Comparative Study on Interlocking Block Masonry and Conventional Brick Masonry under Different Experimental Investigations

[1]Meghana A Patankar, [2]Ankith Gowda, [3]Sandeep TD

[1]Assistant professor, New horizon college of Engineering

[2]Assistant Engineer, Indian Space Research Organization

[3] Assistant professor, New horizon college of Engineering

[1]patankar.meghana6@gmail.com,[2]ankithgowda@gmail.com,[3]Sandeeptd7@gmail.com

Abstract

Masonry in general is the construction of structure by using individual units which are laid and mortar is used for binding those units. One of the high durable types of construction is masonry. The common masonry materials are burnt clay bricks, stones such as marble, granite, concrete blocks, stabilized earth blocks, etc. The most commonly used masonry units are burnt clay brick (conventional brick) and concrete blocks. Interlocking blocks are the new improved innovative structural components used for construction of buildings which initiates mortar-less construction. These blocks can be produced both by mechanically as well as manually. These blocks bring about economical production, reduction in cost of labour and utilization of abundantly available materials for construction of structures for both urban and rural development. These blocks have grooves which lead to proper fixing of blocks (blocks will be locked on either side since grooves are provided). The assembling of these blocks does not require skill and can be assembled faster with high efficiency. In temporary structures, the dismantling is very simple and no part of the wall is destroyed. In this dissertation work, tests like water absorption test, dimensionality test, modulus of elasticity test, compression test on prisms, shear strength test on wallets are conducted for both interlocking block masonry and conventional brick masonry. The test results proved that interlocking block masonry gave better results than conventional brick masonry. Also, the design is being done to check the suitability of interlocking blocks in buildings and is found safe for up to G+4 storeys, that is interlocking blocks can be used for load bearing walls for up to 5 storeys.

Keywords: **Binding, interlocking blocks, mortar-less, grooves, water absorption, dimensionality, modulus of elasticity, compression, prisms, shear strength, wallets**.

1. Introduction

Masonry in general is the construction of structure by using individual units which are laid and mortar is used for binding those units. One of the high durable type of construction is masonry. The common masonry materials are burnt clay bricks, stones such as marble, granite, concrete blocks, stabilized earth blocks, etc. The most commonly used masonry units are burnt clay brick (conventional brick) and concrete blocks. Generally, masonry units possess high compressive strength, but masonry units will possess low tensile strength. Tensile strength can be increased by increasing the thickness of wall and providing columns (piers) at regular intervals.

1.2 Interlocking Block Masonry

Interlocking blocks are the new improved innovative structural components used for construction of buildings which initiates mortar-less construction. These blocks can be produced both by mechanically as well as manually. These blocks bring about economical production, reduction in cost of labour and utilization of abundantly available materials for construction of structures for both urban and rural development. These blocks have grooves which leads to proper fixing of blocks (blocks will be locked on either sides since grooves are provided). The assembling of these blocks does not require skill and can be assembled faster with high efficiency. In temporary structures, the dismantling is very simple and no part of the wall is destroyed.

2. Material and Methodology

2.1Cement

For good quality of mortar, the selection of Portland cement is very much important. Different brands of cement give different strength results due the variation in composition and fineness of particles. Strength development will be dependent on both cement characteristics and cement content. Birla Super Ordinary Portland cement of 53 grade confirming to IS: 12269-1987 is used in our investigation.

2.2 Fly Ash

In this particular case, fly ash was used to replace the cement for about 50%. Fly ash is a by-product of thermal power plant. Fly ash collected from Mettur thermal power plant is used for this study.

2.3 Sand

Crushed stone sand which is popularly known as manufactured sand (M Sand) passing IS: 480 sieves are used in this study. Sieve analysis is conducted as per specifications of IS: 383-1970 and IS: 2386 Part-I 1963.The sand used in this study comes under Zone IV.

2.4 Bricks

Bricks which are available will be having large variation in shapes and sizes. According to IS: 1077-1992, according to the dimensions, bricks can be classified as modular and non- modular bricks. Standard sizes of modular and non-modular bricks are
tabulated in table

Table 1: Standard sizes of modular and non-modular bricks

Modular Bricks		
Length (mm)	Width (mm)	Height (mm)
190	90	90
190	90	40
Non-modular Bricks		
Length (mm)	Width (mm)	Height (mm)
230	110	70
230	110	30

2.5 Casting of interlocking blocks

Fine aggregates that are stone dust and sand are mixed thoroughly with cement and fly ash and bought into semi-consistency by adding water in the pan mixer. This mix is transferred into the dual mould mechanical machine and pressure of 45 tons is applied to obtain the blocks of high compaction effort and density. The dimensions of the block is 300mm length, 150mm width and

150mm height. Here the mix proportion chosen with respect to cementitious material to the aggregates is 1: 6, the mix detail are given in table

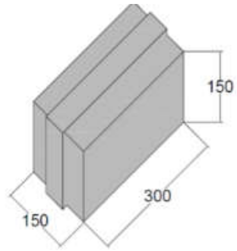

Fig 1:Dimensions of interlocking block.

