

## Interlocking dry stacked masonry

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### ABSTRACT:

*This paper is motivated by urgent need to identify, innovative technologies to supplement age-old concrete and brick & mortar based construction for masonry work. Current times require technologies which are sustainable in terms of one or more of the following parameters i.e. use of locally available resources – material & manpower, cost effectiveness, eco-friendly, easy to adopt in construction practice, can be cast – in situ to reduce transportation, faster to build and energy efficient.*

*Interlocking block masonry by Hydraform (or by others) is one such building system which almost full fills all such requirements of being a sustainable masonry. It has been tested in the field as well as by experiments and has been found to be much superior than the conventional brick masonry using cement sand mortar (1 cement : 6 sand). The basic compressive stress is much more than the minimum values given in the Indian masonry design standard (IS 1905-1987).*

*However, Indian masonry design standard (IS 1905-1987) does not deal with dry interlocking block masonry, hence does not prescribe the design values for this masonry like basic compressive stress, tensile stress & shear stress. However the same code recognizes some other types of masonry and recommends that a prism test of different masonry may be done and these values may be accepted for designing the masonry.*

*This paper addresses the technical specifications, raw material options, mix designs, construction procedure, and conformity with the building standards. It further presents case studies, cost efficiency and testing procedure.*

**Keywords:** *Interlocking, Block, India*

## 1 INTRODUCTION

This Interlocking masonry known as Hydraform block masonry (in the present case but this is generic and can be tried with other interlocking blocks also) replaces the conventional brick and mortar based construction masonry. The other components of the conventional building system remain largely unchanged. The system is a dry stacked-Interlocking masonry system that enables aesthetic and affordable building, speedier construction of high quality in stretcher bond. The blocks have an extremely appealing face-brick finish and provide a pre-pointed straight masonry. The walls may be left exposed, plastered or finished with cement paint.

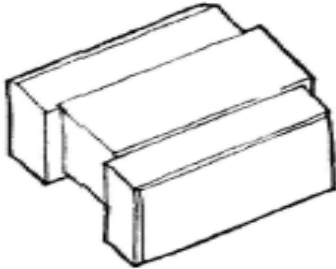
The system has originated from South Africa and has extensively been in use over different continents. A number of constructions have been made using interlocking building system in India over last few years.

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## 2 INTERLOCKING MASONRY FEATURES

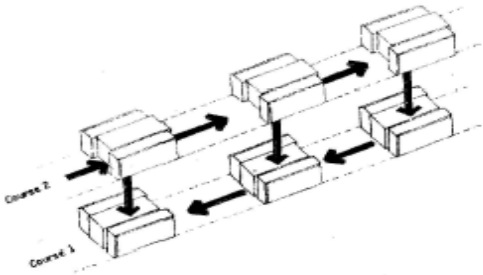
### 2.1 Interlocking Block



**Figure 1.** Interlocking Block

### 2.2 Interlocking Profile

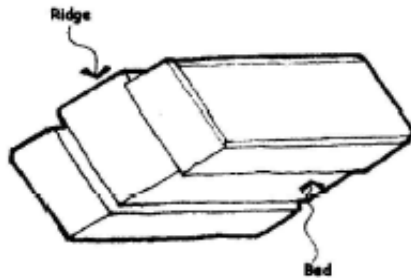
The locking of a male face of one block with the female face of another or the locking of the bed of one block with the ridge of the one below it is called Interlock.



**Figure 2.** Placing of Interlocking Blocks

### 2.3 Bed and Ridge

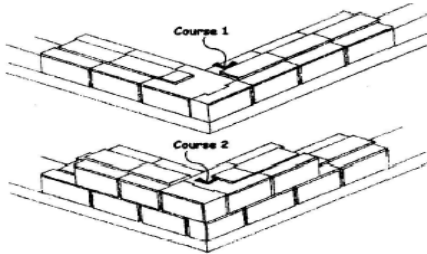
The recessed under surface of the block is referred to as the bed. The raised top surface of the block is called the Ridge.



**Figure 3.** Bed and Ridge

## 2.4 Block laying Courses

One (horizontal) layer of blocks is called a course.  
Height of a course = 115 mm.



