



# INTRODUCTION TO CONCRETE BUILDING PRODUCTS:

## INFORMATION FOR POTENTIAL SMALL-MEDIUM-SCALE PRODUCERS

### Use of Concrete as a Building Material

Concrete can be considered to be any material which has been fabricated from a binder and a filling material. As such it is a composite material formed of two or more primary components. Each of the components contributes something to the characteristics and properties of the composite.

The best known binder for making concrete is Ordinary Portland Cement (OPC). Less commonly, lime-pozzolana cement and gypsum have been used as binders. Binders such as sulphur, synthetic organic resins and high alumina cement have also been used for certain specialist applications.

The filler normally makes up the majority of the concrete. It forms the skeletal structure of the concrete and is integrally linked with the binder to produce a material which can be given shape and acquire hardness and strength. The filler normally used in concrete products is a mixture of gravel or crushed rock and sand, collectively known as aggregate. Good quality aggregate can, however, be expensive and its extraction from the ground can cause loss of agricultural land or even changes in the flow of watercourses if taken from river beds, so attention in recent years has been focused on alternative aggregates, including recovery from demolition wastes and using residues from process industries and agriculture.

In truth, however, most alternative aggregates have proved to provide inferior properties for the concrete compared with conventional aggregates of rock, stone and sand extracted from the ground. Most agricultural and plant wastes, such as rice husks, wood chips and broken nut husks generally produce quite a poor quality concrete, unless they have been treated in special ways. Others, such as metallurgical slags and mining and mineral processing wastes may offer more promise. A few wastes, such as pulverised fuel ash (pfa) from coal burning power stations and silica fume from silicon production, can even improve conventional concrete properties if used in specific proportions; mainly due to their pozzolanic properties.

Pozzolanas are materials that react chemically with the lime present in the concrete to give additional hardened materials. Pozzolanas consist of silicon, aluminium and iron oxides and are finely pulverised and treated by heat to make them active. As well as pfa and silica fume other types of pozzolana include rice husk ash, some types of volcanic ash, brick dust from fired clay brickworks and pulverised and heat-treated diatomaceous earth.

In this brief waste materials as aggregate in concrete are given little further consideration, except in the case of potential pozzolanas and demolition wastes. It is assumed that most producers of concrete items would be using conventional stone or rock and sand as aggregate.

Water is the final very important ingredient for concretes made with hydraulic binders such as OPC, lime-pozzolana or gypsum, which set by chemical reaction with water.

Sometimes special admixtures are added to concrete to make it more workable, set faster or slower, or make it more frost resistant, for example. However, many such admixtures are usually very expensive and more usually used for concrete cast-in-situ at the building site rather than at the concrete products yard. They are therefore little considered further in this technical brief.

See the companion Technical Brief – *Concrete Works: Information And Guidelines For Concrete Products Makers And Builders Making And Using Concrete At The Building Site* for further information about the constituent materials for concrete and admixtures.

Since the invention and development of Ordinary Portland Cement (OPC) by Joseph Aspdin and others in the first half of the nineteenth century, use of mortar and concrete made using OPC as the binder has become very widespread throughout the world. OPC concrete can be mixed and used at the building site where it can be considered as cast-in-situ concrete, fresh concrete mixed at a plant away from the building site then transported to it by truck – known as ready-mixed concrete, or cast into moulds to produce building components and elements at the production yard that are transported for use at the building site after curing. The latter process is called precasting and is the subject of this technical brief.

There are many thousands of small-to-medium-scale producers of concrete products throughout the world. Wherever significant building activities are taking place and not that many building materials producers and suppliers operating in the area there may be an opportunity to set up a concrete products fabrication yard. The main requirements are a sizeable fairly level site, access to a regular water supply and easy road access to the yard for transport of materials.

If the producer already owns the land or can rent a plot it can cost less than US\$1,000 to set up a very small manual operation, or less than US\$10,000 for a slightly larger operation using concrete vibration equipment. The producer can start by making concrete blocks, for which there is a widespread and universal demand in many places. Micro concrete roofing (mcr) tiles have also gained ground for roofing in many places in recent years and the prospective producer can also consider making these instead of or in addition to concrete blocks.

Experienced producers of concrete blocks and tiles can consider diversifying into other more specialised items and components, for which the purchase of additional moulds and equipment would be needed. These can include concrete beams, columns and lintels – usually reinforced with steel rods, pavers for roads and footways, floor and wall tiles, cylindrical water pipes, ventilation elements, curved blocks for water tanks, window and door frames, pit latrine slabs, paving slabs, fencing posts, balustrades, staircases, roadside kerbs and decorative or practical garden ornaments.

Many experienced builders like to build with concrete blocks as they can put up buildings and structures relatively quickly. Casual builders, including many households building their own homes and business premises, can also prefer concrete blocks to other materials such as the smaller fired clay bricks as they are easier to lay and there is less potential to make serious mistakes.

Both producers and builders using concrete products need to understand how concrete behaves when it is freshly mixed, when it is placed into moulds, when it is curing in the moulds and outside them, and when it is loaded and stressed as it is used in buildings. These subjects are covered in greater length in the brief *Concrete Works: Information And Guidelines For Concrete Products Makers And Builders Making And Using Concrete At The Building Site*. Here only a summary is presented.

### **Characteristics of Fresh and Hardened Concrete**

Concrete made with OPC is a very versatile material for making into a large variety of shapes because just after it is mixed it can be highly workable and able to take the shape of the mould into which it is poured.

Normal concrete consists of a mixture of sand, gravel or stones, and cement in various proportions, with added water. The larger the amount of water used in the mix the more workable it becomes. However, this comes at the expense of the final strength of the concrete that generally decreases as the amount of water is increased. It is usual to specify the water to cement ratio, by weight, for concrete mixes. Most concrete is made with water to cement ratios of 0.4 to 0.7, although in some specialist applications ratios outside this range can be used. It is normal to set the water to cement ratio as the minimum required to make the mix sufficiently workable, but no higher to avoid weakening the concrete and the risk that it could become less durable.

Concrete hardens by the chemical reaction of OPC with water. This is quite a slow reaction, but importantly concrete starts to set and stiffen after only about half an hour. It is therefore poor practice to make too much concrete that cannot be used up within half an hour or, at the latest, 40 minutes, and then to try to make the mix more workable again by adding more water.

Even when freshly mixed, concrete can still feel quite stiff, especially if a lean (low cement and high aggregate) mix is used. It won't then fill the mould completely if simply poured in and edges and corners of the mould can be left void. Concrete needs to be assisted to fill the mould completely, either by tamping it manually to force it into the corners and edges, or still better by mechanical vibration.

Once concrete begins to set it still takes considerable time to reach sufficient strength for the products made from it to be handled. This needs to be at least 10 hours, but preferably a whole day. Then most types of products can be safely taken out of their moulds to continue curing for a minimum of a further seven days in normal curing conditions, but preferably 10 days before they can be put to use in the building.

The chemical reaction between OPC and water in the concrete while it cures generates heat. The heating can cause drying out of the concrete and for the chemical to stop or become very feeble. This can cause low strength of the concrete. It is therefore very important to ensure that concrete products remain damp during the first 7 to 10 days of curing. This is best done by curing products underwater or by spraying them regularly and frequently.

Concrete products may be used in building after 10 days, although at least double this time might be required for some high strength and specialised products. The bonus is that concrete continues to gain strength weeks, months and even years after casting, so surpassing its design strength and giving an additional margin of safety.

Hardened concrete is a relatively strong but brittle material. It is strong in compression. Most loading in buildings is compressive, so concrete is suitable for taking this loading. However, concrete is relatively weak in resisting bending, twisting, shearing or powerful impacts. If it is expected to sustain these types of forces concrete needs to be reinforced with steel rods, bars or mesh or, to withstand these forces at lower levels, the incorporation of fibres. Reinforcement of concrete with steel or fibres is a detailed subject area that it is not possible to cover in this brief.

Concrete is a highly durable material that if well made can last 100 years or longer. However special precautions need to be taken if it needed to carry intermittent heavy loads such as truck or heavy machinery movements, exposed to regular freezing and thawing due to the climate, used in seawater or exposed to certain chemicals, mainly some types of oils and acids.

