How to make concrete bricks & blocks

1. Introduction

The small-scale manufacture of concrete bricks and blocks for masonry is well suited to small businesses. Production can be carried out in the open, the process is simple and equipment does not require high capital investment.

The aim of this publication is to provide the information needed to set up and run a blockyard to manufacture concrete bricks and blocks on a small scale. The publication is intended mainly for development agencies, local authorities, builders' associations, housing consultants, trainers, etc, but could be of use to entrepreneurs and blockyard managers.

Aspects dealt with include the feasibility study, selecting and establishing a site, selection of equipment, materials for blockmaking, trial mixes and production.

This publication focuses on technical information. Topics outside the scope of this leaflet are:

- Detailed cost analysis
- Manufacture of paving blocks

Bricks and blocks are masonry units and are referred to as such in SABS standards. Units may be solid or hollow. The difference between bricks and blocks is one of size. In this pamphlet "block" is used throughout, but the same principles apply to brick.

2. Feasibility study

It is easy to make a concrete block. The successful blockyard must however make blocks of uniform quality and sell them at a price high enough to cover costs and make a reasonable profit.

Before you start a blockyard, it is essential therefore to investigate the economic feasibility of the venture.

Determine first what demand there is for blocks in your area (how many per month) and find out if there would be competition from other blockyards.

Then estimate costs based on various methods of production and output.

Factors which influence unit cost include:

- Purchase price or rental of site
- Cost of site improvements: fencing, paved areas for production and stockpiles, pathways, roadways and buildings
- Cost of equipment: concrete mixer, blockmaking machine, miscellaneous equipment, eg wheelbarrows and trolleys, and tools.
- Cost of services: water and electricity
- Material costs (See section 7.2 for mix ratios. As a first estimate, assume that 1-m^3 of loose aggregate will yield 0,7-m^3 of concrete volume.)
- Wastage
- Maintenance costs of site and equipment
- Output: number of blocks per day – dimensions of block, solid or hollow.
- Labour costs
- Cost of finance

A list of possible sources of information and assistance is available from the C&CI.

3. Selecting a site

In selecting a site, consider location, access, ground slope and size. Each of these is discussed below.

3.1 Location

This should be considered in relation to:

- Supply of raw materials
- Market for blocks
- Location of the labour force
- Security of the area
- Availability of services, i.e. roads, water, sewerage, electricity, etc.

3.2 Access

The site must be accessible to trucks delivering aggregates and cement and collecting finished blocks.

3.3 Ground slope

Ideally, the site should be level or nearly so. Steep slopes make handling and production difficult. Terracing a steep slope is expensive.

3.4 Size

The site should be big enough for aggregate stockpiles, cement storage, production (slab or stationary machine) block stacking, staff facilities, an office and on-site access.

4. Establishing the site

The site should have provision for stockpiling aggregates and storing cement, a production area, a stacking area, staff facilities, an office, and access between different areas and facilities. Each of these is discussed below.

4.1 Aggregate stockpiles

Aggregates must be stockpiled in such a way that: they do not become contaminated by soil, leaves, etc; different aggregates are kept separate; and rainwater can drain away.

Ideally therefore, aggregates should be stockpiled on a concrete slab. If this is not done, the layer of aggregates in contact with the soil should not be used for production. Aggregates must not be stockpiled under trees. Partitions should be erected between different types of aggregate. Stockpiles should be on a slight slope so that rainwater does not collect in the aggregates.

4.2 Cement store

The best way to store cement is in a silo. For most small-scale blockyards however, cement will be delivered in bags.

Cement in bags should preferably be stored in a weather-proof room. Bags should be stacked on a plastic tarpaulin or on closely spaced wooden strips so that they do not absorb damp from the floor. The storeroom should be big enough to hold at least a week's supply of cement.

If it is not possible to provide a storeroom, cement in bags should be stored in stacks raised above the ground and completely covered with tarpaulins.

4.3 Production area

The size of this area depends on the method of producing blocks.

A stationary machine, which forms blocks on pallets, needs a relatively small area with space around it for operators.

A mobile "egg-laying" machine needs a fairly large slab on which blocks are made. Details of such a slab are discussed below.

Construction of a production slab

Area

A flat concrete slab, big enough for at least one day's production, is required. To minimise breakages in cold weather, increase the cement content of the mix or the curing period before moving blocks.

