Advantages / Disadvantages:** Although the strength of circular bars is sufficient for all Rural Building purposes, it is advisable to purchase ribbed bars if they are available in the market. Ribbed bars are preferred because their rough surface texture provides a better grip to the concrete. This, along with their greater strength, allows the Rural Builder to space the ribbed bars wider apart, thus saving materials and reducing the total weight of the member.

**Reinforcement Mats**

A variety of reinforcement mats are available. They are usually made out of two layers of reinforcement bars laid across each other and secured together by welding. The mats are either square or oblong *in shape*. They reduce the work needed to reinforce large members of the structure such as floors, walls, slabs, etc. Regular reinforcement mats are hardly necessary in Rural Building, but two special kinds are frequently used for burglar proofing and to reinforce thin concrete slabs like manhole covers, draining boards in kitchens, and coping slabs.

These two are "expanded metal fabric" and "steel wire netting".

- **Steel wire netting:** The most common steel wire netting has square meshes measuring 5 by 5 cm and is manufactured In the same way as reinforcement mats. The same kind of wire mesh can also have oblong meshes.

- **Expanded metal fabric:** This is made by slitting metal sheets and then stretching them to form a diamond-shaped mesh. Always wear leather gloves when working with expanded metal fabric, as the edges are very sharp.
Reinforcement mats are sold in sheets approximately 2.15 m wide and 5 m long. Expanded metal fabric and steel wire netting can be purchased in sheets of about 1.5 m wide and 2.5 m long.

![Cross Ribbed Bars](image1.png) ![Circular Bar](image2.png) ![Expanded Metal Fabric](image3.png) ![Steel Wire Netting](image4.png)

**Figure 9.**

**Binding wire**
This is a soft steel wire about 1 mm in diameter, used for binding reinforcement bars at the points where they cross each other. It is bought in rolls and may also be called lashing wire, annealed wire or tying wire.

**Rebar Spacing And Placing**

<table>
<thead>
<tr>
<th>Type of Slab</th>
<th>Thickness (cm)</th>
<th>6 mm bar</th>
<th>Spacing of Rebar (cm)</th>
<th>8 mm bar</th>
<th>10 mm bar</th>
</tr>
</thead>
<tbody>
<tr>
<td>Floor</td>
<td>8</td>
<td>15</td>
<td>30</td>
<td>40</td>
<td></td>
</tr>
<tr>
<td>Roof</td>
<td>8-9</td>
<td>12</td>
<td>12</td>
<td>33</td>
<td></td>
</tr>
<tr>
<td>Roof</td>
<td>9-11</td>
<td>10</td>
<td>10</td>
<td>27</td>
<td></td>
</tr>
<tr>
<td>Roof</td>
<td>11-13</td>
<td>8</td>
<td>8</td>
<td>22</td>
<td></td>
</tr>
<tr>
<td>Roof</td>
<td>13-15</td>
<td>7</td>
<td>7</td>
<td>19</td>
<td></td>
</tr>
<tr>
<td>Roof</td>
<td>15-17</td>
<td>6</td>
<td>6</td>
<td>17</td>
<td></td>
</tr>
</tbody>
</table>

Rebar must have a minimum of 3 cm of concrete covering it; roof slab rebar 3 cm from the bottom and floor slab rebar is set 3 cm from the top of the slab.
MIXES

Mortar
For masonry and plastering.

The total volume of mortar is equal to the volume of sand in the mix because the cement mixes with water to fill the voids between the sand particles. Obviously the more cement there is between in the voids gives a stronger mortar. The amount of sand is therefore said to be 100% of the volume and a 1:4 mix requires 100% sand and 25% cement, also a 1:3 mix requires 100% sand and 33% cement.

<table>
<thead>
<tr>
<th>By weight or volume</th>
<th>Amount for 1 m$^3$ of Mortar</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Cement:Sand</td>
</tr>
<tr>
<td>Ordinary</td>
<td>1:4</td>
</tr>
<tr>
<td>Reinforced Brick Roof Slabs</td>
<td>1:3</td>
</tr>
<tr>
<td>Spatterdash (1$^{st}$ Coat Plaster)</td>
<td>1:4</td>
</tr>
<tr>
<td>Rough Plaster (2$^{nd}$)</td>
<td>1:3</td>
</tr>
<tr>
<td>Final Plaster</td>
<td>1:2</td>
</tr>
<tr>
<td>Grout</td>
<td>1:1 – 1:1½</td>
</tr>
</tbody>
</table>

Concrete
For floor and roof slabs.

