CHAPTER 2

EVALUATION OF THE INTERLOCKING DRY-STACK MASONRY SYSTEMS

2.1 Introduction

In this chapter, 23 different existing dry-stack masonry systems are presented and discussed. The discussions are based on the available information from different sources. The systems discussed utilise concrete interlocking units and some utilise compressed soil- cement-interlocking units all of different types and shapes. Most of the systems are commercially available in many countries in America, Europe, Asia and Africa.

2.2 Hollow interlocking dry-stack masonry wall systems

Hollow masonry wall interlocking systems are usually partially grouted after dry stacking and they function as hollow masonry walls only during construction period. During that time the load transfer mechanism is required to resist only wind load and other constructions loads. Because of the tolerance between the interlocking mechanism it follows that when no precompression forces are applied, there are unavoidable free translations and/ or rotations until the interlocking mechanism is developed. In addition there is no tensile resistance (or bonding) in the direction of block insertion. Thus in actual wall system the deflection under small load may be fairly large. When the deflections due to such free movements exceed a serviceability limit state, the resulting interlocking mechanism may have little structural meaning. Basically concrete dry-stack masonry systems are made of hollow interlocking masonry units. The units are made to allow placement of horizontal and vertical reinforcements including grouting. The cells are filled with grout to enhance axial load capacity, provide out - of- plane resistance to transverse load and provide in plane shear resistance. Interlocking hollow blocks reduce the use of shuttering.

2.3 Solid interlocking dry-stack masonry wall systems

Soil-cement dry-stack masonry systems are basically made of solid soil-cement interlocking masonry units. Because of the low strength of the soil-cement units the cavity where applicable should be kept minimum. Code BS 3921 defines a solid masonry unit as a unit containing cavities not exceeding 25% of the gross volume of the unit. The cavities are introduced to provide interlocking mechanisms and allow for placement of reinforcements. Units can be manufactured on site using local aggregates and soil saving the transportation costs. Because cement is one of the expensive components in masonry construction compressed soil-cement masonry units which utilise less cement is increasingly popular particularly in the developing countries. The system is considered to be “low energy intensive” and therefore environmentally benign as no firing of the units is required.

2.4 General Advantages and Disadvantages of Interlocking Dry-stack Masonry System

2.4.1 Advantages

1. System is more rationalized; It has simplicity of handling and laying
2. Wall erection is faster
3. Alignment can be completed faster
4. Quality variation due to mortar joints is eliminated
5. Erection during cold winter is possible
6. Dependence of skilled labour is reduced.
7. Load of super structure can be immediately applied.

8. Ductility can be improved
9. Unlike mortared joint construction, use of smaller units does not consume more material but does take more time.
10. Units can be manufactured on site using local aggregates and soil.
11. Demolition of dry-stack masonry is basically conducted by simply unplugging the dry-stack masonry units allowing the re-use of the units.
12. Least energy intensive and environmentally benign technology.

2.4.2 Disadvantages

1. Hollow system may be unstable to resist certain types of out of plane loading during the construction; this can be overcome by external bracing or grouting the hollow section at intervals.
2. Bond patterns are limited thus architecturally more restrictive. Traditional aesthetic appeal may be compensated by troweled or spray surface treatments.
3. Difficult to form curve walls with most interlocking systems (a few systems include solution to this problem)
4. Initial seating deformation may decrease strength and stiffness of hollow system.
5. Manufacturing and handling costs are marginally increased (concrete bocks)
6. Use of hollow systems without partial grouting and surface bonding is restricted.
7. More accessory units may be required.
8. Dimensional tolerance of the units

2.5 Evaluation Criteria for Dry-stack Masonry System

Criteria for evaluating interlocking dry-stack masonry system are discussed in this section. Various interrelated factors, many of them not directly related to structural performance, are considered in developing a good interlocking block system. The importance of each factor will vary with the particular application and the sophistication of other available competitive forms of construction, including the more traditional masonry system. In this section, these factors are grouped into several aspects and discussed.

2.5.1 Aesthetics

In conventional masonry the architectural appearance is achieved by application of different types of mortar and joints treatment. Dry-stack masonry may limit this traditional aesthetic appeal, although in some commercial available dry-stack units this factor is incorporated by introducing specific finishing to the bed and perpend edges of the units to give the required appearance such as pointing, etc. In public eyes, still dry-stack masonry is perceived as being structurally unstable regardless of its actual performance. Only testing and experience will help to overcome such negative perceptions.

2.5.2 Social and political

Because of the "dry stacking nature" of the construction, the demand for skilled labour is reduced providing job opportunities to wider range of people in the community particularly in the developing countries where specialised skill is scarce. Also the anticipated increased volume of construction will absorb more masons needed to perform the special tasks. Therefore, the ill perception of job loss may not hold particularly in the developing countries.

2.5.3 Nominal dimensions and tolerance

Like in conventional masonry, most of the commercially available dry-stack interlocking units are being developed based on Modular Co-ordination Method to enable components to be built in on site without modifications. The South African Bureau of Standard (SABS) have adopted 100 mm (4 inch) module as the basic module for horizontal and vertical dimensions in conventional masonry. So far the same module has been adopted by the most of interlocking masonry developers. In conventional masonry British Standards and SABS allow tolerance on work sizes of up to ±10 mm. In dry-stacking research so far has suggested a tolerance of ±1.5 mm, which remains to be the greatest challenge to the manufactures (VanderWerf, 1999).

2.6 Ancient dry-stack masonry in Africa

The occupants of the great Zimbabwe ruins lived in a clay huts with thatched roofs but built substantial dry-stack masonry walls to form large enclosures to the settlements, as shown in Figure 2.1 The dry-stack stone masonry walls vary in height between 1 m and 12 m and also in thickness between 0.5m and 8m. Are either free standing or retaining walls. The freestanding wall comprises two outer leaves of regular coursed blocks separated by a core of irregularly stacked blocks. No ties or mortar were provided to link the two faces. A dry-stack masonry lintel is provided over openings.

a) Dry-stack fencing wall b) 11m high conical dry-stack tower

Figure 2.1 Zimbabwe Ruins

The dry-stack stone masonry walls vary in height between 1 m to 12 m and also in thickness between 0.5m and 8m. Are either free standing or retaining walls. The freestanding wall comprises two outer leaves of regular coursed blocks separated by a core of irregularly stacked blocks. No ties or mortar was provided to link the two faces. A dry-stack masonry lintel is provided over openings.