As a guideline, a slab 50-m^2 in area is suitable for a production of 1-000 bricks or 200 blocks.

Slope

Normally block production is carried out in the open, and the concrete slab should have a minimum slope of 1 in 100 to ensure proper drainage.

Thickness

The minimum thickness of the slab is normally 125-mm. However, in the case of temporary works or works using a small hand machine, a thickness of 100-mm could be considered. Large production machines may require a minimum slab thickness of 150-mm.

Concrete

If you mix the concrete yourself, the proportions shown in Table 1 should be used.

Size of stone mm	Proportions by volume*			Quantities per cubic metre of concrete		
	Cement	Sand	Stone	Cement ** bags	Sand m^3	Stone m^3
19,0 or 26,5	1	2	2	8,7	0,7	0,7
	1 bag	75 ℓ	75 ℓ			
13,2	1	2	1⅓	10	0,8	0,8
	1 bag	75 ℓ	55 ℓ			

* Loose, uncompacted state except for cement in bags
** Complying with SANS 50197-1 (see 6.1)

Table 1: Concrete mix proportions for production slab

The amount of water is not given in the table because it depends on the materials used. Use enough water to make a workable mix that can be properly compacted.

For concrete ordered from a ready-mix supplier or contractor, specify a strength of 30 MPa at 28 days and 19 mm stone. Slump should be 75-mm if the concrete is to be compacted by mechanical vibration and 125-mm for hand compaction. A woodfloated finish permits easier removal of blocks.

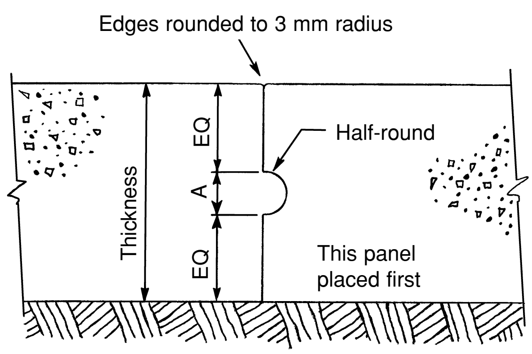
Joints

To prevent uncontrolled cracking of the slab, it should be divided into panels which should be square or as close to square as possible. A construction joint is shown in Figure 1. The halfround keyway prevents differential settlement of adjacent slabs.

The maximum joint spacing depends on the thickness of the slab and should not exceed 3,0, 3,75, 4,5- and 6 m for slab thicknesses of 100, 125, 150- and 200 mm respectively.

It is not necessary to reinforce the panels with steel rods or mesh.

Figure 1: Construction joint



Thickness of slab, mm	Dimension A, mm
100	20
125	25
150	30
200	40

4.4 Stacking area

An area big enough to stack two weeks' production is needed for curing (see section 8.5) and drying (see section 9.3) blocks.

It is normally not necessary to pave this area. To avoid muddy conditions, a layer of concrete stone, about 100-mm thick, should be enough.

4.5 Staff facilities

These include toilets, ablutions, and possibly change rooms.

Facilities should meet minimum requirements of local authorities if applicable.

4.6 Office

An office should be provided for all but the smallest of yards.

4.7 On-site access

Pathways and roadways between the different parts of the yard should be wide enough for barrows, trolleys or trucks and may have to be paved or covered with aggregate to make them usable in wet weather. Paving would in any case be necessary where trolleys are to be used to move blocks.

5. Equipment

Blockyard equipment consists essentially of a means of moulding blocks, a concrete mixer, and various general-purpose tools and equipment. These are discussed below.

5.1 Blockmaking equipment

There are two basic types of equipment, depending on the method of moulding the blocks:

- Stationary machines that mould blocks, one or more at a time, on pallets.
- "Egg-layer" machines that mould blocks on a concrete slab.

Some advantages and disadvantages of stationary and egg-layer machines are given in Table 2.

For both types, equipment available includes small hand-operated devices, which have limited output, and a range of electrically powered machines of high output. The machines listed in Table 3 represent a small selection of the models currently on sale.

Detailed information on the output and price of specific machines should be obtained from manufacturers and suppliers. A list of suppliers is available from C&CI.

