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ACCELERATED MASONRY CONSTRUCTION WITH INNOVATIVE INTERLOCKING BLOCKS

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Abstract

The conventional masonry construction for walls and foundations using bricks/blocks and mortar is very slow to meet i) the ever increasing demand for housing, which is a growing concern in most of the developing countries, and ii) present day rate of construction required by the industry. Hence there is a need to accelerate the masonry construction process. Several interlocking blocks/mortarless masonry systems have been reported in literature using blocks of different geometry, ranging from normal weight to lightweight and solid to hollow block. These systems are essentially applicable for wall construction. No attempt has been made to accelerate the construction of foundation for the masonry walls. For continuity in construction an interlocking between wall and foundation is preferred. This paper discusses the conceptual design of such a system for foundations and walls using interlocking blocks developed at IIT Madras and the construction methodology. The wall system with interlocking blocks has been proof tested in the laboratory for its constructional, structural and functional performance and these results are summarized. Results show that this wall system improves productivity in construction, enhances structural behaviour and has comparable functional performance to conventional brick masonry.

Keywords

Masonry , Mortarless masonry, Interlocking block, Accelerated construction.

1 Introduction

In general building construction, for load bearing and non-load bearing walls and as in-fills in RCC frames, masonry using stone, brick, hollow concrete blocks have been widely adopted. Structural masonry, apart from performing simultaneous function of carrying load and enclosing space, possesses a high degree of fire resistance, thermal and sound insulation, excellent durability and minimum maintenance cost. The limitations of conventional masonry construction are i) labour intensive, ii) slow due to large number of mortar joints, iii) heavy due to use of high density and low-strength units. Behaviour of masonry under compression is greatly influenced by the presence of mortar bed joints. The efficiency factor (masonry strength / brick strength) is very

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low, i.e. around 0.3 - 0.4. In addition, poor workmanship results in non-uniform thickness of bed joints, which further reduce the strength of masonry (Hendry, 1990). Constructional difficulty like squeezing out of freshly laid mortar due to self-weight of masonry resulting out-of-plumb masonry and functional performance problem like moisture penetration due to the porous nature of the mortar joints are also present. Adoption of block masonry increases the rate of construction to a certain extent and the reduction in number of joints results in relatively higher efficiency factor (0.6-0.75 (Drysdale et. al. 1994)). The construction output of conventional brick/block masonry is not able to cope up with the present day requirement of the construction industry, viz., mass housing requirements and large-scale post-disaster reconstruction activities. Hence there is a need to accelerate the construction process.

Several attempts have been made to accelerate the rate of construction and to reduce labour intensiveness, ranging from increasing the size of masonry units to non-conventional methods. Adoption of non-conventional methods of masonry construction using interlocking blocks is a potential alternative to conventional masonry to accelerate the construction process.

2 Interlocking block masonry

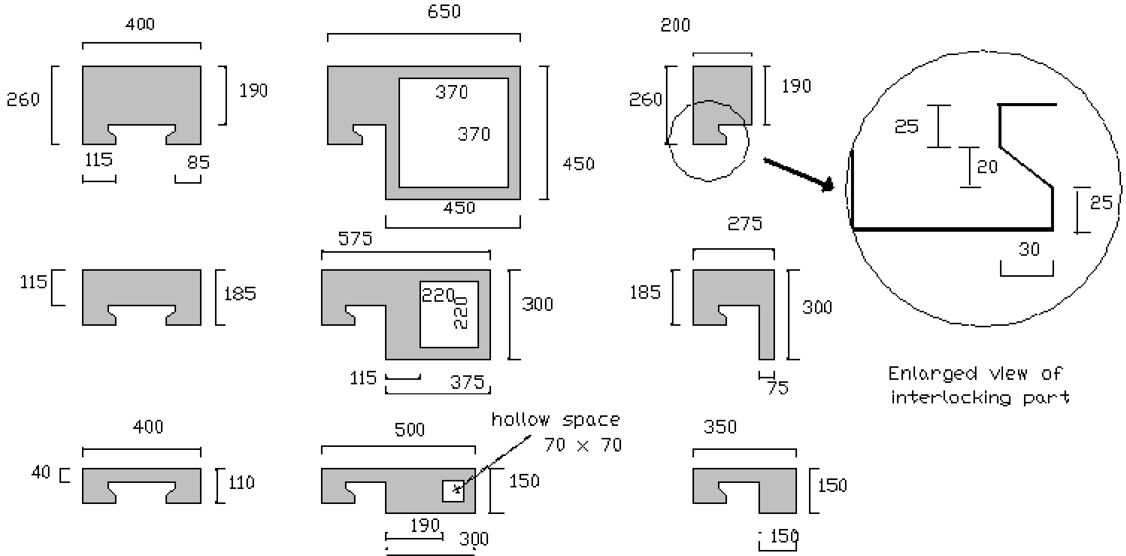
A review of the literature reveals a strong worldwide interest in the development of mortar-less masonry construction (Drysdale and Gazzola, 1991; Crofts, 1993; Oh, 1994). Accelerated mortarless construction developed or being used in USA, Canada, China, Peru, South Africa and by various researchers vary in material, geometry and interlocking mechanisms. A classification of such systems along with the salient features of each system is presented by Ramamurthy and Nambiar (2004). The advantages of mortar-less interlocking block masonry are (i) block laying is very simple; (ii) faster rate of wall erection leading to increased productivity; (iii) dimensional variation due to workmanship is reduced and (iv) superimposed load can be applied on the wall earlier. The technology of most of the interlocking block manufacture is patented and blocks have complex geometries requiring sophisticated production methods. These systems are essentially applicable for wall construction only. Hence there is a need to accelerate the construction of foundation for the walls. In addition, there is a need for interlocking between the different steps of foundation and foundation to wall for continuity in construction. So the geometry of interlocking blocks are to be developed keeping in view of the above factors. In a study at IIT Madras, India, an integrated system of foundation wall block has been developed and evaluated. This paper highlights the salient aspects of this system.