## Common Types of Concrete Products

### Blocks

Concrete blocks are generally popular for structural walls of up to two storey heights. They may also be used for infill in taller buildings built on the structural frame principle. Special higher strength and density blocks are required if the blocks are used in foundations or in other applications where they are subject to a high level of wear and stress. Blocks specifically used for insulation contain lightweight aggregate such as exfoliated perlite, vermiculite or pumice.

Three types of concrete block are generally made:

- Hollow block
- Solid block
- Ventilation or louvred block

Hollow blocks are by far the most common type of block produced and some producers may make only this type of block and nothing else. The empty space in the block helps to save on concrete and makes the blocks easier to handle by builders.

Hollow blocks can be used as a single layer to build satisfactory walls for low-rise housing and other types of buildings. They are therefore not made to a particularly high compressive strength. Five to 10 N/mm<sup>2</sup> (MPa) is typical. In contrast cast concrete for structural applications is usually specified to reach a particular minimum compressive strength within the range 20 to 50 MPa after 28 days curing.

Hollow blocks for non-structural use for use in freestanding walls or infill panels in which the blocks are required to support only their own weight and blocks above them can be made to a target compressive strength of only around 3 MPa. It is not usually practicable to make concrete blocks to strengths lower than 2.5 MPa. Even though they might only be lightly loaded they can be vulnerable in other ways, e.g. prone to breakage during transport and handling or damaged by repeated heavy rains or abrasion by contact with people, animals and objects.

Concrete hollow blocks that are used in certain demanding situations such as in foundation levels below the water table, for large water storage tanks and for buttresses and retaining walls to stabilise very unstable slopes may need to be produced to higher strength specifications of 15 MPa, or higher. However, in such conditions it is more common to use solid rather than hollow blocks.

Concrete blocks can be economical to produce due to their lower cement requirement than conventional concrete. This is because:

- Concrete blocks are usually made to a lower strength specification than conventional concrete, as noted above, so the mix can be leaner in cement.
- Concrete blocks are relatively small objects with the concrete tamped or vibrated vigorously to fill the mould. The concrete mix can then be relatively stiff rather than flowing with a lower water to cement ratio than conventional cast-in-situ concrete. This further reduces the cement requirement.
- Large visible holes or voids are completely acceptable for concrete blocks in most situations, whereas they would not be in concrete cast at the building site. Then mixing and matching the aggregate size fractions to fill nearly completely all the voids becomes less important. In particular an excess of the largest size of aggregate can then be used, and this is usually the cheapest fraction. Also a further reduction in cement can be considered as the cement and sand paste is only needed to coat the larger size aggregates rather than to fill the spaces between them. Note, however, that with hollow blocks, the largest aggregate pieces have to have a diameter of at the most one three quarters the width of the thinnest section of the block, otherwise they become difficult to place in the mould and lead to weakness in the block. This can place a limit on the size and amount of large stones that it is possible to include in a mix for hollow blocks.

Solid concrete blocks are little produced except for special applications such as for below ground foundations or basements prone to flooding risks. The main drawback of solid blocks for builders is their heavy weight, making them difficult to handle. For construction in demanding situations many builders may prefer to use smaller concrete bricks that are made with dense and strong concrete to resemble fired clay engineering bricks.

Ventilation or louvred blocks can be incorporated in walls to provide airflow in and out of buildings in hot climates. The moulds for these have a more intricate shape than for conventional blocks and incorporate thin and curved sections to maximise the size of the openings in the block. This means

that a stronger and richer concrete is required than for conventional hollow blocks and quality control needs to be very good. However, ventilation blocks can be sold at a premium price, so it can be very worthwhile for producers to make them if they are confident that they can maintain the required quality.

Producers need to follow national or international guidelines and guidelines for the sizes of blocks. Typical sizes are 40 x 20 x 20 centimetres for hollow or solid blocks and 20 x 10 x 10 centimetres for bricks for the length, width and height.

The following are some typical dimensions for hollow blocks, showing the hollow sections. Most blocks are made with two or three cavities. Larger numbers of cavities are possible, but this makes the mould design and the moulding process more complicated. More than three cavities may be used, for example, if steel reinforcing rods are to be pushed through the blocks then grouted in to give concrete block structures that are strong in tension and bending as well as in compression.

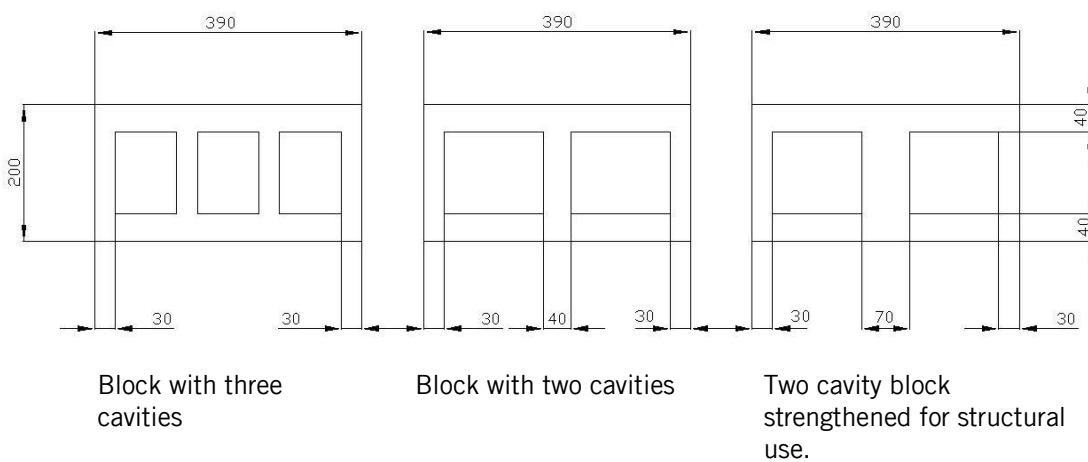


Figure 1: Dimensions of Concrete Blocks Showing Cavities, in millimetres.

Illustration: Neil Noble / Practical Action. From *Geometric Design of Cores in Concrete Hollow Blocks for Optimum Weight*, by Fada Casi Al-Subaei, Master of Science Thesis, King Saud University, Saudi Arabia, 1994.

Curved concrete blocks, usually solid, can also be made, for example for circular buildings or water tanks. With more elaborate moulds straight or curved concrete blocks can also be made interlocking in which an extended section from one block slots into a groove of the next block. In this way buildings made with interlocking blocks can be strengthened. However, the sizes of interlocking blocks need to conform to very tight specifications as otherwise there are gaps between the fitting of successive blocks and the building structure does not work as well.

### Tiles and Slabs

These products are thin and rectangular and most commonly comprise:

- Roofing tiles
- Wall tiles
- Floor tiles
- Paving slabs
- Fencing panels
- Pit latrine slabs.

Paving can also be carried out with pavers, which resemble more closely small concrete bricks than slabs. Pavers are more commonly used for highly active areas, especially where there is vehicular traffic as they are far less likely to crack and break in service.

Concrete roofing, wall and floor tiles are usually made with just sand and cement and no coarse aggregate such as gravel or crushed rock. This is because of their thinness, usually 6 to 20mm in height, although floor tiles may be thicker. Such a mix can be called micro-concrete (mc).

The mc mix typically has a cement to sand ratio of 1:3 by weight, so it is quite a rich mix. Only the minimum amount of water is used to make the mix just workable enough, and vibration is usually used to distribute the mortar in the mould. Quality control in production needs to be good or numerous tiles can get broken during transport and use.

Floor and wall tiles are rectangular in their most basic form, but other shapes, e.g. hexagonal, are possible for a more decorative appearance. There are few specifications for the sizes of wall and floor tiles in any of the national standards. A typical size can be 230 by 230 by 16mm. However, as sawing or splitting equipment for concrete tiles is expensive it is best to choose a size for the lateral dimensions that they can fit exactly within the typical sized rooms used in an area.

With micro-concrete roofing (mcr) tiles it is not all that common to make flat tiles (slates). More usually tiles with a curvaceous profile are made as they offer some technical advantages compared with flat tiles and are easier to fit by builders who are not specialist roofing contractors. The most common of the curved shapes is the pantile.

Mcr tiles typically have dimensions of 500 by 250 by 6, 8 or 10mm. For further information on mcr tiles see the companion technical brief - *Micro-Concrete Roofing Tile Production*.

Mixes for concrete slabs can contain coarse aggregate as well as sand and cement. A typical size is 600 by 600 by 50mm. Mix proportions of 1:2:6 cement: sand: coarse aggregate by weight may be used. Similar proportions can be used for fencing panels and pit latrine slabs.