5.2 Concrete mixer

It is possible to make blocks on a small scale without a concrete mixer. Hand mixing has the advantage of reducing the amount of capital required and providing employment, but may limit output and not always be thorough.

Hand mixing should be done with shovels on a concrete slab or flat steel sheet. Never mix directly on the ground because this results in contamination of the mix.

A pan mixer is the only type of machine mixer suitable for blockyards. Pan mixers, with a forced mixing action, can cope with the semi-dry mixes used for making blocks. Drum mixers do not work because they cannot mix the semi-dry concrete.

The output of the mixer should match that of the block-making machine. A mixer of adequate capacity for making hollow units may have insufficient capacity for solid units.

5.3 Miscellaneous equipment

This includes wheelbarrows, batching containers, trolleys (for moving blocks), shovels, hosepipes and plastic sheeting.

6. Materials for blockmaking

6.1 Cement

Cement should comply with SANS 50197-1. Strength class should be 42,5N or higher because the concrete must develop strength as rapidly as possible. Note that it is illegal to sell cement which does not bear the SABS mark.

6.2 Aggregates

Sand and stone are used for most block production.

> Clinker or hard-burnt ash often contains harmful impurities and should not be used as aggregate unless it is found to be acceptable by laboratory test. Good quality clinker can be used instead of sand or stone but blending with sand or stone may be necessary.

Sand and stone are fragments of rock and differ only in size. Sand particles will pass through a sieve with 4,75 mm square openings. Stone particles will not.

All aggregates should be clean and not contain organic matter such as roots or humus. If the aggregates contain clay it should be in a very small fraction.

The following aggregates may be considered:

- Fine sand with particles mainly smaller than 1-mm: pit, fine river or dune sand
- Coarse sand with the biggest particles approximately 5-mm in size: crusher, pit or coarse river sand
- Stone with a maximum size of 13-mm for bricks or solid blocks or 10-mm for hollow blocks

It is normally possible to make blocks with coarse sand on its own. Alternatively combinations of aggregates may be used:

- A blend of coarse sand and fine sand
- A blend of fine sand and stone
- A blend of fine sand, coarse sand and stone

For small-scale production, the best aggregate or combination of aggregates is normally found by trial and error. Information on a more scientific approach is given in Appendix 1. Assessment of aggregate blends is dealt with in section 7.3.

6.3 Water

Water that is fit for drinking is suitable. Most river and borehole water may be used.

Table 2: Advantages and disadvantages of stationary and egg-layer blockmaking machines

Type of machine	Factors
Stationary	A relatively small space is needed for production. Block machine can be under cover. Pallets are necessary. For most systems, enough pallets for a day's production are needed. Pallets are therefore an expensive item initially. They also involve ongoing expense as damaged (or stolen) pallets have to be replaced. (Some hand operated machines for making bricks need only a few pallets because bricks are removed from the pallet directly after moulding.)
Egg-layer	A fairly large slab is needed for production of blocks. The slab is expensive and increases the size of the site necessary for a blockyard. Pallets are not necessary.

Table 3: Information on a small selection of available blockmaking machines

Equipment	Operation H = hand P = power	Brick or block		** Approx. maximum daily production
		Size, mm	Type	
6-brick hand mould	H	222 x 106 x 73 or 220 x 105 x 75	Brick	1 200
10-brick egg-layer	H		Brick	4 000
15-brick egg-layer	H		Brick	8 000
Vibrating egg-layer*	P		Brick	10 000
Vibrating 8-drop with pallets	P		Brick	10 000
1-block mould	H	390 x 190 x 190	Hollow block	500
1-block mould	H	390 x 190 x 140	Hollow block	500
4-block egg-layer	H	390 x 190 x 190	Hollow block	1 200
5-block egg-layer	H	390 x 190 x 140	Hollow block	2 000
Vibrating egg-layer*	P	390 x 190 x 190	Hollow block	1 600
Vibrating egg-layer*	P	390 x 190 x 140	Hollow block	2 400
Vibrating egg-layer***	P	190 x 90 x 90	Brick	1 000
Vibrating egg-layer***	P	290 x 140 x 90	Solid block	5 000

* Vibration —-petrol, diesel or electric operation
Manual forward movement
Vibrating egg-layers have the added advantage that due to better compaction a leaner mix can be used

** According to machine manufacturer and assuming that mixing output is sufficient

*** These units are modular size and are preferred over the imperial sizes (eg 222 x 106 x 73). Modular size units are in keeping with the National Building Regulations requirements of:
– 140-mm single leaf exterior walls
– 190-mm single or double leaf exterior walls (90-10-90)
– 90-mm interior walls

7. Trial mixes

7.1 Introduction

The aim is to find a mix that will produce blocks that have an acceptable texture and are strong enough but as cheap as possible. Because cement is more expensive than aggregates, the lower the cement content the cheaper the block.