Table 2: Quantity to be added to pan mixer for 10bricks

QUANTITY TO BE ADDED TO PAN MIXER (For 10 Blocks)	
MATERIAL	**QUANTITY(kg)**
Cement	7.937
Flyash	14.739
Aggregates	139.481
Water	13.400

3. Experimental Investigations

This deals with the different experimental studies conducted on interlocking block masonry and conventional brick masonry.

The experimental studies conducted are:

1. Compression test on interlocking blocks and conventional bricks.
2. Water absorption test on interlocking blocks and conventional bricks.
3. Dimensional test on interlocking blocks and conventional bricks.
4. Modulus of elasticity test on interlocking blocks.
5. Compression test on prisms of both interlocking block masonry and conventional brick masonry.
6. Wallet test to find the shear strength of both interlocking block masonry and conventional brick masonry

3.1 Compression test of Interlocking Blocks

The compression test of interlocking blocks was done after 28 days of curing for three samples. Steel plates were placed on the grooves of the interlocking block. The typical test setup is shown in figure. The results of the compressive strength are tabulated in table. According to the specifications given in IS: 2185 (Part 1)-2005, the value of compressive strength should not be less than 4 N/mm2.

Fig 2: Compression test setup of Interlocking and Compression test setup of Interlocking Block

3.2 Compression test of Bricks

Compressive strength for bricks is done for three specimens. The factors affecting the compressive strength of bricks are the ingredients, method of manufacture of the brick and rate of loading. Voids on the surface of the brick were filled with cement mortar. The test is performed by proper packing and by providing steel plate of 15mm thick on both sides while testing. According to the specifications of IS: 1077 – 1992 the minimum compressive strength should not be less than 3.5 N/mm2.

Fig 3: Compression test setup of normal brick

3.3 Water Absorption test of Interlocking Blocks

Water absorption test of interlocking blocks were conducted as per the specifications of IS: 2185(part1)-1979, which specifies that the interlocking concrete blocks should not absorb more than 10% of water. The results obtained are satisfied according to this code

3.4 Water absorption of Conventional Bricks

Water absorption of conventional bricks was calculated as per the specifications of IS: 3495 (Part II) – 1992, which specifies that the bricks should not absorb more than 20% of water. The results obtained are satisfied according to this code.

3.5Dimensional test of Interlocking Blocks

Dimensional test of interlocking blocks was carried by arranging 12 blocks lengthwise on an even surface. The length, width and height of the arranged blocks are measured and tabulated The typical figure is shown in figure Standard size for 12 interlocking blocks is 3600 mm in length, 150 mm width and 150 mm height. The test was carried out for three samples.

Fig 4: Dimensional test of Interlocking Blocks

3.6 Dimensional test of Conventional Bricks

Conventional bricks which are available will be having large variation in sizes and shape. IS-1077 (1992) classifies conventional bricks as modular and non-modular bricks.

The results obtained shows that the bricks neither belong to modular bricks nor nonmodular bricks. The width and height of the bricks considered are very much closer to non-modular bricks

3.7 Modulus of elasticity of Interlocking Blocks

Modulus of elasticity of interlocking blocks is found by fixing strain gauge to the block. The strain gauge reading was noted for every 1000 kg increment in load. The load was applied through compression testing machine. Load vs deformation graph is plotted, the slope of this graph gave the modulus of elasticity of interlocking block. The modulus of elasticity (E) is found to be 2021.2121 N/mm2

3.8 Details of Specimens

1.Three interlocking block masonry prisms of dimension 470 (height) x 300 (length) x 150 (width) mm were cast. Cement slurry was used for bonding between the blocks. Cement slurry was mixed by trial and error method.

2.Interlocking block masonry wall of dimension 910 (length) x 810 (height) x 150 (width) mm is casted

3. Conventional brick masonry prisms of dimension 490 (height) x 220 (length) x 100 (width) mm are casted. Here cement sand mortar of 1 : 6 ratio is considered.