2.6.1 Structural problems in ancient walls.

A study of the structure of the great Zimbabwe civilization (Walker *et al*, 1991) showed that the site was abandoned and left to deteriorate for about 300 years. It suffered further damage from diggings by treasure hunters after it was found by European explorers in the mid 19th century. Several researchers, including Walker et al (1991), have studied structural damages encountered by the masonry wall. The studies give an indication of typical weakness of dry-stack masonry as follows-:

- *Toppling of masonry units* - The masonry units depend on friction and the interlocking mechanism between the rough surfaces for proper bonding. The top units do not have the critical mass to develop adequate friction and will therefore topple at a small disturbance.
- *Bulging of wall panels* - Sections of the stone walls have bulged outwards due to active pressure. The bulging generally occurs between the ground level and mid-height. The friction between the units has been reduced by the penetration of clay/silt materials at the interfaces thereby reducing the resistance to bulging. A monitor of movement conducted by Walker et al revealed a peak movement of 0.3mm per week.
- *Progressive collapse of wall panels* – The stability of a wall panel depends in part on the continuity of the system. Blocks at the edge of a collapsed zone become unstable, which results in progressive collapse of the wall.
- *Splitting of the wall panel* - Splitting within the units were particularly observed at the joints between a re- built section and the original wall. This may be caused by differential settlements.

2.7 Concrete Dry-stack Masonry systems

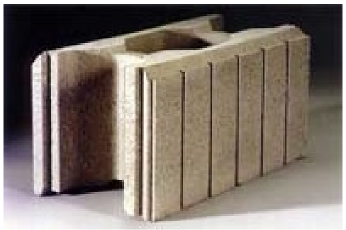
2.7.1 Introduction

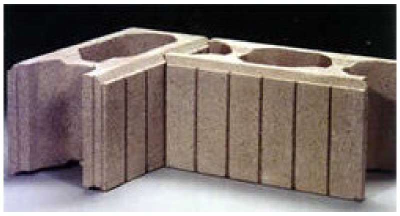
Conventional masonry using mortar bonded joints have series of technological and workmanship set backs, such as low construction speed, extra costs of the bonding materials, difficulties in control workmanship in jointing, i.e; mortar joints often fail to serve as air tight or water barriers against external environment or differential deformations due to shrinkage. The search for more rapid and less workmanship - dependent building procedures has led to the need to develop dry-stack masonry units which can be laid without mortar. Hollow dry-stack concrete masonry units, which allow placements of horizontal and vertical reinforcements is likely to give solutions to the above problems, including reducing or eliminating the use of shuttering and therefore reducing the total cost of the project. In some building projects in conventional concrete masonry, shuttering costs account for up 20% of the total cost of the project.

2.7.2 Azar dry-stack system -Canada

Azar Block is a mortarless concrete masonry wall system developed by Azar Group International Inc. of Canada. The system is made of Azar interlocking hollow blocks. The blocks have mechanical interlock in both bed joints and head joints. The cells are filled with grout to enhance axial load capacity, provide out of- plane resistance to transverse load and provide in plane shear resistance (see Fig 2.2a).

The company report (Azar Block, 2000) indicates that out of plane interlock is produced by three mechanisms. The first includes a key on the top of the web that first fits into a recess on the bottom of the web of the block above it. Another interlocking mechanism is created by two levels of bearing surface along each face shell at the bed joint. The overlap creates interlock. The gap between the outer parts of the face shell simulates mortar joints. These two interlocking features ensure vertical alignment of blocks and resist out of plane displacement along a vertical line. The third mechanism is the face shell interlocking of adjacent blocks along the head joint using the shiplap geometry. Azar blocks are designed to allow vertical and horizontal reinforcements including grouting. The interlocking features assist with the alignment and levelling, and limit the maximum construction tolerance. This dry-stack form of construction allows floor and roof load to be applied immediately upon completion of walls and construction continues without interruption. Figure 2.2b shows dry stacking Azar blocks, and Table 2.1 shows some of the physical characteristics of the Azar blocks.





(a) Azar Interlocking Blocks

b) Dry-stacking Azar blocks

Figure 2.2 Azar System (2000)

Table 2.1 Physical properties of Azar block.

Property	Unit	Result
Length	mm	406
Width	mm	203
Height	mm	203
Mass	kg	17.9
Block density	kg/m^3	2075
Saturated moisture content	% by weight	6.85
Net area of Block Mid-height	mm^2	43,858
Linear shrinkage	%	0.0365
Average Compressive strength for net area	MPa	29.1 (C.O.V 7.5%)

Source: (Azar, 2000)

2.7.3 Spurlock dry-stack system – Canada

The Spurlock building system is made of Spurlock interlocking concrete hollow blocks laid in stretcher bond. The Spurlock system avoids the height problem altogether by placing blocks in a stack bond, where each block rests exactly on the block below instead of overlapping two units. So, if the blocks below are of different heights, it does not affect the wall’s plumbness or stability. Sparlock units interlock like puzzle pieces. Workers slide them down into place using half-high units for the first course on one side of the wall resulting into staggered bed joints. This arrangement adds vertical bending strength to the wall system and retards the fire and sound from passing through. The resulting wall has 2 to 4-hour fire ratings and STC of 52. After a few jobs, crews stack at a rate of equivalent of nearly 40 conventional sized blocks per hour. No further structural work is necessary after stacking for a low or moderate-load wall. Analytical and experimental studies of the system have been reported by (Drysdale, 1990; Hatzikolas et al, 1986; VanderWerf, 1999).

To date, the manufacturer has focused on the firewall market. This system has enough strength and fire resistance without grout to be an interior, non load bearing fire partition wall. There is no special provision for reinforcements in either direction although it is possible to place vertical bars using a very high slump grout. The blocks are produced in special moulds on standard block equipment. Their unusual shape requires some extra thought cubing, but otherwise no special steps are necessary. Figure 2.3 shows the type of Sparlock units including a wall system. No design specifications available.