### Extended Elements

These comprise long and thin products that are usually reinforced with steel rods or frameworks. The main types of these products are:

- Lintels over door, window and other openings
- Coping stones to provide protection to the tops of exposed walls
- Structural beams and columns
- Fencing posts
- Concrete pipes
- Roofing channels
- Roadside kerbs.

Note that coping stones and kerbs are usually made thicker than the other types of element and may not need reinforcement. Concrete pipes are also usually made without reinforcement.

These are quite specialised types of product that may not suit the small to medium scale producer, except for coping stones that are relatively easy to make. Potential difficulties for non-specialised producers are the need to know how much reinforcement to use, where to place it in the mould and how to ensure that the workers in the yard know how to place the reinforcement and maintain it in position as the concrete is poured. Additionally, medium to high strength concrete would be needed for structural elements, generally above 20 N/mm<sup>2</sup> (MPa) at 28 days and this presents particular quality control issues at the production yard including the use of large-scale vibration equipment to ensure that the sections are evenly vibrated throughout their whole length.

Prestressing is a technique to enable elements loaded in flexure or tension to relieve some of these stresses by utilizing the high compressive strength of concrete. In this way savings can be achieved on the quantity of expensive reinforcing steel used. There are essentially two methods of pre-stressing:-

- (i) In pre-tensioning the steel reinforcement rods are stretched by jacks with concrete cast around the rods. When the concrete has hardened sufficiently the pressure in the rods is released and it is taken up by increased compression of the concrete.
- (ii) In post-tensioning reinforcing rods are passed through hollow ducts in the concrete product after it has hardened, then tensioned and mortar grout poured around the rods. The grout hardens and the tension in the rods is subsequently released.



Both methods of prestressing rely on the use of expensive equipment and are not suitable for small-scale operation. It should also be noted that it is more difficult and less safe to demolish a building containing pre-stressed concrete elements than one incorporating conventional reinforced concrete.

**Decorative Products**

These comprise garden ornaments and statuettes, benches and seats and balustrades for staircases, for example. They are usually made with a mix rich in cement that is made flowing by the addition of excess water or the use of superplasticizers. The maximum aggregate size may be limited, e.g. to one centimetre across for larger products and half a centimetre, or less for smaller and more decorative products.

Colouring or staining of the concrete may be used to achieve the decorative effects. They can also be painted, although most paints do not hold fast well on concrete, especially outdoors.

The concrete is usually poured into plastic or stiff rubber moulds that have been specially fabricated for the products. These can incorporate quite intricate shapes. When the concrete has hardened the plastic moulds are simply prised open while rubber moulds can be peeled off. It is especially important to keep these moulds clean between uses and to discard them when they start to deform with usage.

**Large-scale Components**

Large prefabricated concrete products are usually made at large factories that use large specialised moulding, handling and transport equipment. Products include wall panels, staircases and even whole sections of buildings that are subsequently bolted together at the building site.

In Europe and North America prefabrication was common for building, especially for mass housing, several decades ago. However, technical problems have been found with significant amounts of this construction leading to the need for demolition in some cases. Quality control at large-scale prefabrication works then needs to be exceptionally high.

Steel reinforcement is used in nearly all large-scale prefabricated components. This may also be pre-stressed.

Experimental and practical studies have also been undertaken on prefabricated building components of ferrocement. Ferrocement is a type of reinforced concrete that uses one or more layers of thin steel wire mesh, e.g. chicken wire, as reinforcement instead of conventional steel rods, ties and cages. It is therefore cheaper than conventional reinforced concrete and more orientated towards the conventional builder rather than more highly engineered construction.

Prefabricated ferrocement wall and roof panels have been

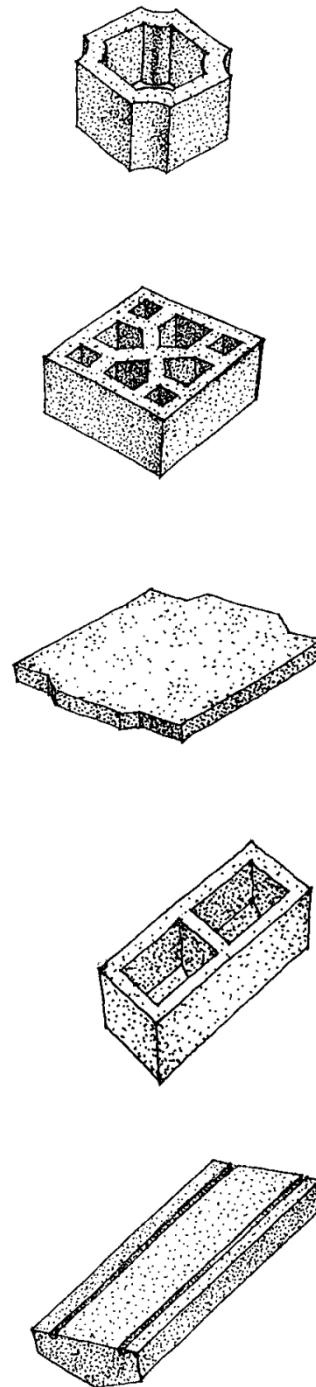


Figure 2: Selection of Concrete Products (page 30) – No. 1 Simple air brick (as made in Kenya), No. 2 More complex example of air brick, No. 3 Floor tile, No. 4 Hollow block, No. 5 Wall coping.

Illustration from Vibrated Concrete Products Production Manual (Draft), by Amon Ng'ang'a, Building Materials and Shelter Programme of IT Kenya, October 1994.

trialled in a number of places and in India the semi-circular ferrocement roofing channels devised by Development Alternatives have been quite successfully disseminated.

### Why Make Concrete Products?

A great attraction of starting a concrete products workshop is that production can be carried out on almost any scale ranging from a small manual operation run by one or two people to a large highly mechanised factory. Even in areas where a large producer supplies most of the market the small producer may be able to find a niche because it is relatively inexpensive to set up to produce concrete products on a small scale. For the small-scale producer with a suitable plot of land, little more would be needed than a small builders' concrete mixer, a number of different moulds, a vibrating table and a curing tank.

Making concrete products is also an industry which allows considerable scope for expansion, providing the market develops. So, a producer might start off making just blocks using a set of inexpensive wooden or steel moulds - locally made, and tamping the concrete in the moulds by hand. As turnover increases this producer might add to the range by buying moulds for making floor tiles, paving slabs, ventilation elements and fencing posts. If turnover increases still further the producer might consider buying an 'egg-laying' machine - to increase production and improve quality of the blocks by vibration, and a larger and more specialised concrete mixer. Alternatively, if the market for concrete products fails to take off the producer can abandon the enterprise at its initial stage without too great financial loss.

Understanding the market is the key to determining if a small-scale concrete products enterprise will succeed or fail. It might be particularly worthwhile to consider setting up a workshop if there are a lot of small-scale building works taking place in the area. It can be a lot more difficult to establish a viable enterprise if there is little building activity taking place or there are already a number of established producers.

In any case, before investing in land or equipment, it would be essential to carry out a feasibility study to determine if concrete products could be produced profitably. This would involve:

- An assessment of the market to know how many blocks and other products the producer might be able to sell
- Finding out the prices in the local market of concrete blocks and other products
- An estimate of production costs comprising raw material and labour costs, estimate of costs of equipment and consumable items (with interest charges factored in if the equipment needs to be bought with a loan), taxes and rates paid to national and local governments (if applicable), marketing and advertising costs and other costs associated with running the business, as well as a contribution to maintaining a working capital or float fund.
- What profit can be made if selling the products at the local prices as the excess funds available over the production costs.

It can be assumed that an efficient producer of concrete blocks will be able to make about 150 blocks from one 50kg bag of cement.

If the potential profit is 10 per cent or higher it is highly likely that the business would be successful. Between 3 and 10 per cent it is quite possible that the business would be successful but it would be vulnerable to changing external conditions (e.g. fall in the value of the local currency if the equipment needs to be brought from abroad) and the business operators would need to be very determined and hard-working to make the business viable. If the study indicates a profit of only one or two per cent, or a loss, then it would probably not be a good idea to go ahead.

The potential producer also needs to assume, unless assured of substantial pre-orders from users before production starts, that there would be a start-up period of between a few weeks to up to a year when full or nearly full production costs would be incurred but there would be little or no income from sales as orders are built up. How to cover this shortfall of funds during this start-up period would be another challenge the potential producer would need to address.