4. Conventional brick masonry wall of dimension 900 (length) x 860 (height) x 100 (width) mm is casted. Here cement sand mortar of 1 : 6 ratio is considered.

3.9 Details of Tests and Testing Setup

In this study, mainly two tests were conducted namely compression test on masonry prisms and shear test for wall. These two tests were conducted for both Interlocking Block masonry and Conventional Brick masonry. According to the loading arrangements and test setup the tests were classified. The following tests are conducted:

- Compression test on interlocking masonry prisms and conventional brick masonry prisms.

- Wallet test to find the shear strength of interlocking block masonry and conventional brick masonry.

3.10 Compression test on Masonry Prisms

According to the specifications of IS: 1905 – 1987, masonry prisms should be of minimum 40 cm height with height/thickness (h/t) ratio between 2 and 5 to determine the compressive strength of masonry prisms. Hence Interlocking block masonry prisms of size 470 (height) x 300 (length) x 150 (width) mm and Conventional brick masonry prisms of size 490 (height) x 220 (length) x 100 (width) mm were considered in this investigation.

Interlocking block masonry prisms were casted in stack bond with height/thickness (h/t) ratio 3.13. Three prisms were casted. Cement slurry mixed with trial and error is used for bonding. Cement slurry joint thickness of nearly 5 mm was maintained. The prisms were cured for 28 days. The specimens were tested in universal testing machine of 100T capacity.

3.11 Test on wall

It is intended to construct the moderately sized wall to find the shear strength parameters of the interlocking block masonry and conventional brick masonry. Interlocking block masonry wall of size 910 mm (length), 810 mm (height) and 150 mm (width) is casted in stack bond pattern by using cement slurry for bonding and conventional brick masonry wall of size 900 mm (length), 860 mm

(width) is casted in English bond pattern by using cement sand mortar of 1:6 ratio.

3.11.1 Experimental setup

The setup consists of a wall (interlocking block masonry wall and conventional brick masonry wall) of the above-mentioned dimensions. The wall is constructed on the 75 mm thick concrete base. The wall is constructed in such a way that it is resting between two vertical members which are expected to carry horizontal loads. At the loading face of the wall, steel plate which is as high as the wall is fitted. The lateral load is applied on the face where the steel plate is fixed with the help of the screw jack of 350 kN capacity. The load is measured with the help of proving ring of 100 kN capacity which is having the least count of 134.4 N. Before applying the load, we have to make sure that the wall is fixed at the other ends, except the loading face to avoid overturning and tilting.

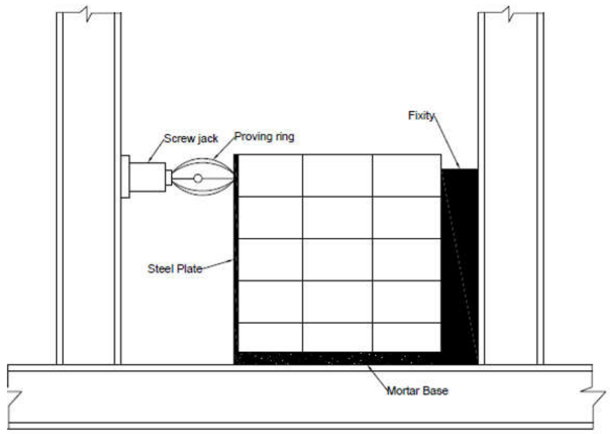

Fig 5: Testing arrangement of wall to find shear strength

3.10.2 Testing Procedure

The procedure includes the application of horizontal load with the help of screw jack. The load is applied on the tension face of the wall (the face where the steel plate is fixed) at about 45 to 55 mm from top of the wall. The rate of loading is kept constant at the rate of 1344 N for every increment. For loading, 350 kN capacity screw jack is used and 100 kN capacity proving ring is used.

4. Results and discussions

Different tests were conducted to study the behavior of interlocking block masonry and conventional brick masonry. This covers the behavior of specimen under each test.