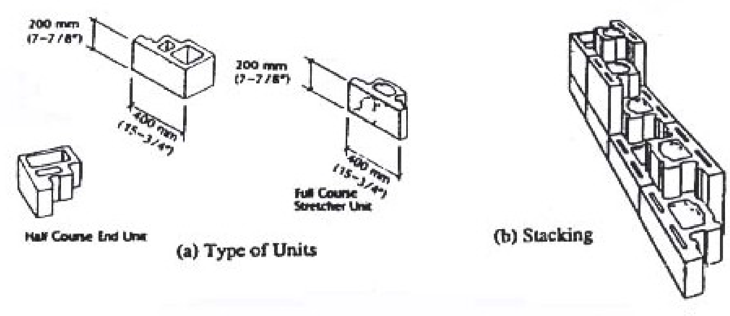


Figure 2.3 Spurlock dry-stack system (1986)

2.7.4 Haener dry-stack system – USA

The Haener building system is made of Haener interlocking concrete blocks laid in stretcher bond (see Fig. 2.4). The blocks are hollow with cavities to allow vertical and horizontal reinforcements. The blocks consist of mechanical interlocking features in the bed and head joints. According to WanderWerf (1999), the Haener block system have been on the domestic market longer than any other mortar less systems, largely attributed to the persistence and adaptability of their inventor, Juan Haener. The blocks webs have raised lugs, formed with a special contoured shoe during manufacture. The webs are offset from their conventional locations so that the lugs align and lock each block into the correct position during stacking. Some workers stack more than 100 blocks per hour. Haener recently designed the Two-block Insulating system, which adds space in each block to insert insulation. Haener blocks have sold well as a “do-it – yourself” product in Los Angeles area. It has achieved success for commercial projects in other locations but it has no single dominant application. No design specifications are available.

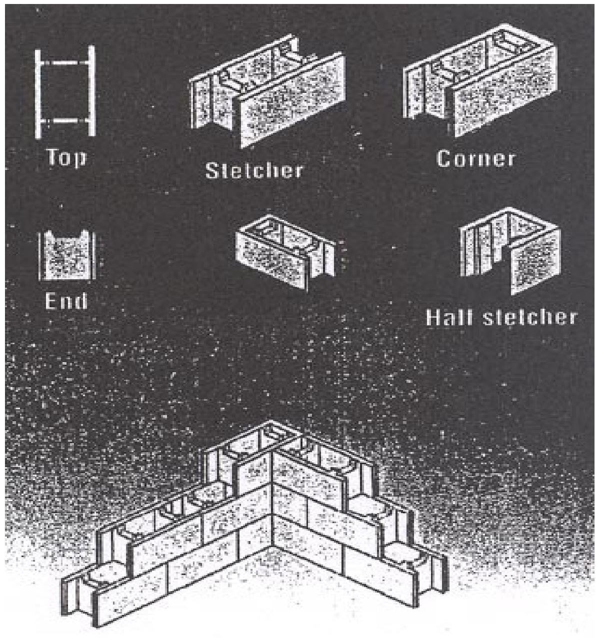


Figure 2.4 Block and stacking of the original Haener system

2.7.5 Linkblock dry stack system - South Africa

Linkblock dry-stack system is made of hollow interlocking concrete blocks laid in stretcher bond. (see Fig.2.5) Linkblocks blocks are manufactured with interlocking features "A-shaped pattern" visible on the face of the wall. The blocks are made to accommodate vertical and horizontal reinforcements including grouting. During construction, the foundation wall must be absolutely straight and level, at predetermined depth below the floor level. The first course must be laid in mortar. Where a stepped foundation is required, ensure that the height of the steps is such that it corresponds with the coursing of the blocks (LinkBlock,1999).

External walls are done independently from internal walls using full blocks only. No half block should be used in external walls. Concrete grout of 25 MPa is used to fill the cavities, done at every 5 courses. Internal walls are tied to the external walls by means of lugs or rods. The roof trusses are anchored to, the concrete ring beam at the top of the wall. Chasing must never be done and must be avoided by proper utilizing the vertical and horizontal cells in the blocks.

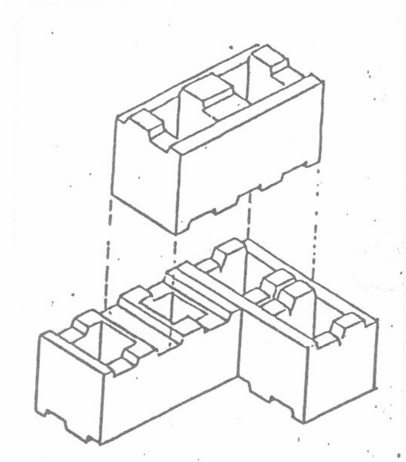


Figure 2.5 Linkblock system

There are only two types of finishes recommended by Linkblock and any deviation from these may result into failure.

a) Selfcote

The following is recommended for external walls and the internal surface of the external walls.

- Wood troweled coat of cement plaster for surface of walls
- Coat of self-bind sprayed into plaster by means of ordinary garden spray.
- Coat of “Super Acrylic” applied with roller
- Finishing coat of “Selfcote” applied with roller.
- For low cost housing the plaster can be replaced with a sand cement wash finished as above.

b) Cemcrete

The following is recommended for external walls

- Wood floated cement plaster
- Coat of “Cemcrete” cement wash

♦ Final layer of texturite roughcast colored cement finish.

2.7.6 The Baker system

The Baker system is a interlocking block system developed in Australia by Baker (Baker, 1972). It consists of interlocking head joints by means of dovetail lugs as shown in Figure 2.6. The advantage of this system is that the courses can be curved, a feature which is not readily achieved in other interlocking dry-stack systems, where special units must be additionally produced if curved or offset walls are required.

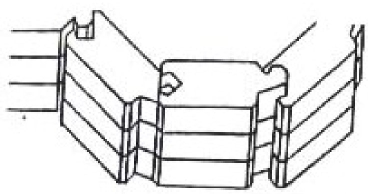


Figure 2.6 Baker System

2.7.7 The German KLB system

The KLB (Klimaleichtblock) system is a solid lightweight concrete dry-stack block system developed in Germany. The blocks interlocks with a tongue and groove interlocking mechanism on the head joint as shown in Figure 2.7 (Glitza, 1991)

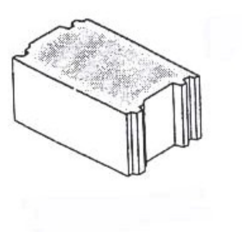


Figure 2.7 KLB block (1990)

2.7.8 Sparfill system

A lightweight block (Figure 2.8.) made of polystyrene aggregate has been developed in Canada and its structural performance when surface bonded, has been reported by (Gazzola *et al*, 1989). The system, which is dry stacked and the surface bonded with material containing glass fibers is marketed for low-rise structures. The test results indicates that for the low rise construction, where gravity loads are not high, the Sparfill block system can be readily designed to resist lateral in-plane and out of plane forces .No reported test data is available.