**Figure 4.** Course of masonry with bonding

## 2.5 Corners

Corner requirements are: Shaved  $\frac{1}{2}$  blocks is prepared. It must be remembered to shave off the ridge and male face of the corner block, as shown and further ensuring that the shaved ridge points upward and the shaved male face point's outwards. One must start the first course with a  $\frac{1}{2}$  block.

## 2.6 Compatibility for Reinforcement for Earth Quake Resistant Construction

The interlocking blocks can be easily reinforced (because of the grooves) against the Conventional masonry. All the relevant bands i.e. roof bands, gable Band, lintel band, cill band and plinth band etc. can be easily incorporated in the masonry ( as per the requirements of the seismic design). Both vertical and horizontal Reinforcement can be provided by means of the groves. The sizes of the grooves can be increased also.

## 2.7 Interlocking Masonry features

The interlocking blocks if made with fly ash based combination has following unique advantages over other comparable products:

- Density of masonry can be reduced in the range of 1300 - 1700 kg/m<sup>3</sup> against the Conventional fired brick system (1920 kg/m<sup>3</sup>) in terms of unit weight.
- High finish blocks so made result in exposed finish aesthetic walls, saving on plaster & finishes.
- blocks can be made with lower water absorption properties making them useful for even relatively wet applications.
- Dry-stacked masonry results in speedier construction.
- blocks can be made with reinforcement / conduit features facilitating Earthquake resistant construction.
- blocks made are eco friendly as no burning is involved

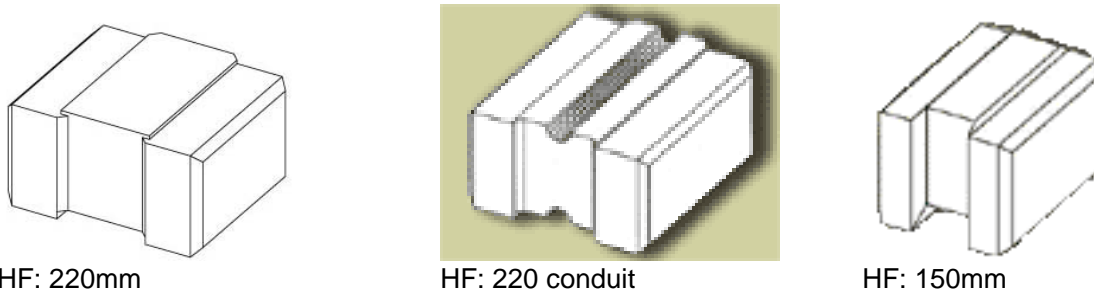
## 2.8 The Interlocking Building System

It comprises of three primary aspects:

- (1) Interlocking Block
- (2) Block making Machine
- (3) Advantages of interlocked stacking of blocks

## 2.9 The Interlocking blocks:

The blocks are of mainly of following size and dimension to suit standard application requirements. However size can be tailored for large quantity application requirements.



**Figure 5.** Size & Dimensions of Hydraform Interlocking Block

**Table 1.** Parameters for the Hydraform blocks

	<b>H F 220 / Conduit</b>	<b>H F 150</b>
Use	External Walls / Boundary wall	Interior/ Partition Walls
Width	220mm (9 inc)	150mm (6/4.5 ins)
Height	115 mm	115 mm
Length	100- 240 mm	100- 240 mm
Weight	9-11kg approx	4.5 -6 Kg approx

Other size options can be made depending on design requirement.

## 2.10 Interlocking Masonry system

The interlocking dry stacked masonry comprises of compressed earth blocks/ fly-ash interlocking blocks that can be laid dry - stacked or using minimal mortar slurry in a stretcher bond.

Dry stacking is mortar- less method of constructing masonry. Except first two block layers above DPC and top two courses leading to roof band, blocks are not laid on mortar, they rely on the Interlocking mechanism to provide resistance to applied loads. Dry stacking results in reduction of building costs due to saving in construction time, reduced requirement for skilled labour and Costly material especially cement and reusability of the blocks. The requirement for unskilled labour makes dry stacking particularly attractive against labour based work.