3 The integrated foundation-wall block system

The interlocking blocks developed, **IITM**-**I**ntegrated **F**oundation **W**all-**S**olid **I**nter**L**ocking **BLOCK** (IITM-IFW- SILBLOCK), for accelerated masonry construction, has simplicity of shapes and a limited number of basic blocks (stretcher, jamb, corner block). The salient feature of the block is that interlocking is possible between foundation steps and foundation and superstructure (wall). Walls and foundation assembled with these blocks have interlocking features in both the horizontal and vertical directions, ensuring discontinuity of bed joints and cross-joints from inner to outer face. Fig.1 shows the shape, dimensional details of units used for a typical foundation and walls construction. The foundation block size depends on number of steps provided for the foundation and calculated from the size of wall block units. The blocks shown in Fig.1 are for a foundation with two steps and for a wall thickness of 150 mm. Size of the foundation blocks are obtained by increasing the thickness of wall block by 75mm for

Stretcher Blocks | Corner Blocks | Jamb Blocks

(All dimensions are in millimetres)



All Blocks have the same interlocking features and a height of 200 mm
(First raw – foundation step I, second raw – foundation step II and third raw – wall blocks)

FIG 1 Shape and Dimensional Details of Blocks

each step which is the offset for the steps of foundation, maintaining the interlocking features unaltered. In this way the wall and foundation blocks can be proportioned to suit any wall thickness. The only limitation is that the weight of the foundation block increases with the width of the foundation. The corner blocks are provided with hollows to reduce the weight of the blocks. Another important feature of the block system is the single type of corner block that allows formation of T, L or cruciform configuration of the foundation/wall by placing it in the appropriate orientation in respective layers.

4 Construction method

The assembly for the foundation begins by placing the foundation blocks on one face (inner or outer) on a layer of bed mortar 50 mm thick, which enables accurate levelling of the first course. Then, these blocks are embedded in concrete for half of their depth (i.e.100 mm) by pouring concrete for that depth, so that half of the block depth will be projecting outside. The top of this concrete is levelled and the foundation blocks are placed on the opposite face. In the first layer, the corner unit is placed to have interlock in one direction of the foundation and in the next layer perpendicular to the first so as to have a locking in the second direction. In the subsequent layers this process is done cyclically. In the case of a T-joint, the corner blocks are placed in appropriate orientation. The hollow cores in the corner blocks can be grouted, if required, after completion of each step of the foundation and then the wall. The construction progresses with insertion/ sliding of blocks alternately at inner and outer faces interlocking each other and the steps of the foundation and foundation and wall and finally ends up with half height of block projecting up when the wall is completed. This half height can be filled with concrete after placing a wooden plank as formwork on that side. The advantage of this concreting is that the casting of half-height blocks for the entire construction can be eliminated. Moreover, horizontal reinforcements can be incorporated in this layer of concrete so that this portion will act as a beam/belt at the