Figure 3: A building of concrete blocks and roof tiles in Nepal. Photo: Practical Action.

Concrete blocks are usually popular with builders and building owners. Building with them is not particularly heavy work, unlike the construction of rammed earth walls, and the builder does not have to have specialist bricklaying skills. The owner may like the thickness of the block walls which confer security and provide good insulation, and may consider a concrete block house to confer a degree of status within the community. As a result the producer may not find it too difficult to sell blocks to small-scale builders and plot owners, provided the selling price is not considerably more than that of other materials.

#### Drawbacks of Concrete Products

Up to now this guide has considered mainly the benefits and advantages of concrete products, but there are also some disadvantages which need to be mentioned.

Firstly cement is used in making the blocks, and in many countries cement is a very expensive commodity. The producer who can minimise the usage of cement through good quality control is at an obvious advantage.

Also, because cement hardens and gains strength rather slowly, concrete products require one or two days undisturbed curing before they can be handled and then at least a further seven days of curing before they can be used in building, a large curing area is required where a whole days production can be set out. In the middle of a city, where land prices can be high, concrete products manufacture might not be feasible.

In addition, although blocks, which are usually made with a semi-dry mix, can be turned out of their moulds straight after casting, other products are usually made with a wetter mix and so need to be left in the mould until hardened. The producer therefore needs to invest in a large number of moulds - equivalent to a full day's production. Steel or plastic moulds are expensive and buying a large supply of them would form a sizeable part of the investment in the whole plant.

When concrete blocks are taken out from the mould, they have little strength and are very fragile. Handling them carelessly at this stage can result in a significant number of damaged and worthless blocks.

<i>CHECKLIST OF ADVANTAGES AND DISADVANTAGES OF CONCRETE PRODUCTS</i>	
ADVANTAGES	DISADVANTAGES
FOR THE PRODUCER	
Production can be started with little capital	Cement, an expensive commodity in many areas, is used in production
Concrete is acceptable to builders and building users, i.e. there is usually a ready market	Cement hardens slowly and a large area of land needs to be set aside to allow products to harden and cure
A large variety of products can be made with concrete	Concrete is rather a brittle material, so care is needed in handling and transport of products to avoid breakages, unless reinforcement is used
Concrete products can be left in the yard without deteriorating	A large amount of water is needed for concrete products
A high level of skill and training is not required to make most types of concrete products	The need to thoroughly clean moulds and machines
FOR THE USER	
Durable	Brittle - risk of breakage during handling, unless reinforcement is used
Easy to build with	Low strength in tension and bending, unless reinforcement used
Fireproof	Attacked by sulphates in groundwater - care needs to be taken if groundwater contains sulphates in below- ground construction
Pest resistant	Relatively high moisture movement, hence need for construction joints in long structures
Little maintenance required	
Good thermal and sound insulation	
High compressive strength - can be used in multi-storey construction	
Relatively weatherproof	
International and national standards available for many products and the products usually acceptable by local building codes and regulations	

**Materials and Mix Proportions**

The types of materials for concrete mixes have already been referred to earlier in this brief and described in more detail in the accompanying brief - *Concrete Works: Information And Guidelines For Concrete Products Makers And Builders Making And Using Concrete At The Building Site*. It is suggested that reader consults this brief for further information on the constituent materials of concrete and their properties.

technical brief

The main constituent materials for concrete are usually sand or fine aggregate, crushed rock or gravel as the coarse aggregate, cement and water. When batching these materials it is recommended to invest in a set of heavy duty weighing scales for the solid materials and a measuring jug or cylinder for the water.

Even for the very small producer buying these items can be worthwhile. This is because it is impossible to batch the solid materials accurately by volume as the materials settle differently when they stockpiled and transported from site to site. The bulk density of OPC can vary from 1200 to 1800 kg/m<sup>3</sup> depending on settling conditions so when batching by volume it is impossible to know exactly how much cement to add to keep with the specified mix proportions. Just to be on the safe side it is then necessary to put in a bit more cement and in the long run this turns out to be more expensive than investing in a set of scales in the first place.

Similarly batching water by eye is also not a good idea as the risk is that too much water is added making the mix too runny and the concrete weak when it sets. Adding more cement to compensate for adding too much water also adds to the costs, and keeping production costs down is important for the business to achieve profitability.

On the metric scale it is very easy to convert the weight of water to volume. The specific gravity of water is almost exactly 1.0 at normal outdoor temperatures. This means that one litre of water weighs one kilogramme.

Mix proportions are therefore only shown by weight in this brief. However, a comparison with batching by volume is shown in the accompanying brief - *Concrete Works: Information and Guidelines for Concrete Products Makers and Builders Making and Using Concrete at the Building Site*.

With batching by weight suitable mix proportions for blocks are 1:3:9 OPC to sand to gravel. With good quality control at the production site such a block may reach a compressive strength of around 5 N/mm<sup>2</sup> (MPa), so suitable for a range of applications in low-rise construction or for non-structural use (e.g. for infill panels) in multi-storey construction. A dry stiff mix with a slump of 20 to 40 mm can be used to blocks. This is likely to correspond to a water to cement ratio of 0.5 to 0.6.

For higher strength blocks richer mixes may be used, e.g. 1:2:6 or even 1:1:3 cement: sand: gravel for strong or super-strong blocks.

If the producer has no alternative than to batch by volume than a mix of 1:2:4 or 5 parts by volume cement to sand to gravel may be trialled. This mix may be used for blocks with a target compressive strength of 5 N/mm<sup>2</sup>. The producer may need to adjust mix proportions after the trials to produce blocks with the required characteristics and be very careful to monitor any changes in the bulk densities of the cement, sand and coarse aggregate that may call for the need to readjust the volume mix proportions.

For most other applications a 1:2:6 mix, by weight, is likely to be suitable. Again a stiff mix would be used with a water to cement ratio of 0.45 or 0.5. With steel reinforcement included in the product a richer and wetter mix may be used to ensure that the concrete mix flows around and bonds with the reinforcement when the product is vibrated in its mould. This corresponds to a slump of 50 to 100mm when a slump cone test is carried out on the fresh concrete. So, a 1:2:4 cement: sand: gravel mix may be tried with a water to cement ratio of around 0.6.

An alternative way to increase the workability of concrete for reinforced concrete products is to add superplasticizers to the mix and keeping the mix proportions and water to cement ratio unchanged from the unreinforced mix.

For ordinary concrete blocks and most other concrete products up to one quarter of the weight of OPC may be replaced by a pozzolanic additive. Pozzolanas are materials of active oxides of

silicon, aluminium and iron that react chemically with the lime (calcium hydroxide) generated by the hydration of cement to produce additional cementitious components. Some examples of pozzolanas include rice husk ash, fired clay brick dust, volcanic ash, activated kaolin and diatomaceous earth. Addition of pozzolanas in this way does not adversely affect the properties of the concrete and can confer some additional advantages such as increased chemical resistance in harsh environments. Note however, that as pozzolanas are very fine materials they may increase the water requirement slightly as well as increase the curing time slightly.

Low strength blocks can also be made entirely with a lime-pozzolana cement. Mix proportions to use can be 1:2:2:4 or 1:3:2:6 lime to pozzolana to sand to gravel.

See the Practical Action technical brief *Pozzolanas: An Introduction* for further information about pozzolanas and their use in cement

Blocks for use in dry conditions can also be made using gypsum as the binder. Mix proportions of 1:1:2 gypsum to sand to coarse aggregate may be used. Note that gypsum mixes cannot carry large aggregate particles as well as OPC concrete so that it may be useful to limit the maximum aggregate size to 5 to 10mm across. Gypsum (plaster of Paris) concrete can be made more durable to occasional exposure to damp conditions with the addition pulverised fuel ash that can replace 10 to 20 per cent of the sand fraction of the mix.

See the Practical Action technical brief *Gypsum Processing and Use* for further information about gypsum as a binder and its technical properties -

OPC properties are relatively similar throughout the world, wherever this cement is produced. However, aggregate properties vary widely. Therefore it is best to treat the above guidelines only as approximate and to carry out trials on the best mix proportions to use for particular products with the locally available aggregates. This applies in particular if lime and pozzolanas are used in the mix as these materials can vary widely in properties even over quite a small area.