There are many examples of dry stacked structures, one such being in the Egyptian Pyramids that relied on their self weight to resist external forces. Whereas interlocking dry stacking utilizes interlocking mechanisms of shear keys as well as self -weight to resist the external loads.

As per the requirement of IS 4326:1993 (Indian Standard on Earthquake Resistant Design and Construction of Building- Code of Practice), a thin mortar of the specified type can be used even in these Interlocking types of the blocks.

With an extremely appealing face-brick finish that provides for pre-pointed straight masonry, these blocks gives flexibility of achieving the final finish.

The Masonry uses minimal or no mortar, construction is fast, blocks are produced on the site saving Transportation cost, Requirement of Skilled labour is less, blocks are water cured and do not require burning of Fuel, wall face surfaces are Even, Plastering is not required but can be done as an option, the thickness of the masonry can be controlled giving more carpet area and less cubic contents of the blocks, are the this masonry's advantages.

(Dry Interlocking Block Masonry in Stretcher Bond)



**Figure 6.** Bonding -Steel Bars & Conduits

### 2.11 Block Compressive Strength

The HYDRAFORM Interlocking blocks/bricks when tested in accordance with IS 3495 Part I-1976 following minimum compressive strength after 28 days of curing was recorded.

**Table 2.** Hydraform SEB blocks

Class designation	Compressive strength in (N/mm <sup>2</sup> )
(I) 30	not less than 30
(ii) 75	not less than 75

**Table 3.** Hydraform fly-ash blocks

Class designation	Compressive strength in (N/mm <sup>2</sup> )
(i) 75	not less than 75
(ii) 100	not less than 100
(iii) 125	not less than 125

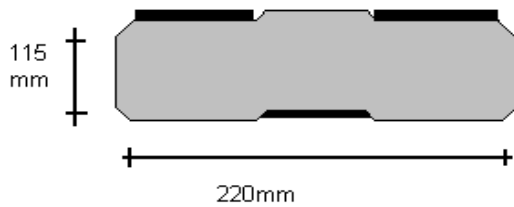
### 2.12 Compressive strength test procedure

Compressive strength test should be done in compression testing machine. blocks should be placed between the jaws and load should be applied gradually. Precaution should be taken such that load should be applied to the flanged portion of the blocks. For this two steel plates of sizes 50mm x 240mm and thickness 10 mm are placed on top flange and gradual load is applied over the plates till the failure occurs and not the maximum load at failure. The load at failure shall be the maximum load at which the specimen fails to produces any further increase is the indicator reading on compression testing machine.

The test report shall be given below:

$$\text{Compressive strength} = \frac{\text{Maximum load at failure}}{\text{Average net area of flanged portion}}$$

The compressive strength of any individual block shall not fall below the minimum average compressive strength by more than 20%. (In accordance with IS 1725-1982.)



Steel Plates: 50mm x 240mm x 10mm

**Figure 7.** Test Sample- Block with Bed Plates

### 2.13 Water absorption limit

The HYDRAFORM Interlocking blocks when tested in accordance with the procedure laid down in IS 3495 Part II-1976, after immersion in water for 24 hours, the average maximum water absorption was:

- For the blocks/bricks with (FAL-G (Fly ash/Cement) bricks/ blocks) not more than 12% (by weight).
- For the blocks/bricks with (SEB (Soil Earth Stabilized) bricks/ blocks) not more than 14% (by weight).

### 2.14 Procedure

Dry the specimen in a ventilated oven at a temperature of 105oC to 1150C till it attains substantially constant mass. Cool the specimen to room temperature and obtain its weight (M1).

Immerse completely dried specimen in clean water at temperature of 27+2degreeC for 24 hour. Remove the specimen and wipe out any trace of water with damp low and weigh the specimen (M2). Complete the weighing within 3 minutes the specimen has been removed from water.

Maximum permissible water absorption - 15% by mass after 24-hour immersion in cold water.

$$\text{Formula for Water Absorption} = \frac{(M2 - M1) \times 100}{M1} \quad (1)$$

### 2.15 Drying shrinkage limit

The average drying shrinkage of the blocks when tested by the method described in IS 4139:1989. The average of three was not exceeding 0.15%.