The total volume of concrete is never less than the volume of the total volume of the aggregate. Typically air voids make up 50% of the aggregate volume, these are filled up with mortar. Excess mortar adds to the volume of the concrete. Remember that the aggregate should contain a variety of sizes so that it fills a volume efficiently and that the maximum aggregate size for roof slabs is 10mm and for floor slabs it is 20 to 25 mm.

<table>
<thead>
<tr>
<th>By weight or volume</th>
<th>Amount for 1 m$^3$ of Mortar</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Cement:Sand:Aggregate</td>
</tr>
<tr>
<td>Normal Work</td>
<td>1:2:4</td>
</tr>
<tr>
<td>Reinforced Work</td>
<td>1:1½:3</td>
</tr>
</tbody>
</table>

Water should be added so that 1 part (volume of cement) is mixed with ¾ parts water.

Note: That if you are trying to keep costs down by using more sand, reinforced concrete should never contain less than 270 kg of cement (about 0.19 m$^3$) per 1 m$^3$.

Remember: that 1 m$^3$ = 1000 liters.

Water Proofing
A day after pouring a floor water proofing plaster can be laid down. A grout of 1:1 worked onto surface to form a thin layer.

Using The Water Displacement Method
Well-graded aggregate seldom occurs naturally and sand and stone s are mixed together. Some "pre-mix" processing would be needed to grade it. Remember that when you make concrete, you are filling the spaces in the aggregate with cement mortar or paste. The amount of cement paste needed for a particular aggregate supply can be found by adding water to a known volume of aggregate. To do this:
• Divide a sample of the aggregate into coarse and fine particles by sifting it through a 0-5 cm (1/4") screen.
• Fill a pail with the coarse aggregate (dry).
• Fill the pail with water. The amount of water used equals the amount of fine aggregate and cement paste needed to till the spaces.
• Into another pail, put an amount of fine aggregate equal to the volume of water used in Step 3.
• Fill the pail with enough water to bring the water level to the top of the fine aggregate. The volume of water used equals the volume of cement paste needed to fill the remaining spaces.
• Add about 10 percent to this volume to allow for waste and to make the mix more workable.
• To find the correct ratios of materials, divide the volume of cement paste needed into the volumes of fine and coarse aggregates.
• Add these two ratios to get the ratio for un-graded aggregate. For example: If you are using a 19-liter (1 gallon) pail, and it takes 12.8 liters (3.4 gallons) of water to fill the pail in Step 3, put 12.8 liters (3.4 gallons) of fine aggregate in the second pail (Step 4). If Step 5 takes 6.4 liters (1.7 gallons) of water, this is the volume of cement paste needed. Divide this volume into the volumes of fine and coarse aggregates to get the ratios of materials:

\[
\frac{19 \text{ liters (coarse aggregate)}}{6.4 \text{ liters (cement paste)}} = 3
\]

\[
\frac{12.8 \text{ liters (fine aggregate)}}{6.4 \text{ liters (cement paste)}} = 2
\]

The sum of the two ratios is 5, so the ratio of ingredients in this case is 1:5, or 1 part cement paste to 5 parts un-graded aggregate, by volume.

Using "Rule of Thumb" Proportions
For a variety of small concrete construction tasks and for repair and patch-work, the following simple "rule of thumb" can be used as a simple guideline.

Use the ratio 1:2.3, by volume, to proportion the cement and aggregate and use a water cement ratio of 29 liters water to 1 sack of cement. That is, for every sack of cement used, add 57 liters of fine aggregate (sand), 85 liters of coarse aggregate and 29 liters of water. The volume of concrete produced by a one-sack batch using these portions will be about 142 liters (0.142 m³).

The most common mistakes made by inexperienced persons are using too much cement, which increases the cost, and using too much water, which produces weak concrete.