## Equipment for Concrete Products and Production Site Layout

### Equipment Requirements

The following equipment may be seen at a medium-scale concrete products yard :-

- (i) Silo for cement
- (ii) Drying kiln for aggregate
- (iii) Conveyors for transporting material
- (iv) Automatic batching boxes (by weight)
- (v) Industrial Concrete Mixer
- (vi) Moulding Machine
- (vii) Water tanks, steam cabinet or autoclave
- (viii) Trolley or fork-lift truck for transporting the products.

A smaller yard may just have some moulds and a two or three wheelbarrows or trolleys or small hand-held trucks, a builders' concrete mixer, a set of weighing scales, and a water tank. Optionally such a yard may also have a small moulding machine for blocks or a vibrating table or electrically-powered vibrating plates that are attached to moulds. At the very lowest level of production, if only producing blocks, it may be enough just to use hand tamping of the concrete in the moulds.

However for most small to medium scale producers the costliest items for would be the concrete mixer and the moulding / vibrating unit; so some further details are given on these.

### Concrete Mixers

Concrete may be mixed manually using shovels on a hard level surface. This is completely acceptable for small quantities, up to about two wheelbarrow loads, provided the mixing is carried out thoroughly, but becomes very cumbersome for larger quantities if done by only one or two people. In practice, except when very small quantities are used, concrete is normally mixed in a

mechanical mixer.

Mechanical mixers can be powered by electricity, or a petrol or diesel engine. Small mixers which run off electricity usually use a single phase mains supply or generator while larger mixers usually use a three phase mains supply. There are also simple manual mixers on the market which require no power supply. One design of such a mixer consists of a specially shaped plastic drum which can be rolled about on the floor. Mixing concrete in this way is said to be easier than mixing with a shovel.

There are essentially two types of mixer used in concrete products yards and building sites - the drum and the pan. Drum mixers are typically used in small yards. Concrete is tumbled in a rotating inclined drum with an opening at one end. Usually the drum can be tilted downwards to discharge the concrete from the open end at after mixing. Pan mixers are usually larger (and also more expensive) than drum mixers. Most types consist of a large bowl with a flat bottom, with this bowl being rotated. Various paddles and scrapers are inserted into the concrete in the bowl and held stationary while the bowl rotates thus churning the concrete. In general it is claimed that pan type mixers are more efficient in mixing concrete than drum types.

The dry ingredients for concrete are usually mixed first in the mixer for a minute or more before the water is added gradually over about a minute. Mixing is continued for another minute, or longer, depending on the type of mixer and the quantities being mixed, until a homogenous concrete mass is achieved. It is good practice in small yards to mix concrete in batches rather than to continuously remove concrete and add more raw materials, because it is easier to keep the mixer clean and also this avoids the inclusion of old concrete, more than an hour old, which has started to set. Note, however, that continuous mixing of concrete will delay setting slightly and this is one extra advantage of having a mechanical mixer.

To prolong the life of concrete mixers it is important that they are thoroughly cleaned after each use. Although most mixers have been designed to minimise concrete getting into the motors, bearings and drive shaft, they are not protected against continual misuse, which may break the mixer after only a few weeks and result in a large repair bill.

### **Moulds and Moulding Machines**

Before considering the different types of moulds and moulding machines used to shape concrete products it is worthwhile to mention the different states in which concrete is used because the type of moulding technique to use will depend strongly on the state in which the concrete is in.

#### **(i) Dry Mix**

In this state the concrete cannot be said to be workable in the conventional sense. In the hand it will barely feel moist. It contains very little water above the quantity required for the cement hydration reaction to proceed. This type of concrete could not be used by the small producer who would not have the equipment to mould it. It is usually moulded in presses exerting very high pressures and cured in a high humidity chamber or heated steam chest. Because of the low water content in the mix, the cured concrete can have very high strength.

#### **(ii) Semi-dry Mix**

A semi-dry mix is not easily workable and will just feel moist rather than wet in the hand. Normally the concrete would have zero to 40mm slump. With semi-dry concrete, consolidation by vibration may not be effective and pressure, or a period of continuous tamping may be preferable. This is the best type of mix to use for products with simple shapes, such as blocks or slabs, which are cast manually into moulds rather than by machine. Normally the moulds are filled in several layers and after each layer the concrete in the mould is pressed down with repeated application of a tamping tool, such as a thick metal plate, about half the size of a hand (about 7 x 5 cm), welded onto a metal handle.

When making blocks with a semi-dry mix the mould can be stripped from the block immediately after casting. The cast block will be strong enough to remain standing without slumping and can

then be left to cure before handling. Since the mould can then be used to make another block, there will be a saving in investment cost because fewer moulds will need to be bought.

### (iii) Wet Mix

This type of mix will feel wet in the hand, will leave a cement stain on the palm and will have an appreciable slump. The slump can be tested in a slump cone by measuring how much a cone of concrete slumps when the cone mould is pulled away.

Some national standards for concrete specify the size of the slump cone to use for test, and the producer should invest in this equipment, if possible. *If a slump test cone cannot be obtained an old bucket with the bottom cut out could be used as an alternative.* The procedure for carrying out the test is as follows:-

1. Put concrete into the slump cone mould in three layers, tamping after each layer.
2. Carefully remove the cone to leave the cast concrete standing in the shape of the mould or slumped to varying degrees.
3. Put the mould against the concrete cone and measure the slump (the distance by which the concrete cone has shortened).

If the cone slumps to about one third of its height, or less, the concrete may be too wet to use for most concrete products because it will be too weak when set, unless it was made deliberately with a high slump by the use of plasticizers and superplasticizers.

With wet-mix concrete, vibration is more effective than pressure to achieve good consolidation. With concrete blocks, wet-mix concrete can still be used to deposit the blocks immediately after casting, provided the slump test does not give a value of more than about 10 per cent slump. Because the blocks are much squatter than the slump cone they are unlikely to slump on standing.

### Hand-Moulding

This is the simplest method of making concrete products. Moulds can be of steel, wood or plastic. Concrete will stick to wood and steel so it is advisable to apply special mould oil or, if this is not available, old engine oil to the inside of the mould to facilitate demoulding, although the used engine oil may give staining. The moulds need to be made in sections to facilitate demoulding. These sections can be held together with removable pins, bolts or light nails in the case of wood.

More elaborate moulds have also been developed for concrete blocks to allow the mould to be dismantled and removed from the block immediately after casting to leave the newly-cast block standing on the ground.

Usually the mould is filled in several layers with each layer being tamped thoroughly. This ensures that the concrete penetrates corners in the mould and that some of the air in the mix is expelled.

Wooden moulds would be good for up to 50 castings, plastic moulds probably for about a few hundred, while good quality steel moulds if well cared for can be re-used several thousand times.

With a simple low-cost machine for producing blocks, concrete is poured into a mould and tamped down. Then a hinged top plate is brought down on top of the block to press it down. After this, the plate is swung back and a lever is used to either eject the block on a wooden bottom plate on which it is left to cure, or the block is ejected still in the mould and the mould is then tipped over and the block ejected on the ground.

With this type of machine, blocks of slightly better quality can be produced compared with purely manual moulding, and working with such a machine is more convenient. A realistic upper limit to the number of blocks which could be produced with such a machine is about 50 per hour.

### Egg-laying Machine

This type of machine is generally used to produce concrete bricks and blocks. The Egg-laying machine is so-called because it is mobile, depositing the blocks as it casts them then moving



forward to cast the next set. The blocks are consolidated in the moulds by vibration and with some machines a head also applies static pressure before the block is ejected. This latter type of machine has the advantage that a drier mix can be used, which responds to pressure as well as vibration.

Small machines are driven by one person standing behind them. Some types are fitted with a control device to ensure that the machine moves on the appropriate distance after each drop. The moulds used are normally gang moulds holding up to 10 individual compartments. Production rates vary from about 60 to about 500 blocks per hour depending on size of block and size of machine.

Most types of egg-laying machines are made in Europe or in North America. The cost of the smallest new machines on the market would be between US\$10,000 and US\$50,000 depending on capacity.

### **Static Machines**

Most static machines can make a range of different products just by changing the moulds. However machines have also been designed to make only one product, concrete pipes for example. They are often larger than egg-laying machines and, because of their high production rate, the production yard may need to be mechanised, relying on an overhead hopper to feed concrete to the machine and a conveyor belt to take cast products away from it.