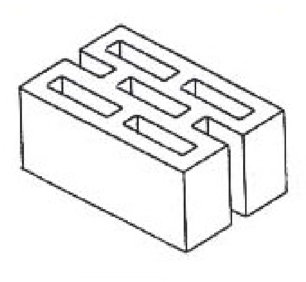


Figure 2.8 Sparfill Block (1989)

2.7.9 The Sinustat system

The Sinustat System proposed by Hilmar Werner of Berlin and Oliver Collignon, of London is a dry-stack system based on an open ended unit with a central cell and two half cells (Oh, 1994). The widths of the basic units are 125 mm, 175 mm and 200 mm and five basic units are needed for general construction. The interlocking mechanism consists of lugs placed on the face shells as shown in Figure 2.9a. The Sinustat system can be easily reinforced in the vertical and horizontal direction with seat available for the ties as shown in Figure 2.9b

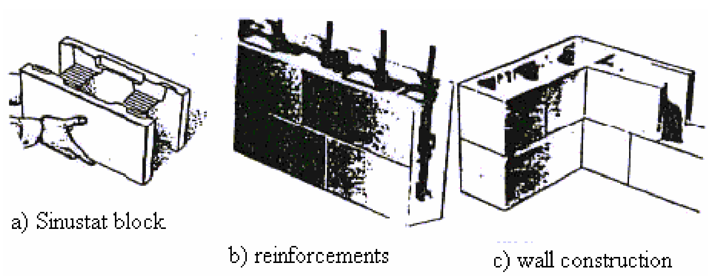


Figure 2.9 Sinustat System (1991)

2.7.10 The Whelan-Hatznikolas-Drexel (WHD)

A novel interlocking unit with a dove tailed end joint and using extruded mortar material on the bed joints was introduced by Whelan in 1985. The geometry of this unit is shown in Figure 2.10(a) and (b). This unit has a dovetailed lug at the same head joints and although it can be reinforced in the vertical direction it requires threading over the rebars during construction. Figure 2.10 (c) and (d) shows the construction details of the system reported by Whelan, 1985.

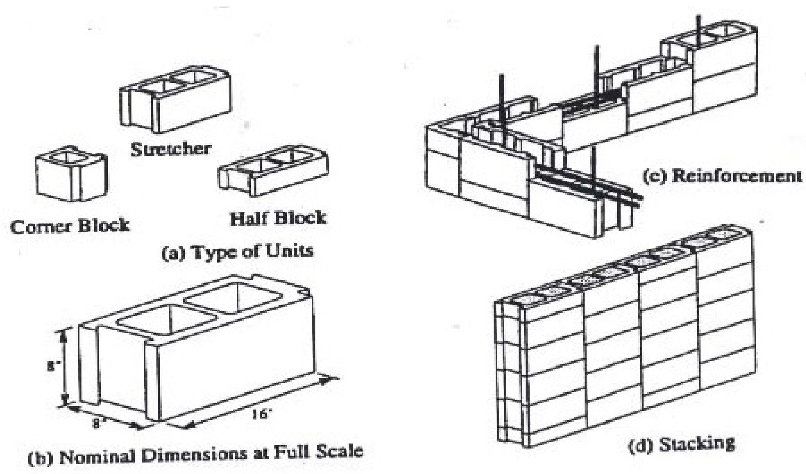
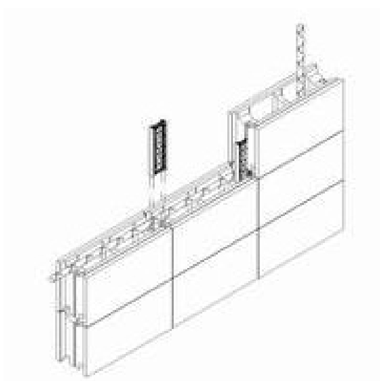


Figure 2.10 Whelan Masonry System

2.7.11 Smart dry-stack system -Australia

Smart Masonry is a dry stacked concrete block system. The system consists of hollow interlocking concrete blocks which are manufactured to controlled dimensional tolerances and which incorporate detailing to permit the dry stacking of the blocks (see Fig. 2.11). The block height is 200 mm and length 398.5 mm. The top and bottom surfaces of the face shell incorporate a stepped profile. The near vertical step is located at the mid – thickness of the face shell. When stacked the outer half of the face shell of each block is in contact at the cursing height. The back of the face shell of the lower block protrude upwards about 4mm to engage the front lip of the upper block in “a tongue and groove” style of joint. This ensures that the blocks are aligned vertically when stacked. The rear of the face shell of the upper block is cut away by 20 mm so that an internal void, of about 16 mm in height, is present in the back of the face shell. This void is filled with grout when cores in the wall are grouted.

The wall is erected by bedding the first course on a leveling grout base. Half–height keys are inserted between blocks in the first course. Further courses are erected with the plastic keys inserted in every vertical block joint (see Fig.2.11b) Reinforcing bars are placed as the wall is constructed. The height the wall can be erected prior to grouting is dependent upon the degree of restraint of return walls and /or the extent of external bracing. The wall is grouted with Smart Masonry Wall Grout, which is a special grade 32 MPa concrete grout, with a 250 slump and 3 mm maximum aggregate size. The system was originally field tested in South Africa and Sri Lanka, and subsequent developments of the system are now being used in Australia (Anderson, 2001)



a) wall system b) inserting plastic key

Figure 2.11 Smart Masonry System (2000)

2.7.12 The modified H-Block system

Modified H-block unit shown in Figure 2.12 is a simple open ended block unit with the tongue and groove interlock on both the bed and head joints developed by Drexel University. It can be easily reinforced in the vertical and horizontal direction. It has good resistance to water penetration due to the raised tongue and groove bed joints (Oh, 1994).

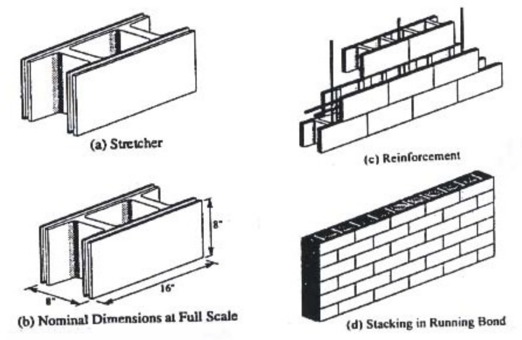


Figure 2.12 Modified H-Block System

2.7.13 The Stepoc building system

The Stepoc building system is marketed in the United Kingdom by Forticrete Architectural Masonry (Stepoc, 1989). It consists of single cell units with one end interlocking block unit laid dry, which are then grouted in the interconnected cavities thus bonding the block Figure 2.13 (a) shows the available blocks which come in widths of 140 mm, 190 mm and 256 mm. No interlock mechanism exists on the bed joints and a weak interlock for alignment is found on the head joints. The Stepoc system can be easily reinforced in the vertical and horizontal directions (Fig. 2.13b). It is suitable for construction of cavity, retaining or foundation walls. The Stepoc system is laid in 1/3 running bond, which create an internal configuration producing a cascade filling effect when the concrete is poured as shown in Figure 2.13(b) and (c).