### 2.16 Weathering limit

When tested in accordance with IS 1725-1982 Appendix A, the maximum loss of weight was not exceeding 5%.

### 2.17 Rainwater Penetration limit

Rain water penetration tests were conducted to evaluate the weather durability of the blocks. In a test, two test walls were constructed and subjected to the rain penetration test. This test was run for a 24hour period at a water spray rate of 40 –50 mm depth of water per hour. This test relates to a mean annual rainfall of more than 1000 mm and hourly mean wind speed of 30m/s. Both the test walls were

coated with a cement based water proof finish on the external walls. The internal wall was plastered to a thickness of 10mm. After a 24hour period no dampness or leakage was recorded on the interior surface of either of the walls.

### 3 VERTICAL MASONRY LOAD TEST ANALYSIS

Determination of Compressive Strength of Interlocking Block Masonry by Prism Test :( In accordance with Appendix B Clause 5.4.4 I.S. 1905-1987)

When the compressive strength of masonry is to be established by tests, it shall be done in advance of the construction, using prism built of similar material under the same conditions with the same bonding arrangement as for the structure. In building the prisms, moisture content of the units at the time of laying, the consistency of workmanship shall be the same as will be used in the structure. Assembled specimen shall be at least 40cm high and shall have a height to thickness ratio not less than 5. If h/t ratio of prism tested is less than 5 in case of brick work & more than 2 in case of block work, compressive strength values indicated by the tests shall be corrected by multiplying with the factors as indicated below. Prism shall be tested after 28 days between sheets of 4mm plywood, slightly longer than the bed area of the prism, in a testing machine the upper platform of which is spherically seated. The load shall be evenly distributed over the whole top and bottom surface of the specimen and shall be applied at the rate of 350 to 700 kN/m. The load at failure should be recorded.

#### 3.1 Correction Factor for Different h/t Ratios

Ratio of height to thickness (h/t):	2.0	2.5	3.0	3.5	4.0	5.0
Correction factor for brickwork:	0.73	0.8	0.86	0.91	0.95	1.00
Correction factor for block work:	1.00	—	1.20	—	1.30	1.37

(Interpolation is valid for immediate values)

#### 3.2 Calculation of basic compressive strength, shear stress and tensile stress

Basic Compressive stress of masonry shall be taken to be equal to  $0.25 f'm$  where  $f'm$  is the value of compressive strength of masonry as obtained from prism test.

An extensive testing was done on this block masonry, which proves that this block masonry is better than brick-mortar masonry. Basic blocks strength is given in Table no 2.

The Prism Test was made with h/t ration of 3.3, as per Clause No 5.4.4 of I.S. 1905-1987 and load testing were done and the value ( $f'm$ ) was 9.9 N/sqmm, with the correction factor of 1.23, so the corrected value was 8.04 N/sqmm. The the basic compressive stress achieved was 2.01 N/Sqmm. The basic compressive stress of brick masonry of bricks of compressive stress of 7.5 N/sqmm with 1:6 (1cement :6 coarse sand mortar) was 0.59 N/sqmm.

The Result is encouraging but this is still not vetted (these needs to be extensilvly tested).

The tensile stress of the masonry given in is 1905 is 0.05N/sqmm for bending in vertical direction and 0.1 N/sqmm for bending in longitudinal direction .

The Shear stress ( $f_s$ ) given in IS 1905 as

$$f_s = 0.1 + f_d/6, \text{ where } f_d \text{ is compressive stress.}$$

The same way the tensile and shear stress values can be derived for the interlocking block masonry using the prism test of the perticular interlocking blocks based masonry.

#### 3.3 Relevant Indian Standards

The interlocking blocks (SEB and fly ash blocks) are in accordance with relevant Indian standards. The references are given in Table no 4.

#### 3.4 Structural Performance

To evaluate the structural performance of the Interlocking blocks masonry these test were conducted:

- Load Testing
- Wind load testing.

### **3.5 Test Conclusion:**

The Prism was made from Interlocking Block as per the procedure given in IS 1905, and the basic compressive stress was found to be quite satisfactory.