Strength of well cured blocks (see section 9.1) depends on:

- Aggregate:cement ratio
- Degree of compaction
- Size of block, solid or hollow

The degree of compaction depends on:

- Overall grading of the aggregates
- Particle shape of aggregates
- Aggregate:cement ratio
- Water content
- Compactive effort

It can be seen that strength depends on a number of interrelated factors. It is therefore not possible to design a mix in a laboratory. Instead, a trial-and-error process, using the equipment of the blockyard, is followed.

This process aims to arrive at the best combination of aggregates and the right aggregate:cement ratio.

7.2 Starting points

The following starting points are suggested.

Aggregates

First try coarse sand only. Then try replacing some of this by fine sand and some by stone, if these materials are available. Alternatively, if coarse sand is not available, try different blends of fine sand and stone.

(Some trial-and-error can be avoided by starting with the gradings given in Appendix 1.)

Aggregate:cement ratio

Try 6:1, 8:1 and 10:1 by loose volumes (230, 300 and 380-ℓ of aggregate respectively per 50-kg bag of cement).

7.3 Trials

For each combination, make up a batch of concrete with optimum water content (see section 8.2) and, using the yard's blockmaking equipment, mould some blocks.

Because block density is a good indicator of strength, blocks can be assessed by weighing them as soon as they are demoulded. Adjust the mix until the heaviest block is achieved.

The next step in assessment of strength is to look out for breakages to corners and edges of cured blocks. (If blocks break when handled, they are clearly too weak.) Strength can also be assessed by knocking together two blocks, after curing and drying out. A ringing sound indicates good strength while a hollow thud probably means that the blocks are too weak.

Ideally, blocks should be laboratory tested for strength. The National Building Regulations require nominal strengths of 7-MPa for solid units and 3,5-MPa for hollow units for single storey houses and buildings.

Also assess the surface texture of the blocks. If the texture is too smooth, reduce the amount of fine material in the mix; if it is too coarse, increase the amount of fine material.

8. Production

8.1 Ordering and stockpiling materials

Aggregates and cement should be ordered in good time. Stocks should be sufficient to prevent stoppages due to lack of material.

As a rough guide, using an aggregate:cement ratio of 8:1 by loose volumes, three and a half bags of cement and a cubic metre of aggregate will be enough to make about 400 bricks. The number of blocks produced from the same quantity of material will depend on block size and whether they are solid or hollow.

Aggregates must be stockpiled in such a way that contamination is prevented and mixing of different types is not possible (see section 4.1).

Cement must be stored so that it is kept dry (see section 4.2). Cement in bags should be used within one month of being delivered.

8.2 Batching

Cement, if supplied in bags, should preferably be batched by the full bag. Cement supplied in bulk may be weighed (preferable) or batched by loose volume.

It is important to batch all materials accurately. Batching containers, eg wheelbarrows, buckets, drums and wooden boxes, should be loosely filled to the brim and struck off flush with it. To avoid errors, there should be enough containers for a full batch to be made without using any container more than once. Dented or broken containers must not be used.

The amount of water to be added to the mix is judged by eye and by doing some simple tests (see *Water content* below). Time can be saved if, once the approximate quantity of water per batch is known, about 90-% of this is measured out and added to the mix at the start of mixing. The rest of the water can then be judged by eye and by test.

Water content

Water content is critical. The mixture must be wet enough to bind together when compacted, but it should not be so wet that the blocks slump (sag) when the mould is removed. A common mistake is the use of mixes that are too dry, resulting in incomplete compaction. The moisture content should be as high as possible as this allows better compaction and thus gives the best strength. Moisture content is approximately right when ripple marks form on a steel rod or the back of a shovel when it is rubbed against some of the mixture. The water content is just over optimum when ripple marks start appearing on blocks when they are demoulded.