The machine vibrates the concrete as it moulds it and sometimes compacts it by pressure as well. Machines are usually driven by a three phase electricity power supply, although there may also be an option with the smaller machines to drive them with a petrol or diesel engine.

Concrete products are normally cast on plastic or wooden pallets, and these pallets can be taken away and stacked, so space requirements for a static machine can be considerably less than with an egg-laying machine.

Prices of static machines start at around US\$20,000. Production rates are 100 products per hour, upwards.

### **Vibration Units**

Vibration of wet mix concrete is very beneficial. It ensures that the concrete completely fills the mould in which it is put and helps to remove air bubbles from the mix. The result is a stronger, denser, more durable and more dimensionally accurate product. There is an optimal vibration time for each type of product, which is usually around 20 seconds. Excessive vibration will lead to segregation of the cement and aggregate and the development of weak areas in the product.

Vibration units are usually cheaper than egg-laying machines or static machines and ideally suited to labour-intensive production in a small yard.

Three types of vibration unit are used in concrete work. They are the poker vibrator, the clamp-on vibrator and the vibrating table.

Poker vibrators are placed inside the concrete. They are little used for concrete products except for very large precast sections.

Clamp-on vibrators are attached to the side of the mould and are suitable for use on a variety of different mould designs.

A vibrating table is essentially a flat metal table standing on legs. The table itself is isolated from the legs by dampers which prevent the vibration of the table being transmitted through the legs and into the ground. These dampers can be stiff springs, rubber studs or of some other elastomeric material. An eccentrically weighted camshaft is attached below the table and turned by an electric, petrol or diesel motor using a belt. Alternatively a commercially available vibrator unit

incorporating an eccentric rotor can be attached to the table, avoiding the need for a belt. The frequency of the vibration can be changed by running the motor faster or slower, and the amplitude, or size, of the vibration can be altered by increasing the eccentricity of the weights below the table. Products of different size and weight will have different optimum amplitudes and frequencies of vibration, although in practice a wide range of frequencies and amplitudes will give satisfactory vibration performance. In the 1990s Practical Action helped to develop a vibrating table in Kenya which includes a small lever type press for pressing down on concrete blocks as they are vibrated - because blocks are usually made with somewhat drier mixes than other products and such a mix consolidates under pressure as well as vibration.

Vibrating tables offer the benefits of allowing a wide range of products to be vibrated and, additionally, they are cheaper than conventional concrete products machines (the F.O.B. price of a table starts at about US\$3,000), and, where suitable workshop facilities exist, they are not too difficult to fabricate locally. Their main drawback is that production rates are low. A person needs to mind the concrete mould while it is being vibrated to avoid it falling off the table, so effectively only one product can be vibrated at any one time. *Alternatively, if the moulds are clamped onto the table while they are being vibrated, extra time is needed to fasten and unfasten the clamps.*

### The Concrete Blockmaking Yard

Before considering layout of a concrete products yard it is important to note that the location of the production site is very important. It should be located close to mains electricity and also close to a water supply. The position in relation to transport of raw materials and finished products should also be looked at and, in addition, if sales are carried out from the yard, this should be located reasonably conveniently for customers, such as close to a main road.

Concrete products should ideally be made on a level concrete surface, although in drier areas concrete products could be left on compacted ground. In wet areas, or in areas subject to seasonal heavy rains, the casting surface should be set on a gentle slope, at least 1 in 100, to facilitate drainage of the site.

Additionally a small one-room office and a shed to store the cement would also be required. The yard should be close to a mains water supply for washing tools, hands and so on. The aggregate should be stored in bunkers and separated into different size fractions. The sand should ideally be kept under cover because when it rains the sand will tend to absorb a lot of water and increase in bulk.

A small yard running a mechanical mixer and either an egg-laying machine or a vibrating table could be run by three people. The operation would run much more smoothly and productivity would be higher if each person was not tied to a specific job and was prepared to work in a flexible manner. The main operations required at the site would be :-

- (i) Buying and, possibly, delivering cement and aggregate for the site.
- (ii) Transporting cement and aggregate around the site.
- (iii) Mixing concrete.
- (iv) Loading the hopper of the egg-laying machine, or filling moulds with concrete.
- (v) Operating the egg-laying machine or vibrating table.
- (vi) Demoulding.
- (vii) Stacking the products once they have hardened sufficiently.
- (viii) Inspecting the products while curing and watering if necessary.
- (ix) Quality control and testing.
- (x) Stock control.
- (xi) Maintaining production records.
- (xii) Maintaining financial records.
- (xiii) Selling and, possibly, delivering the products.
- (xiv) Cleaning of tools and equipment.
- (xv) Security.

A minimum size for the concrete products yard is 100 m<sup>2</sup>, or at the very minimum 90 m<sup>2</sup>, even for

very small scale operation. Somewhat larger operations with a number of different types of products can require operating areas several times this. If space is restricted consider putting up sturdy shelving to store finished products. This can also help to display the products to the customers.

Cement needs to be stored in a dry storage shed as any exposure to water will cause it to start to set and harden. More limited protection to wetting of the cement can be provided if the cement bags are stored under a simple open roofed structure with the bags wrapped securely in plastic or tarpaulin sheeting.

The sand also needs to be protected from heavy or prolonged rain. This is because most types of sand readily absorb water and bulk up and increase in weight when they are wetted. It can then become difficult to add sand in the right proportions to the mix, thus affecting the properties of the concrete from which it is made. If rain is expected it is best to cover the sand securely with plastic or tarpaulin sheeting.

Normal working clothes are recommended for the people working at the production site. These clothes are bound to get covered in concrete. In addition, because of the risk of dropping heavy moulds or concrete products when carrying them, stout shoes are recommended. Concrete is not normally harmful to skin, but care should be taken that none get into the eyes. If this happens, the affected eye should be washed out with plenty of clean water. Hands should always be washed thoroughly after working with concrete before eating or drinking.

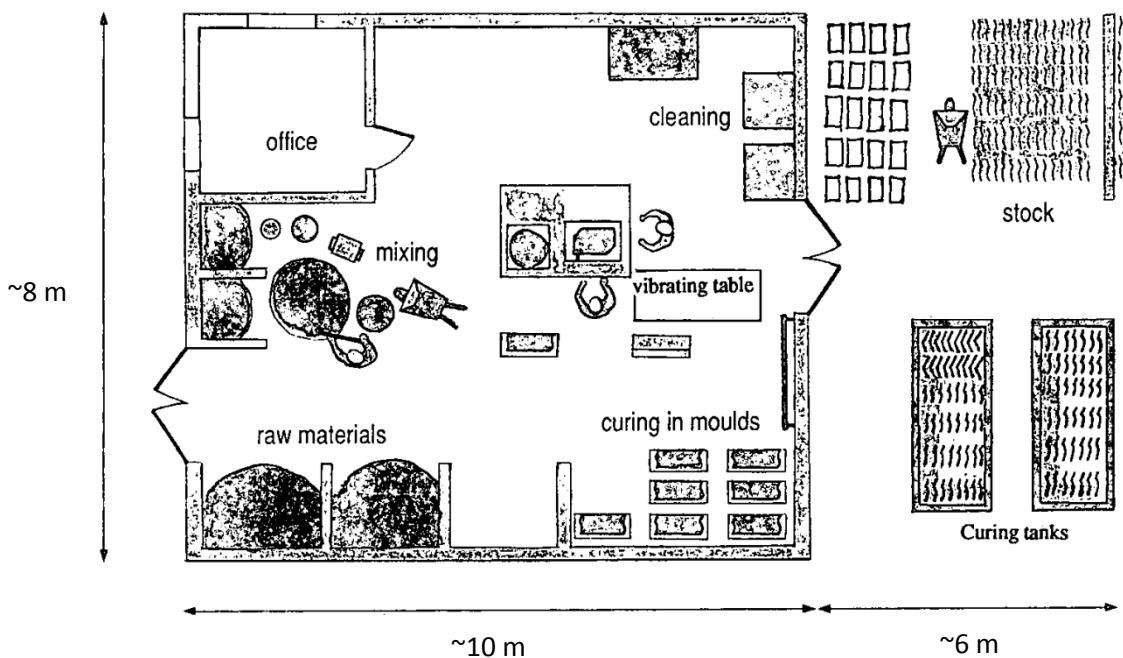


Figure 4: Layout of Small Concrete Products Workshop and Yard Utilising Vibrating Table (page 6). Illustration from *Vibrated Concrete Products Production Manual* (Draft), by Amon Ng'ang'a, Building Materials and Shelter Programme of IT Kenya, October 1994.