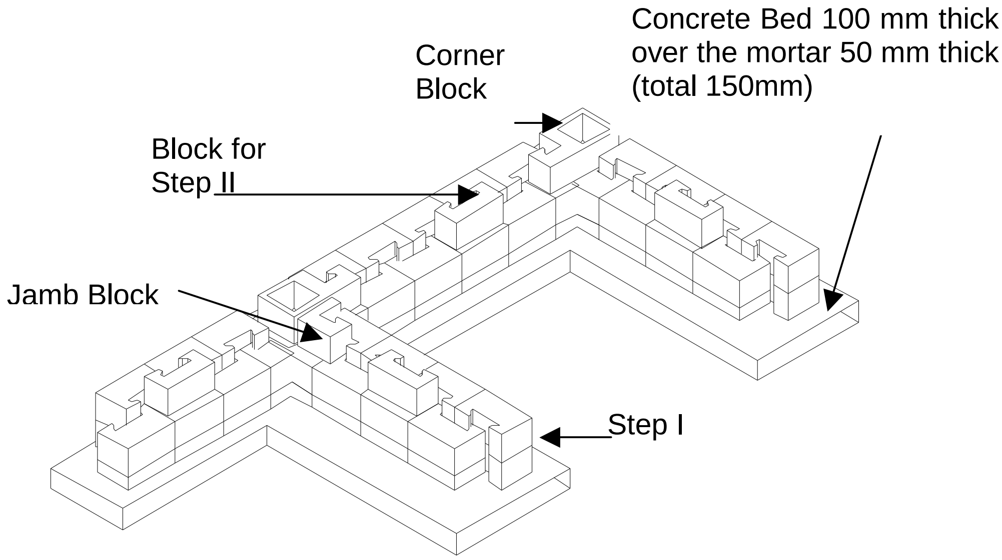


FIG 2 (a) Completed Form of Foundation (Step I)

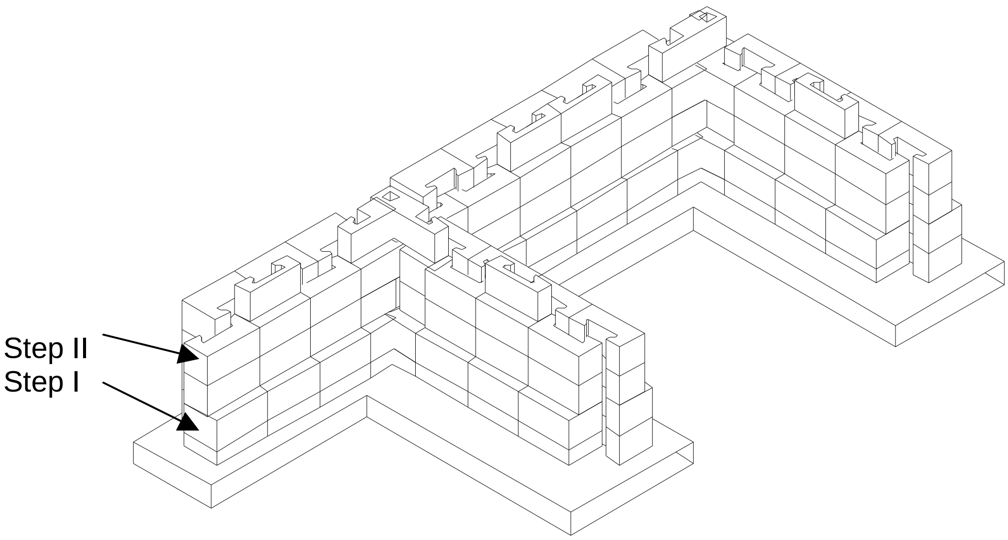


FIG 2 (b) Completed Form of Foundation (Step I and II)

top of the wall. The block stacking procedure mentioned above ensures discontinuity in bed joints and cross-joints from the inner to the outer face. The various stages of construction of a typical stepped foundation of 300 mm and 450 mm width and a wall 150 mm thick are shown in Figs 2(a) through 2(c).

5 Performance evaluation

Performance evaluation was carried out on wall units only. The influence of two types of bedding, Dry-stacking and Thin jointing, was studied through tests on prisms/wallets. In Dry-stacking the blocks were simply dry stacked utilizing the physical interlocking

features and the joints pointed. In Thin jointing, to ensure uniform seating between blocks of successive layers, slurry bedded thin-jointed masonry was adopted.

5.1 Constructional performance

Crew-based work sampling was done to observe major difference in the work patterns between conventional brick/block masonry and interlocking block masonry. Table-1 presents the results of the productivity study used to evaluate the construction performance (compare the output per productive hour) of the interlocking block masonry and conventional masonry (Anand and Ramamurthy, 2003). Productivity enhancement of 80-120% was observed for dry-stacked masonry and 60-90% more for