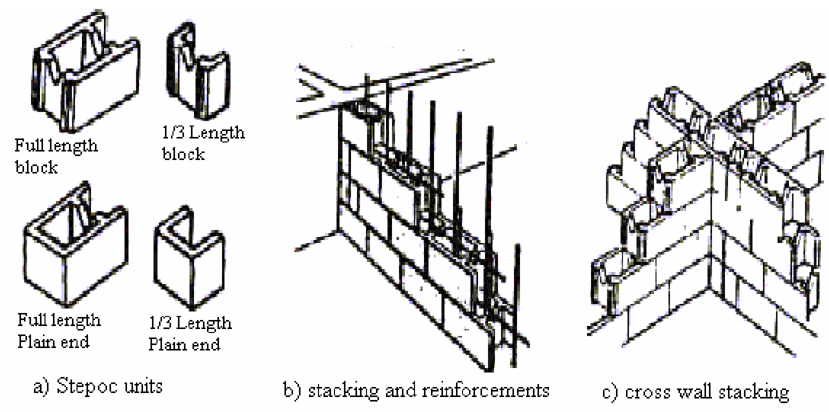


Figure 2.13 Stepoc System (1989)

2.7.14 Jordanian interlocking system

An interesting three-cell interlocking mortaless block has been used in Jordan for low cost, low-rise housing. The basic stretcher unit has a raised lip around the cells which provides horizontal interlock and open ends with tongue and groove fit on the head joints as shown in Fig 2.14. The system is laid in stretcher bond and allows the placements of vertical and horizontal reinforcements including grouting as reported by (Bakeer, 1988).

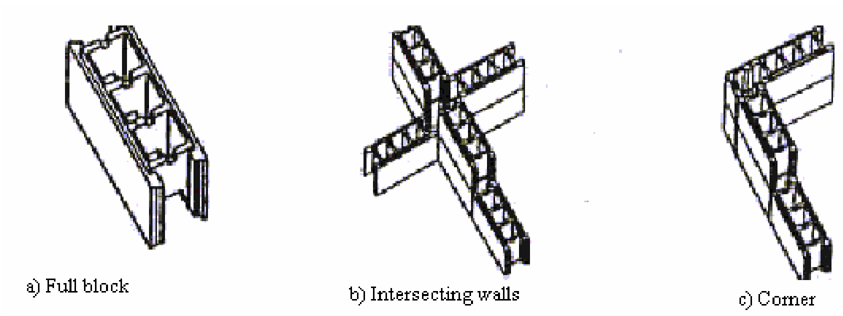


Figure 2.14. Jordanian System (1988)

2.7.15 The Mecano system

A mortarless system, which can be dry-stacked then reinforced and grouted in the vertical and horizontal directions, was developed in Peru by Gallegos in 1987. (Gallegos, 1988). This system, known as Mecano system was developed for earthquake resistance construction. The units are made of sand-lime mix and are 12 cm wide, have no interlocking geometry; rather continuity in the vertical and horizontal directions is made through the grout cores (Fig.2.15). Since the block cells are small a very fluid mix must be employed. The units shape creates two-way modular cores which are 15 cm apart thus allowing of closely vertical reinforcing. The horizontal reinforcement is placed during unit stacking and the vertical reinforcement is placed after stacking. Testing on the compressive strength of the units and prisms as well as diagonal tension tests has been reported.

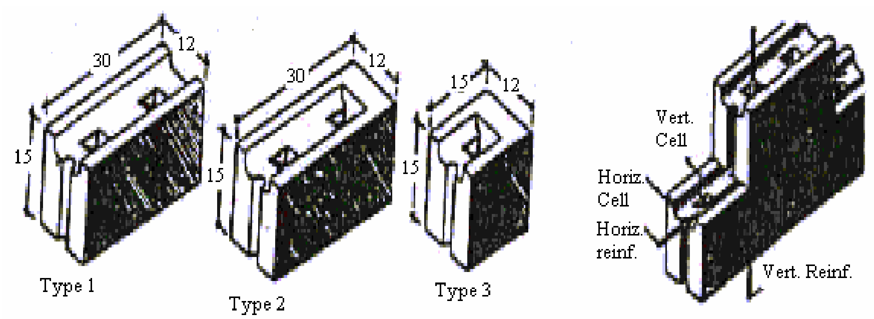


Figure 2.15 Mecano System (1988)

2.7.16 Barlock interlocking system

The Barlock was developed in the mid eighties by Barrett Industries of San Antonio, Texas. The barlock system (Fig 2.16) uses the same dovetail lug arrangement proposed by Whelan in1985 and has a smooth bed joint. The system can be reinforced vertically or horizontally using a bond beam with knock out webs (Barlock, 1992).

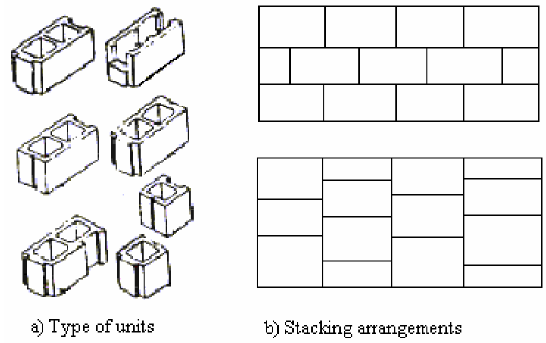


Figure 2.16 Barlock Interlocking System

2.7.17 Whelan interlocking masonry

A novel interlocking unit with a dove tailed joint and using extruded mortar material on the bed joints was introduced by Whelan in 1985. The geometry of the unit is shown in Figure 2.17. This unit has a dovetailed lug up the head joint, although it can be reinforced in the vertical direction it require vertical threading over the rebars during the construction (Whelan, 1985).

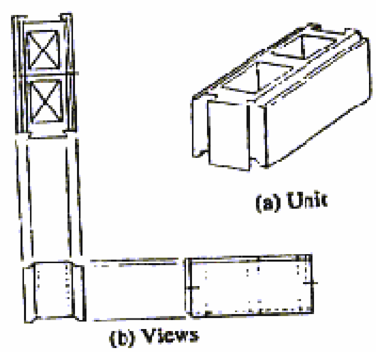


Figure 2.17 Whelan Interlocking system

2.7.18 **McIBS, Inc. mortarlesss interlocking system**

McIBS interlocking mortarless concrete block (McIBS, 1986) is two cell closed end unit with a tongue and groove interlocking mechanism on the bed and head joints. Figure 2.18a shows the various lightweight concrete units that can be produced and Figure 2.18b shows the stacking and reinforcing arrangement. The closed end unit has distinct disadvantages in earthquake resistance construction because it must be threaded onto the vertical reinforcing bars. The control of the block height is very critical for dimensional control and no details available on how accurate the tongue and groove fit on the bed joints.