4.1 Compressive strength of interlocking and conventional brick block masonry prisms

Table 3: Compressive strength of interlocking block

Sl No	Specimen size l x t x h (mm)	Load (N)	Compressive Stress (N/mm^2)	Normalized compressive stress (N/mm^2)	Mode of failure
1	300 x 150 x 470	89000	1.98	2.40	Crushing
2	300 x 150 x 470	92000	2.044	2.47	Crushing
3	300 x 150 x 470	90000	2	2.43	Crushing

Table 4: Compressive strength of normal block

Sl No	Specimen size l x t x h (mm)	Load (N)	Compressive Stress (N/mm^2)	Normalized Compressive Stress (N/mm^2)	Mode of failure
1	228× 108× 490	62791	2.55	2.52	Splitting
2	220× 100× 495	53072	2.41	2.38	Splitting
3	220× 100× 498	55760	2.53	2.50	Splitting

The average compressive strength of interlocking blocks is found to be 10.76 MPa, which is satisfied as per IS: 1905-1987 which specifies the minimum compressive strength should be 4 MPa. The average compressive strength of conventional bricks is found to be 6.65 MPa, which is satisfied as per IS: 1077 – 1992 which specifies the minimum compressive strength should be 3.5 MPa.

Fig 6: Failure mode of interlocking and normal brick

4.3 Test on Interlocking block masonry wall and conventional brick masonry wall (wallet test)

Table 5: Test result data for interlocking block masonry wall

Sl No	Divisions	Load (kN)
1	0	0
2	40	4.84
3	80	10.55
4	120	16.26
5	160	21.98
6	200	27.69
7	240	33.40
8	280	39.11

The maximum shear stress for the maximum shear force (load at failure) as generated by elemental beam theory is given by 9.6555×10^{-6}

The maximum shear stress of the interlocking block masonry wall is 0.377 N/mm^{2}.

Table 6: Test result data for conventional brick masonry wall

Sl No	Divisions	Load (kN)
1	0	0
2	20	1.98
3	40	4.84
4	60	7.70
5	80	10.55
6	100	13.41
7	120	16.26
8	140	19.12
9	160	21.98
10	180	24.83
11	200	27.69
12	220	30.96

The maximum shear stress for the maximum shear force (load at failure) as generated by elemental beam theory is given by 9.6555×10^{-6}

The maximum shear stress of the interlocking block masonry wall is 0.377 $N/mm^{2.}$

Shear strength equation is generated from the elemental beam theory and the equation is of the form $6.09\times 10^{-6.}$ The shear stress of interlocking block masonry wall is found to be 0.377 MPa. The shear stress of conventional brick masonry wall is found to be 0.188 MPa.

4.4 Water Absorption test of Interlocking Blocks and conventional bricks

Table 7: Water Absorption test of Interlocking Blocks

Sl No	Dry weight of interlocking block	Wet weight of interlocking block	Water absorption (%) by mass
	M1 (gms)	M2 (gms)	[(M2 – M1)/M1]x100
1	12110	12950	6.93
2	12234	13100	7.07
3	12902	13920	7.89
Average Water Absorption			7.29%

Table 8: Water Absorption test of normal Brick

Sl No	Dry weight of Brick	Wet weight of Brick	Water absorption (%) by mass
	M1 (gms)	M2 (gms)	[(M2 – M1)/M1]x100
1	3002	3332	10.99
2	3124	3442	10.18
3	3040	3392	11.58
Average Water Absorption			10.91%

The average water absorption of interlocking blocks is found to be 7.79%, which is satisfied as per IS: 2185(part1)-1979 which specifies the solid interlocking blocks should not absorb more than 10% of water.
The average water absorption of conventional bricks is found to be 10.91%, which is satisfied as per IS: 3495 (Part II) – 1992 which specifies the conventional bricks or burnt bricks should not absorb more than 20% of water.

4.5 Dimensional test of Interlocking Blocks and Conventional Bricks

Table 9: Dimensional test of Interlocking Blocks

Sl No	Length (mm)	Width (mm)	Height (mm)
1	3700	150	154
2	3670	150	153
3	3690	150	154

Table 10: Dimensional test of normal brick

Modular Bricks		
Length (mm)	Width (mm)	Height (mm)
190	90	90
190	90	40
Non-Modular Bricks		
Length (mm)	Width (mm)	Height (mm)
230	110	70
230	110	30

The dimensional test on interlocking blocks is conducted by arranging 12 blocks length wise and the length, width and height is measured. The length is 3686 mm which is supposed to be 3600 mm, width is 150 mm which has no error and the height is 153.6 mm which is supposed to be 150 mm. The errors here are relatively small. The dimensional test on conventional bricks is conducted by arranging 20 bricks lengthwise as per the code IS-1077 (1992), and the length, width and height is measured. Conventional bricks are further classified as modular and non-modular bricks based on the dimension. The measured length is 4413 mm, width is 2180 mm and height is 1426 mm. The results obtained here belong to neither modular bricks nor non-modular bricks. However, the results are much closer to non-modular bricks.