Though much Laboratory data is not available on the Structural Performance of this system, but this has been in use since a decade in India and has performed well, is the sole criterion for being a stronger masonry system. However many test like shake table, Shock Table besides the prism test on this masonry are done at many places and results were encouraging. However these are still under compilation stages.

This masonry, if is used with cement mortar, than it is governed by Indian Design Standard for Masonry i.e. IS 1905.

### **3.6 Construction Procedure**

A dry stacked interlocking masonry is laid on conventional strip footing. Foundation walls are built with blocks of higher strength laid in mortar bed or even conventional type foundation.

Hudco (Housing & urban development Corporation, a government of India undertaking) has done a large number of construction using Hydraform Interlocking and other type of SEB (Soil stabilized Blocks), throughout India (Gujarat Earthquake Rehabilitation Works, Vivekananda Kendra, Kanyakumari, Development works around Qutub Minar , Delhi and many more places and found these blocks suitable for masonry. However in all these places, cement slurry was used to join these blocks, as per IS 1905, as Indian Design Standards do not recognizes the Interlocking block based masonry, concept yet.

Different conventional finishes can be applied to suit the aesthetic needs of the owner. The Construction details are as per Figure No 2 & Figure No 4. The Horizontal Bands are as per Figure no 6 and vertical Bands are as per Figure no 9.

### **3.7 Suitability of Interlocking Block works in**

#### **3.7.1 Load Bearing Masonry**

Since blocks are on 220 mm width and can be made of block strength  $> 75 \text{ N/mm}^2$ , same can be safely used for Load Bearing construction. Depending on structural requirements of the building, appropriate RCC bands can be used. Extensive Tests have been conducted from time to time for conformity of dry stacked masonry in G+2 storey building. Fly Ash based interlocking blocks can be made of higher compressive strength to suit the Load bearing construction requirements beyond Ground floor to suit structural requirements. In terms of IS 1905, masonry can be done with thin mortar slurry of 1:3 to satisfy this requirement.

#### **3.7.2 Framed Structure Masonry**

Framed construction mainly require brick / block work to be used as an infill only, therefore dry stacked interlocking block work can be used in out walls of  $\pm 220 \text{ mm}$  thickness. For block work of lesser width it is recommended to use mortar slurry. Blocks have standard height of 115 mm makes it easier to design the beam height for required number of courses. Ends with beams and columns are same as in brick work.



**Figure 8.** Building with Hydraform Dry Stacked Interlocking Blocks

### 3.7.3 Reinforced Masonry

Interlocking blocks with horizontal and vertical cavity provide an ideal solution for using reinforcements to suit the structural design requirements, of reinforced masonry.



**Figure 9.** Vertical Steel in Masonry

### 3.7.4 Boundary Walls

Dry stacked Interlocking block work is well suited for this application and is very fast, aesthetic and cost effective. Depending on height, Area, application, Width and other parameters structural design can be done to adopt intermittent columns, and band can be designed. Conduit blocks can also be used for intermittent reinforcement to act as beam / Column.



**Figure 10.** Boundary wall with Interlocking Blocks

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- [1] Bansal, Deepak, CBRI ROORKEE, INDIA, Feb 2009
- [2] Dawar Deepak, Hydraform India Pvt Ltd; [www.hydraformasia.com](http://www.hydraformasia.com)
- [3] Gujarat State Disaster Management Authority, India, Guidelines
- [4] Hudco’s publications, India
- [5] Bureau of Indian Standards for relevant standards as under:

**Table 4.** Bureau of Indian standards

IS 12984: 1990	Fly –ash- lime bricks-specification
IS 2110: 1980	Code for practice for in situ construction of wall in building with soil cement
IS 1725:1982	Specification for soil-based blocks used in general building Construction.
IS 4326: 1983	Earthquake resistant design and construction of building code of practice
IS 3495: 1992	Method of tests of burnt clay-building bricks
	Part (1) Determination of compressive strength
	Part (2) Determination of water observation
	Part (3) Determination of efflorescence
IS 13759: 1993	Fly ash building bricks specification.
IS 1905: 1987	Code of practice for structural use of unreinforced masonry.
IS 1893: 2003	Indian standard for Seismic Zoning & Earthquake resistant design.
IS 5454: 1978	Method for sampling of clay building bricks.