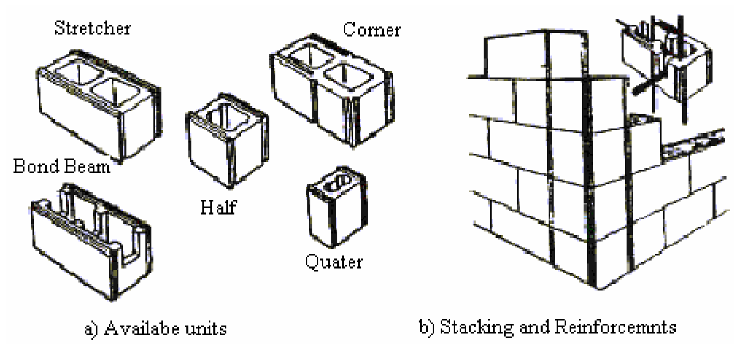


Figure 2.18 McIBS Masonry system (1980)

2.7.19 The Etherington "building system"

An Interlocking system developed in the late seventies and early eighties for low cost housing in developing countries has been reported by Prof. Bruce Etherinton of the university of Hawaii (Etherinton, 1983). The system has been used in several large projects including 350 housing units in Manila and a 202 units development in Bangkok. The main interlocking block types are shown in Figure 2.19a. The basic block is closed ended two-cell unit with a raised lip around each cell creating a horizontal interlock. Vertical interlock is achieved through small cells placed in each web, which are continuous in the vertical direction and are sealed with cement grout. It can accommodate vertical and horizontal reinforcements see Figure 2.19b. According to the inventor, some of the buildings using this system have survived for very strong earthquakes

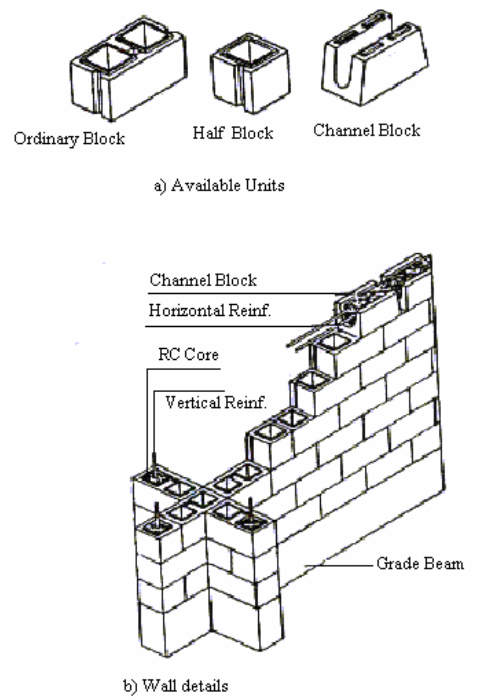


Figure 2.19. Etherington System (1979)

2.7.20 The ACECOMS dry-stack system – Thailand

Asia Center for Engineering Computations and Software (ACECOMS) of Thailand is involved in the development of dry-stack masonry system. ACECOMS system is made of hollow interlocking concrete blocks laid in stretcher bond. The cavities in the blocks allow placement of vertical and horizontal reinforcements and grouting.

ACECOMS Blocks (Fig.2.20) Specifications ACECOMS, 1998

- Full block (300 mm long x150 mm wide x100 mm high)
- Half block (150 mm long x150 mm wide x100 mm high)
- U-Block
- Half U-block

The two later types of bricks allow reinforcements to be laid horizontally (along the full length of the wall) in the “U” cell on top of the blocks. Vertical cell allows vertical reinforcements and grouting.

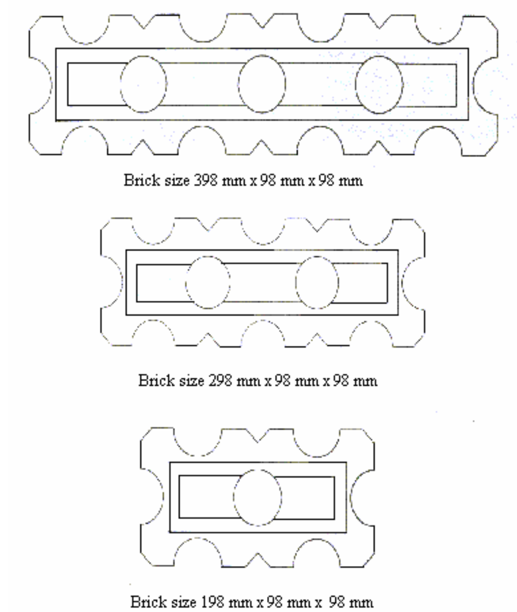


Figure 2.20 ACECOM Dry-stack blocks

2.8 Soil-Cement Dry-stack Masonry Systems

2.8.1 Introduction

Dry stacking using compressed soil-cement interlocking blocks is a recent technology, which is increasingly becoming popular in the developing countries. It has a potential for meeting the low cost housing needs for millions of people. A cost comparison between compressed earth blocks and conventional concrete blocks carried out by Killick (1998), indicates savings of about 20 % on the cost of normal blocks. It utilizes the locally available materials, and therefore reduces the transportation costs. Dry stacking increases the speed of construction and reduces the need for skilled labour. Dry stacking using compressed soil-cement consumes less cement; no firing of brick is required and therefore least energy intensive and environmentally benign technology.

2.8.2 The Unique dry-stack building system - South Africa

Unique building system is made of soil-cement or concrete (UNIQUE, 2001). The blocks consist of interlocking features in the bed and perpend joints including a square cell, which allow for placements of vertical reinforcements and grouting to increase wind and earthquake resistance. Unique block dimensions are-:

- Full block – 200 mm length x 200 mm width x 90 mm thick
- Half block – 200 mm length x100mm width x 90 mm thick

The block strength depends on the type of materials and the mix ratios used. The average compressive strength range from 5 MPa for soil blocks to 21 MPa for concrete blocks. The products are classified according to SABS 1215 as a solid masonry unit. The code defines a solid masonry unit as a unit containing cavities not exceeding 25% of the gross volume of the unit. The UB-200 with its 12% volume of air voids meets these criteria. Figure 2.21shows the Unique system.