4.6 Modulus of elasticity

The modulus of elasticity of interlocking blocks is found to be 2021.2121 MPa.
The modulus of elasticity of bricks is found to be 600 MPa.

5 Suitability of interlocking blocks in Buildings

Aim: To know the number of floors that can be built using Interlocking blocks.

Assuming the following conditions:

1. 4 storey (G+3) building.
2. RCC slab of 150mm thick and 65mm thick lime terracing.
3. Effective span of 3m.
4. Live load on floor = 2 kN/m^2.
5. Live load on roof = 1.5 kN/m^2.
6. Floor finish – 0.3 kN/m^2.
7. Weight of lime terrace – 1.7 kN/m^2.
8. Unit weight of RCC – 25 kN/m^3.
9. Unit weight of Block – 19.25 kN/m^3.
10. Dimension of block – 300 x 150 x 150 mm

Dead weight of Interlocking block wall = 4 * 1 * 0.3 * 3 * 19.25 = 69.3 kN

Dead weight of RCC slab = 4 * 1 * 0.15 * 3 * 25 = 45 kN

Dead weight of terrace = 1 * 1 * 1.7 * 3 = 5.1 kN

Live load on floor = 3 * 1 * 2 * 3 = 18 kN

Live load on roof = 1 * 1 * 1.5 * 3 = 4.5 kN

Floor finish = 3 * 1 * 0.3 * 3 = 2.7 kN

Total load = 145 kN

Actual stress at plinth level = = 0.48 N/mm^2.

Consider an Interlocking block of strength 10.76 N/mm2 and assuming H-2 grade mortar.

From table 8, pg. 16, IS 1905-1987

Basic Compressive strength, (fb) = 1.03 N/mm2.

Allowable Stress = fb * ks * ka * kp

To find stress reduction factor, (ks)

From IS 1905-1987, clause 5.4.1.1, pg. 16

Slenderness ratio = 2.25/ 0.15 = 15 < 27 (Table 7, Pg. 15)

Assuming eccentricity (e) = 0, for ratio of 15

From table 9, pg. 16, IS 1905-1987

Stress reduction factor, ks = 0.755.

To find area reduction factor, ka

From IS 1905-1987, Clause 5.4.1.2, pg. 16

Area of section = 1 * 0.15 = 0.15 m2 < 0.2 m2.

Ka = 0.7 + (1.5 x 0.15) = 0.925

Therefore area reduction factor, ka = 0.925

To find shape reduction factor, kp

From IS 1905-1987, Clause 5.4.1.3, pg. 16

Height to width ratio = 150/150 = 1

From table 10, IS 1905-1987, pg. 17

Upto 1 ratio the value of kp for 10 N/mm2 block strength is 1.1

Therefore, kp = 1.1

Allowable stress = 1.03 * 0.755* 0.925 * 1.1= 0.7912 N/mm2 > 0.48 N/mm2, hence safe.

Similarly we can do the analysis with different grades of mortar and it is found

that
structure can be built safely till 4 storeys.
Similarly we can do analysis for 5 storeys with block strength of 10.76 N/mm2
and mortar
grades of H2, M1 and M2 type, it is found that allowable stress for all grades
mortar is
more than actual stress and hence is safe to build up to 5 storeys (G+4).

7. Conclusions

1) The average compressive strength of interlocking blocks which is 10.76 MPa which is found better than the compressive strength of conventional bricks which is 6.65 MPa.
2) The average water absorption of interlocking blocks is found to be 7.79% and that of the conventional bricks is 10.91%. Interlocking blocks absorb less amount of water comparing to conventional bricks.
3) The dimensional test is conducted on interlocking blocks and conventional bricks. The dimensional errors are found to be relatively small in interlocking blocks and the dimensions of conventional bricks closely belong to non-modular bricks.
4) The modulus of elasticity of interlocking block is found to be 2021.2121 MPa and that of the conventional brick is 600 MPa.
5) The compressive strength of the interlocking block masonry prisms is found to be 2.43 MPa and that of the conventional brick masonry prisms is found to be 2.46 MPa. Here the results of both interlocking blocks and conventional bricks are more or less the same.
6) The maximum shear strength of interlocking block masonry wall is found to be 0.377 MPa and that of the conventional brick masonry wall is found to be 0.188 MPa. Here the shear strength of interlocking blocks is found better.
7) The suitability of interlocking blocks wall for upto 5 storeys is designed as per IS: 1905-1987 and is found safe. That is we can go upto 5 storeys by using interlocking blocks for load bearing walls.