## Quality Control and Testing

### The Importance of Quality Control

Good quality control is very important, even at a small yard, to minimise the use of cement, which is an expensive commodity, and to ensure that most of the production run is usable. In addition, a good quality consistent product is likely to be a major factor in ensuring the long-term survival of the yard and customers will be very much attracted to buying the products.

The quality of some types of concrete products, blocks and bricks for example, is likely to be governed by national or international standards. Other products, such as fencing posts, are unlikely to have any standards for them, in which case the producer may need to experiment with different concrete mixes to achieve a product which is not costly to make but which satisfies market demand.

There are two aspects of good quality control - good production practices and regular testing of the materials and products. Good production practices can be achieved with training and experience and by maintaining a commitment to good quality production. Some aspects of good production practice have already been mentioned in this text including the need to keep tools and equipment clean and well maintained, not keeping mixed already concrete so long that it starts to set before use, adequate curing of the products and maintaining good production records.

Batching by weight, as already mentioned, is also much better for maintaining quality than batching by volume. However, the small producer may find it easier to initially batch out by volume using separate batching boxes for cement and aggregate. The boxes may then be taken to the scales for weighing and adjustments made by adding or taking material away to ensure that the proportions of cement, fine and coarse aggregate correspond to the mix proportions determined to be used for the mix.

### Quality Control Tests

The best way to test if concrete is sound is to perform compressive strength tests on hardened cubes or cylinders of the concrete, usually at 7 and 28 days, but also optionally after 3 and 90 days after mixing. To perform the tests samples are taken from the concrete batch to fill several cube or cylinder moulds. These are cured for the specified period under closely controlled conditions before testing in a special compression machine.

It is unlikely that a small-scale producer would want to spend a lot of money to produce the concrete samples and then to get them tested independently, although evidence from such tests can be very useful in case of disputes with customers over product quality. Instead, two simple qualitative tests can be used which would at least give an indication of a bad quality product.

In the ring test the product is lifted off the ground and struck with a coin or other small metal object. A high sharp sound indicates satisfactory performance, while a dull lower-pitched noise indicates that there could be a problem. A large product should be struck in several places in case there are any areas of weakness in it. In the scratch test attempts are made to scratch the product with a coin or similar metal object. If noticeable grooves are left in the product then it is probably not of satisfactory quality.

Weighing a number of the same type of product is also a useful check for consistency. If the weight varies by more than about 5% of the expected weight then that could indicate a problem with production procedures or the raw materials used.

In some countries or districts building standards or local regulations give specifications for sizes of some types of products. These apply particularly to bricks and blocks because these would tie in with standard sizes for door and window openings. If possible, the standards on sizes should be consulted or, at least, measurements made of products already available for sale and used for building. When buying an imported machine it is important to ensure that it can fit a mould of the standard size in the locality.

If no local sizes are available for guidance, fairly standard sizes are 40 x 20 x 20 centimetres for hollow or solid blocks and 20 x 10 x 10 centimetres for bricks.

The length, width and height of products need to be measured periodically with a ruler or measuring tape to check that they conform to the specifications. With repeated use moulds can become deformed or misshapen and change in the dimensions of the products can indicate that this is happening. Moulds which have changed significantly in dimensions should no longer be

used.

### **Maintaining Records**

Maintaining reliable records of production, income and expenditure and stock is very important, even for a very small producer of concrete products. Good records will assist in :-

- (i) Ensuring that production is not held up because the raw materials have been used up.
- (ii) Assessing accurately how many items are sub-standard and need to be thrown away.
- (iii) Assessing the productivity of the workshop.
- (iv) Assessing the profitability of the workshop.
- (v) Aiding the making of decisions on improvements in the production schedule.
- (vi) Aiding the making of decisions on new product lines and products to be no longer made.
- (vii) Discovering any theft and pilfering which might exist.
- (viii) Providing reliable information to a lending agency on the probability of fully repaying a loan, if a loan was used to start up the workshop.
- (ix) Ensuring that supply of products can meet customers' demands or, if the demands are unexpected, the customer can be accurately told of when delivery of the products can be expected.
- (x) Identifying production problems.
- (xi) Generally give an impression of professionalism to customers and employees.

Daily logs of production and income and expenditure should be kept. However, the records should be filled in after each batch of concrete has been used up, or each sale made, or each purchasing trip, rather than at the end of the day because this will help to avoid mistakes. It would also be useful, at the end of the day's production, to take stock of how much cement, aggregate and mould oil is left for the next day's production, and also how many moulds are available. The records should also not just be kept for the sake of it, but be analyzed every few weeks to identify particular trends, such as an increase or a decrease in demand for a particular product.

Payment for sales may be made by the purchaser on the spot or, regular and reliable customers may be sent an invoice which they can settle periodically. If invoices are sent, most payers would want to pay by cheque or electronic transfer, in which case the workshop would need to have its own bank account. It is also recommended that separate record books are maintained, in addition the daily records on income and expenditure, of bills paid, for example for cement, aggregate, rent of site, electricity, water and repair or order of equipment, and of payments received or invoiced for the sale of the products. These can be referred to in case of query. It shows a professional approach if any purchaser of products is given a bill, containing the price and company letterhead or logo and the type and number of products bought. The purchaser retains one copy of the bill and the workshop retains another copy. These copies can be referred to in case of any future queries.

Examples of records on stock control, income and expenditure and production are given below, however, a particular workshop might wish to make use of somewhat different formats for their records if this suits their style of operation.

STOCK LOG									
To be completed at beginning and end of shift									
Date:					Shift No:				
Materials									
Material	Start of Shift			End of Shift			Comment		
Sand Bins	e.g. almost empty			half full			1 tonne of sand delivered		
Gravel Bins									
Cement	5.2 bags			2.5 bags					
Other (e.g. mould oil)									
Moulds									
	Start of Shift			End of Shift					
	In use	Available		In use	Available		Wasted		
Product 1									
Product 2									
Product 3									
etc.									
Products									
	Start of Shift			End of Shift					
	Curing	Availab le	Total	Sold	Wasted	Made	Curing	Availab le	Total
Product 1									
etc.									

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PRODUCTION LOG				
To be completed at end of shift				
Date:			Shift No:	
Materials Used				
			Comment	
Sand	10 buckets (or give the weight used if scales available)		Sand wet after recent heavy rain	
Gravel				
Cement				
Products				
	Cement: sand: gravel ratio	No. of satisfactory products made	No. of products wasted	Comments
Product 1				
Product 2				
Product 3				
etc.				

INCOME AND SPENDING			
To be completed at the end of each day			
Date:			
Income			
Received from	Reference *	Amount	Comments
Customer A			
Customer B			
Customer C			
etc.			
Other Income			
Total Income Received			
Spending			
Cement			
Sand			
Gravel			
Other materials			
Wages			

Taxes and rates			
Loan repayment and interest			
Transport			
Other costs			
Total spent			
Income minus spending			
Amount banked			
Amount in stock			

\* Reference should be made to the bill or invoice, e.g. printed on a book of sheets of invoices, held separately.

A cumulative total of daily surplus and loss should also be maintained to assist in preparing the end of year financial records.

Note: some quantities appear in more than one table. This is for completeness and to facilitate cross checking.

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 Cement & Concrete Institute  
 Block 'D' Lone Creek  
 Waterfall Office Park  
 Bekker Road  
 Midrand  
 PO Box 168  
 Halfway House  
 1685  
 South Africa  
 Tel: 011 315 0300  
 Fax: 011 315 0584 / 315 8180  
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Vadianstrasse 42  
CH-9000 St.Gallen  
Switzerland  
Tel: +41 71 228 54 54  
Fax: +41 71 228 54 55  
E-mail: [info@skat.ch](mailto:info@skat.ch)
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New Delhi - 110016, India  
Tel: +91 (11) 2696-7938, 2656-5370, 2685-1158  
Fax: +91 (11) 2686-6031  
E-mail: [dainet@devalt.org](mailto:dainet@devalt.org)  
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c/o Mining Media International  
8751 E. Hampden Ave B1  
Denver, CO 80231  
United States of America  
Web: <http://www.concreteproducts.com/>.