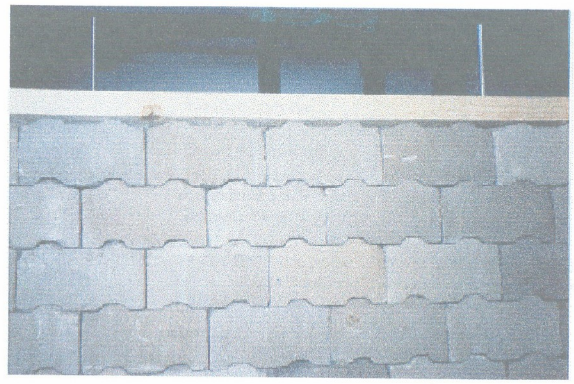


Figure 2.21 Unique system

Construction details of Unique Building System

In the construction of Unique system, the foundation wall is usually laid on conventional strip foundation. The foundation wall courses are laid in cement mortar up to at least 300mm above the ground level. The dpc is provided before construction of the superstructure. The superstructure courses are dry-stack up to the lintel level. Vertical reinforcements are introduced in the cells where is necessary. Windows and door frames are fixed in conventional ways and lintel installed above them. The roof structure is tied down on the vertical reinforcements to resist uplift. No design specifications available.

2.8.3 IPI dry-stack system –Tanzania

The IPI dry-stack system is made of soil-cement interlocking blocks (IPI, 2000). The blocks are made with round cells which allow the placement of vertical reinforcements including grouting wherever necessary to increase the stability and resistance of the wall against lateral load. The blocks are manufactured using manually operated block press machine in a special moulds in which compaction can be done by hand. The blocks are usually made directly at the site to avoid transportation costs. Institute of Production Innovation (IPI) at the University of Dar-Es-salaam in Tanzania is currently developing a manual block press machine for making interlocking blocks. The machine can also produce normal block by changing the moulds. IPI is currently working on one type of block

- Full block 300 mm length x150 mm width x 100 mm thick
- Half block150 mm length x150 mm width x100 mm thick (see Fig.2.22)

The average compressive strength of earth block made of Red soil (95%) +slaked lime (5%) at the age of 14 days is 1.5 MPa, and that of Clay soil (84.6%)+ cement (5.3%) + (1.5%) gave average compressive strength of 2.8 MPa compared with normal sand cement solid blocks from street vendor made of sand (92.6%) + cement (7.4%) at the age of 14 days gave compressive strength of 2.25 MPa, below the local standard of 3.0 MPa. The low compressive strength of the soil block is attributed to low manual compaction load. The research is in progress to modify the manual compression system for high quality blocks (IPI, 2000).

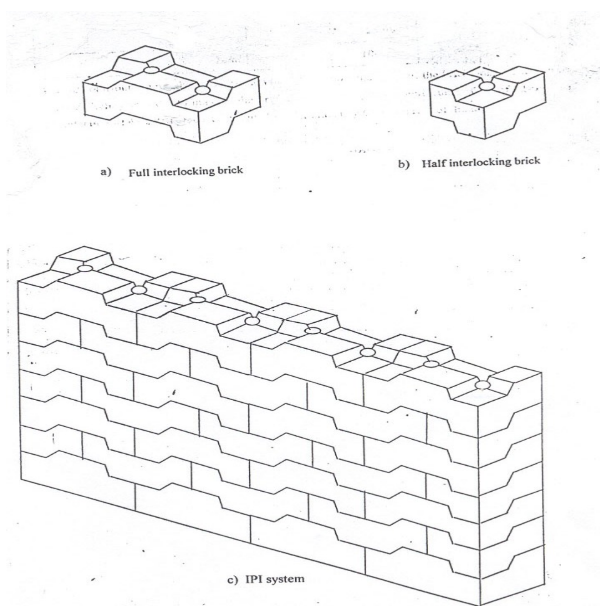


Figure 2.22 IPI dry-stack system

2.8.4 Hydraform dry-stack building system – South Africa

This research is based on the Hydraform dry-stack construction system using "Hydraform Interlocking blocks". The blocks are manufactured by compressing a soil and cement mixture in a hydraulic block press - machine. The blocks contain *"tongue &groove"* type of interlocking features in the bed and head face. Some units are designed to allow placements of reinforcements and grouting. The blocks are found in two categories. Category one represents ordinary Hydraform blocks for ordinary daily construction and the second category, Hydraform Seismic blocks to be used where higher lateral strength is required i.e. earthquake resistance.

Types of blocks are currently manufactured

i. 220 mm width x 115 mm height x 230-250 mm length for external walls (weight 12 kg) see Fig. 2.23

Figure 2.23. Ordinary dry-stack block

ii) Ordinary block type II

115 mm width x 115 mm height x 230-250 mm length for internal non-load bearing walls (weight 6 kg) see Fig. 2.24

Figure 2.24 Partition block

Figure 2.25 ordinary corner block

2.8.4.1 Construction details of Hydraform building system and use limitations

In the construction with the Hydraform dry-stack system (Hydraform, 1988) the foundation wall is built on a conventional cast in situ concrete strip or raft foundation depending on the nature of the soil. The foundation wall is laid on cement mortar preferably using higher strength blocks. In order to provide a level surface to keep the wall aligned vertically and horizontally the starter course is laid in ordinary sand cement mortar. Hydraform system normally utilises stretcher bonding. (Figure 2.26a). The courses for the super structure are dry-stack, up to the lintel level as shown in Figure 2.26b. The top three to four courses are also laid in mortar to form a ring beam at the top. The roof is tied down to the ring beam by galvanized wire to prevent up lift. Windows and door frames are embedded in conventional ways and lintels installed above them. Plumbing and electrical piping are chiselled into walls in the conventional ways. The external walls may be plastered and painted, or other suitable type of finishing applied. Internal walls are finished as prescribed by the client, but it is recommended to plaster the internal walls to prevent rainwater penetration and improve thermal and sound insulation. The wall cross-section detail is shown in Figure 2.26c