8.3 Mixing

Hand mixing should be done, using shovels, on a level concrete slab or steel plate.

First spread the aggregate out 50 to 100-mm thick. Then distribute the cement, and stone if any, evenly over the sand. Mix aggregate and cement until the colour is uniform. Spread the mixture out, sprinkle water over the surface and mix. Continue with this process until the right amount of water has been mixed in.

For machine mixing, first mix aggregate and cement then add water gradually while mixing until water content is correct.

8.4 Moulding

Hand operated machines should be used as instructed by the manufacturer.

The mould of a powered machine should be filled until approximately six to eight cycles of compaction are required to bring the compacting head to its stops. Too little or poor compaction should be avoided as it results in greatly reduced strengths.

Demoulding or removal of the mould should be done carefully so that the fresh blocks are not damaged. Fresh blocks should be protected from rain with plastic sheets or any suitable covering during the first day and from the drying effects of the sun and wind until curing starts.

In some cases it may be necessary to protect blocks from frost damage. Covering with plastic sheeting with the edges held down is normally sufficient.

8.5 Curing

The day after production, blocks should be removed from the production slab or pallets and stored in the stacking area, ready for curing. Stacks should be carefully built to avoid chipping edges and corners.

Curing is the process of maintaining a satisfactory moisture content and a favourable temperature in the blocks to ensure hydration of the cement and development of optimum strength.

In the South African climate it is normally sufficient to cover blocks with plastic sheeting to prevent moisture loss or to spray blocks with water.

Blocks should be cured for at least seven days.

9. Quality control

Three aspects should be monitored to ensure quality masonry units: strength, dimensions and shrinkage.

9.1 Strength

Quality of blocks should be controlled so that strengths are adequate (to avoid breakages or rejection by customers) and mixes are as economical as possible.

Ideally, blocks should be regularly tested for strength and mixes and production processes modified if necessary.

If testing is impracticable or unaffordable, block strength should be continually assessed by noting whether corners and edges, or even whole blocks, tend to break in handling.

Strength can also be assessed by knocking two mature bricks together (see 7.3).

9.2 Dimensions

The length and width of the units are determined by the mould and will not vary greatly. However, the height can vary and should be monitored using a simple gauge. Units of inconsistent height will lead to difficulties in the construction of masonry and possible rain penetration.

9.3 Shrinkage

Concrete masonry units shrink slightly after manufacture. In order to avoid this happening in the wall, blocks should be allowed to dry out for at least seven days before being used for construction.

Appendices

Appendix 1:

Optimum grading of aggregates

The grading, i.e. particle size distribution, of each aggregate is determined using standard sieves in accordance with SABS Methods 828:1994 and 829:1994.

A recommended combined grading is as follows:

Standard sieve size mm	Percentage by mass of aggregate passing
4,75	70 – 85
2,36	50 – 65
1,18	35 – 50
0,60	25 – 40
0,30	10 – 25
0,15	5 – 15
0,075	0 – 10

Note that the figure implies that between 15 and 30% of the total aggregate should be stone.

Appendix 2:

Definitions

Block: A masonry unit with dimensions that satisfy any of the following conditions:

- Length between 300 mm and 650 mm
- Width between 130 mm and 300 mm
- Height between 120 mm and 300 mm

Brick: A masonry unit with dimensions that satisfy all of the following conditions:

- Length not exceeding 300 mm
- Width not exceeding 130 mm
- Height not exceeding 120 mm

Masonry unit: A rectangular unit intended for use in construction of masonry walling.

Hollow masonry unit: A hollow unit containing cores which exceed 25%, but do not exceed 60% of the gross volume of the unit.

Solid masonry unit: A masonry unit either containing no cores, or containing cavities not exceeding 25% of the gross volume of the unit.

Masonry: An assemblage of masonry units joined together with mortar or grout.

Cement & Concrete Institute

PO Box 168, Halfway House, 1685

Tel (011) 315-0300 • Fax (011) 315-0584

e-mail info@cnci.org.za • website http://www.cnci.org.za

Published by the Cement & Concrete Institute, Midrand, 1996, reprinted 1997, 1999, 2003, 2006.