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### Glossary of Selected Terms Related to Concrete Products

- *Abrams Law* - This states that with an increase in water to cement ratio there is a proportional decrease in compressive strength. It forms the basis of most methods of concrete mix design.
- *Accelerated Curing* - Any method of curing concrete at elevated temperatures to accelerate the curing process.
- *Admixture* - A material (not water) added to concrete to modify its properties, for example to make it more workable, to make it set faster or slower, or to introduce air bubbles into it.
- *Aggregate* - The inert non-cementitious component of concrete which usually makes up the bulk of the concrete. Usually the aggregate consists of a mixture of sand and gravel.
- *Autoclave* - A high pressure steam vessel, usually of stainless steel, to achieve rapid curing of concrete.
- *Block* - A rectangular building element, usually used for wall construction, several times larger in volume than a brick.
- *Cast-in-situ* - A process of building with concrete whereby the concrete is poured and consolidated in formwork and, after curing and removal of formwork, forms part of the building fabric.
- *Compressive Strength* - Concrete is a strong material when it is loaded from above and supported from below, i.e. under compression or pressure. The compressive strength is the ultimate load the concrete can carry in compression divided by the area of the concrete

section. Compressive strength forms the basis of quality control of concrete and the design of concrete structures. If concrete is loaded in any other way (such as tension, flexure, torsion or shear) it can carry much less load and reinforcement may be required.

- *Curing* - The gain in strength of concrete after the cement has set due to the continuing chemical reaction between the cement and water. Under normal curing conditions, concrete will have gained less than half its ultimate strength after a week and more than 90% of its ultimate strength after 90 days.
- *Drum Mixer* - A type of concrete mixer with an inclined drum and, usually no paddles. Concrete is often removed from the mouth of the drum with shovels. Mixing is less effective than with a pan mixer.
- *Dry Mix* - Concrete with only a small amount of water added. The concrete will barely feel moist and will not flow at all. It needs to be rammed into moulds at high pressure.
- *Egglaying Machine* - A type of concrete blockmaking machine which will mould blocks from freshly-mixed concrete and then eject them on the ground. The machine can then be moved on a short distance to deposit another set of blocks.
- *Ferrocement* - A type of reinforced concrete usually incorporating a thin, relatively low cost dense steel reinforcing mesh, such as chicken wire or fencing wire. The reinforcement improves impact resistance, tensile and flexural strength, and enables thin sections of concrete to be made.
- *Flexure* - Another word for bending. This typically occurs when a beam is loaded by an imposed weight along its length. Concrete is weak in flexure and reinforcement often needs to be provided when significant flexural loads are expected.
- *F.O.B.* - Free on Board, i.e. the purchase price includes the cost of packaging, insurance and transport to a port in the suppliers' country. The purchaser is responsible for all subsequent transport costs.
- *Form* - Solid material made to the shape of the intended concrete product or section. Concrete is poured into the form and takes its shape. A form is used for cast-in-situ concrete, whereas moulds are used for the same purpose in precasting.
- *Hydration* - The chemical reaction of Ordinary Portland cement and some other types of cement with water. Concrete sets, hardens and gains strength due to hydration of cement.
- *Lean Mix* - Concrete which contains a relatively small amount of cement. It will be an economical mix, but the compressive strength of the concrete will be relatively low.
- *Micro-concrete (mc)* - Concrete, usually quite a rich mix, made with just sand and cement and without stones, gravel or coarse aggregate. This mix is usually used for roofing and other types of tiles that have a thin profile.
- *Moisture Movement* - Concrete will expand and contract on wetting and drying. This process is known as moisture movement. In long building sections, movement joints need to be provided to allow for moisture movement and avoid cracking.
- *Mould* - See *Form*.
- *OPC* - Ordinary Portland Cement. A type of cement commonly used for concrete throughout the world. International standards and often, also, national standards govern its properties such as compressive strength, fineness, chemical composition, setting and hardening times and other properties.
- *Pan Mixer* - A type of mixer containing a flat rotating pan and in which various paddles and scrapers are inserted to facilitate mixing of concrete. After mixing the pan can be tilted up for removal of concrete.
- *P.f.a.* - Pulverised fuel ash - a very fine ash obtained from the chimneys of coal burning power stations. It usually has a high silica content and significant pozzolanic activity. It may partially replace a proportion of cement in a mix.
- *Poker Vibrator* - A rod incorporating a vibrating unit. It is inserted into a concrete mix to vibrate it and is usually used for large-scale sections.
- *Pozzolana* - A material, rich in silicon and aluminium oxide, which can react with lime to produce a hydraulic cementitious material. When mixed with OPC it reacts with the by-product lime produced during cement hydration and can, therefore, replace a proportion of OPC.
- *Precasting* - The process of producing concrete products separate from actual construction activities. After the products are sufficiently cured, they can be transported to the location

where they are needed for building.

- *Pre-stressed Concrete* - A method of construction often used for beams heavily loaded in tension or flexure. The steel reinforcement rods in the beam are first stretched and the concrete then cast around them. When the concrete has hardened the tension is released so that, in effect, the concrete is permanently under compression in the beam. Care needs to be taken when demolishing buildings containing pre-stressed elements.
- *Reinforcement* - Concrete is weak in tension and flexure and to resist these types of forces reinforcement often needs to be provided. The reinforcement is often steel, which is strong in tension and flexure, although other materials such as a plastic mesh and fibres such as sisal or glass have also been used in certain applications.
- *Rich Mix* - A concrete mix which contains a high proportion of cement. This mix will be costly but it will also have high strength. Rich mixes are generally used for thin sections, such as tiles, and hard-wearing surfaces, such as floors.
- *Semi-dry Mix* - A concrete mix which contains a relatively small amount of water but, nevertheless, sufficient to allow it to be moulded without application of a very high amount of pressure. Concrete blocks, made with a semi-dry mix, can be demoulded immediately after forming and will be freestanding without slumping.
- *Slump* - When a wet concrete shape is taken from its mould immediately after casting it will usually collapse, or slump, partially or wholly. The extent by which it slumps is a measure of the wetness of the mix and can be used as a quality control test.
- *Staining* - another term for adding pigments or colouring agents to concrete to give coloured concrete products.
- *Static Moulding Machine* - This type of machine is not mobile, unlike the egg-laying machine. Concrete products are usually deposited by the machine on pallets which are then taken away for curing.
- *Tamper* - A heavy tool with a flat base used to consolidate concrete in the mould by lifting, dropping and pressure. It is often applied manually in small-scale production.
- *Vibrating Table* - A flat metal surface suspended on dampers which has a vibration unit attached to it. Moulds with concrete are put on the table to vibrate them and consolidate the concrete.
- *Vibration* - A wet concrete mix will contain many small air bubbles which will lead to low strength and inconsistent quality of concrete products. Vibrating the concrete will remove some of the air bubbles and give a stronger and more durable concrete when hardened. Excessive vibration, however, is not advised because it will lead to separation out of the cement, water and aggregate fractions.
- *Volume Batching* - This is the process of measuring out quantities of materials by volume. Batching boxes may be used to provide the required volumes of cement, sand and coarse aggregate. Volume batching is not recommended for the concrete products yard. Weight batching is more accurate and gives more consistent products with less wastage of materials. Volume batching may be acceptable for on-site mixing in small construction jobs.
- *Water to Cement Ratio* - This is the weight ratio of water to cement used in a concrete mix. It is related to the compressive strength of concrete by Abrams law and is an important factor in concrete mix design.
- *Weight Batching* - This is the process of batching out raw materials for concrete production by weight. It is considered to be more accurate than volume batching, but is often impractical at a small building site.
- *Wet Mix* - A concrete mix with substantial water added to make it easy to mould and to fill out corners and edges of moulds. Increasing the water content will make a mix more workable but reduce the compressive strength of the concrete, so a compromise often needs to be chosen. The wetter the mix the higher the slump value given by the slump test, and this test is effective in gauging the wetness of a mix.
- *Workability* - Workability is a measure of how easy or difficult it is to make a concrete mix flow and take up the shape of a mould. The higher the water to cement ratio for a given mix, the higher the workability would be but the lower the compressive strength of the hardened concrete.



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Practical Action  
The Schumacher Centre  
Bourton-on-Dunsmore  
Warwickshire,  
CV23 9QZ  
United Kingdom  
Tel: +44 (0)1926 634400  
Fax: +44 (0)1926 634401  
E-mail: [inforserv@practicalaction.org.uk](mailto:inforserv@practicalaction.org.uk)  
Website: <http://practicalaction.org/practicalanswers/>

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# technical brief