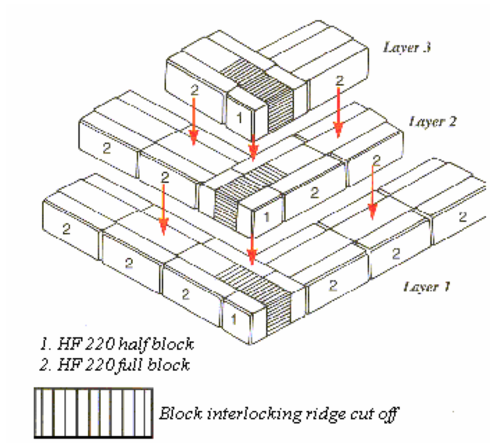


Figure 2.26(a) Dry-stacking Stretcher bond

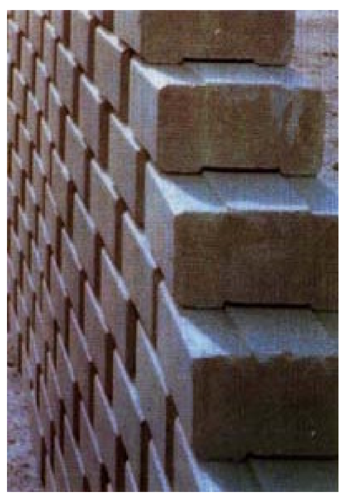


Figure.2.26 (b) Dry-stacking the mid courses

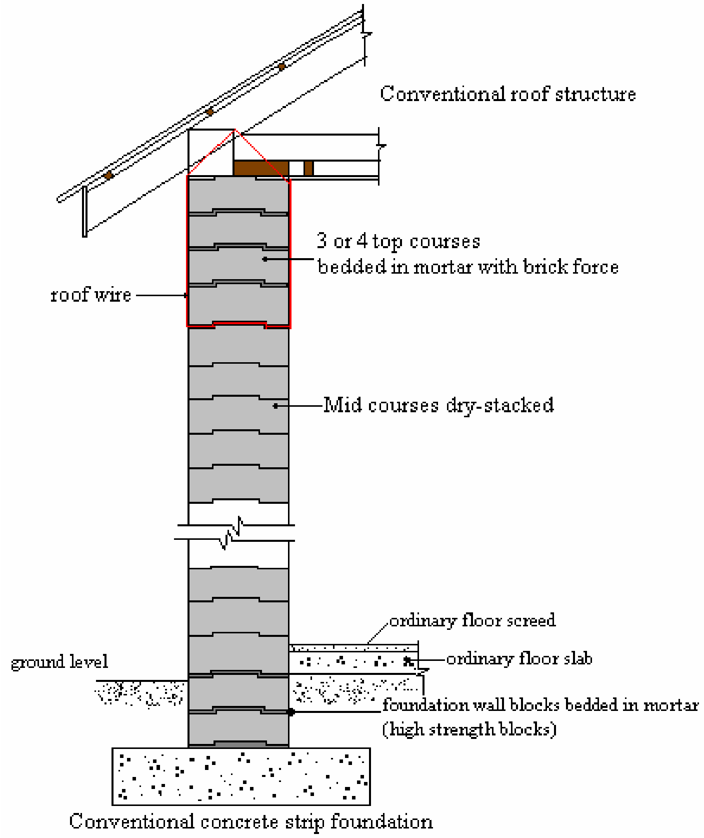


Figure 2.26(c) Wall construction details

According to the South Africa National Building Regulations Agrement Certificate (1996), the Hydraform building system is so far limited to erection of single story buildings of the following category-:

- Non-residential school buildings (A3)
- Moderate and low risk commercial services buildings (B2) and (B3)
- Moderate and low risk industrial buildings (D2) and (D3)
- Clinics and other institutional (residential) buildings (E3)
- Small shops (F2)
- Offices (G1)

- Hostel, semi detached, row houses and detached houses (H2), (H3) and (H4)

The system has also been used in the USA, India, Argentina Nigeria, Ethiopia, Uganda, Tanzania and many other African countries to build hundreds of low cost houses under government low cost housing schemes (Hydraform, 2000). Appendix A shows some of the projects constructed using Hydraform system.

2.8.4.2 Manufacture of Hydraform Blocks

Hydraform compressed interlocking soil-cement blocks can be produced with a sandy soil of 5-20% clay content and 5-25 % silt content. Blocks can even be produced with higher clay and silt content, but you need to determine the plasticity index to see if the soil is suitable for block production. Generally, soils with low clay content and silt portions, below 10% will be difficult to handle when coming out of machine. Soils with high clay and silt contents, above 35-40%, will need to be blended with a sandy soil. The soil must be free of organic material, must not contain harmful quantities of salts and should contain just sufficient clay to bind the block so that they may be handled immediately after manufacture without disintegrating. Generally the soil should comply with the grading and plasticity requirements set out in the table below

Table 2.2 Basic requirements of Soil for CEB′s production

Soil Range	% By mass passing the 0.075 mm sieve (silt and clay fraction)		Plasticity Index (maximum)	Estimated block compressive Strength (After curing)
	Min.	max		
A	10%	35%	15	4 MPa (using soil range A)
B	10%	25%	10	7 MPa (using soil range B)

Source: Hydraform, 1988

Soil range A - should produce a block with a compressive strength of 4 MPa; Soil range B - should produce block with a compressive strength of 7 MPa; Soils with higher plasticity (over 15) are acceptable provided that the material has been pre - treated with lime, laboratory testing will confirm the required dosage and additional curing time required. Water must be clean and should not contain any harmful quantities of acid, alkalis, salts, sugar or any other organic or chemical material. Potable water will normally be satisfactory. The cement required will normally be in the range of 4 to 7% by mass of the dry soil for 4 MPa blocks and 7 to 10% by mass for 7 MPa blocks. That will require a hydraulic press machine of a compression load of between 8 to 13 MPa. For example a soil mix with 5% cement content will produce blocks with average compressive strength of 4 to 5 MPa, while 10% cement content will give average strength of 7 to 8 MPa. In production of 5% cement blocks, 23 bags of cement (standard size 50 kg) will produce 1500 blocks, where in 10% cement, 45 bags will produce 1500 blocks.

Block production process involves breaking up lumps in freshly delivered or excavated soil, sieving the soil (Fig. 2.27a), batching and adding cement, dry mixing until uniform colour is achieved, adding water, wet mixing and loading the mix into the machine (Fig. 2.27b). Hydraform blocks are produced using a mobile diesel or electrical driven hydraulic block making machines normally vertically extruded (Fig. 2.27c). Different geometry is achieved by simply changing the moulds. The production capacity of the machine is 200 to 250 blocks per hour. Seven trained Hydraform technicians produce ± 1600 blocks per day (Hydraform, 2004).

a) sieving of soil

b) block production

c) Hydraform mobile block making machine

Figure 2.27 Production of Hydraform interlocking blocks

Freshly produced blocks are stacked (not exceeding 6 blocks in height) and covered immediately with plastic sheet to protect the blocks from weather. Curing is commenced after 24 hrs by wetting the blocks daily for five to seven days and keep them covered properly as shown Figure 2.28. Curing is very crucial in the strength development of the blocks. On site production do not involve transportation of the blocks. Blocks manufactured outside the site are delivered by trucks in palettes as seen in Figure 2.29 (Hydraform, 2004).

Figure 2.28 Block curing

Figure 2.29 Delivering of the blocks in pallets