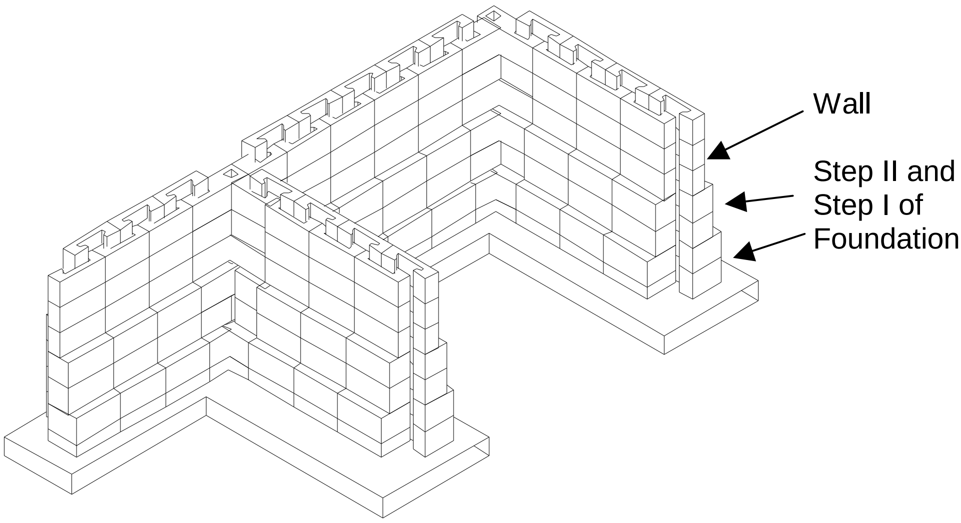


FIG 2 (c) Completed Form of Foundation and Wall

thin-jointed interlocking block masonry compared to brick masonry. Even though the manufacturing costs of interlocking blocks are marginally higher than conventional blocks, it is more than offset by the reduction in labour, construction time and material requirement (savings in mortar). Also, this blocks are most suited post-disaster reconstruction as i) the casting of blocks can be done at the site itself on a self-help basis or through a small centralized casting yard to cater to a group of houses, and ii) the manufacturing process does not require specially trained/skilled labour. This process eliminates transportation of blocks. Unlike conventional mortar-bedded brick masonry, the construction of interlocking block masonry does not demand high levels of trained labour. The construction of interlocking block masonry can be carried out with semi-skilled labour itself.

Table 1. Comparison of Construction Output

Type of masonry	Overall output (m^2/h)	Contributory work time (as fraction)	Net output (m^2/ productive hour)
Brick masonry	0.81	0.84	0.96
Dry-stacked interlocking block	1.69	0.72	2.33
Thin-jointed interlocking block	1.47	0.78	1.89

5.2 Structural performance

Structural performance evaluation (Ramamurthy and Anand, 2001) of dry- stacked and thin-jointed masonry prisms/wallettes under axial compression and flexural loading were carried out. The results of axial compressive strength and of flexure loading parallel to bed joint and normal to bed joint are presented in the Table-2. This shows that the masonry using interlocking blocks results in a relatively higher efficiency factor than mortar bedded masonry. Test results indicate that contrary to conventional mortar-bedded masonry, the flexural capacity of interlocking masonry normal to their bed joint is higher than that parallel to bed joint. Under axial compression as well as flexure, thin-jointed masonry has higher efficiency over dry-stacked masonry.

Table 2. Structural Performance of Interlocking Block Masonry

Behaviour under axial compression				
Mean block strength (MPa)	Compressive strength (MPa)		Efficiency factor (ratio of masonry strength to block strength)	
	Dry-stacked masonry	Thin-jointed masonry	Dry-stacked masonry	Thin-jointed masonry
12.9	9.16	12.22	0.70	0.94
8.41	6.67	7.97	0.79	0.95
Flexural strength (MPa)				
Mean block strength (MPa)	Loading parallel to bed joint		Loading perpendicular to bed joint	
	Dry-stacked masonry	Thin-jointed masonry	Dry-stacked masonry	Thin-jointed masonry
8.41	0.61	1.05	0.28	0.50

5.3 Functional performance

The functional performance was evaluated through water penetration resistance adopting ASTM E 514-90. The influences of type of bedding (dry stacked and thin jointing) and surface finishes (stucco and plaster on one side or both sides) were studied (Anand and Ramamurthy, 2003). Table-3 presents a relative comparison of total leakage and percentage dampness for alternative masonry construction investigated with plastering on the tested face of the wall at 500 Pa test pressure at the end of test period (after 4 h). With surface finishing on the external face, interlocking block masonry's performance is comparable with respect to leakage and better with respect to dampness than conventional masonry.

Table 3. Comparison of Functional Performance

Type of construction	% Mean Dampness	Mean Total leakage (ml)
Brick masonry	24.1	340
Dry-stacked interlocking block masonry	4	569
Thin-jointed interlocking block masonry	10.1	507

6 Conclusions

- The main features of this unique integrated foundation-wall interlocking block system are: integration of foundation and wall, simplicity in shape and

interlocking in vertical and horizontal direction, which make it suitable for mass housing and post-disaster rapid reconstruction.

- Test results show that the wall system using interlocking blocks improves productivity in construction, enhances structural behaviour
- The functional performance is comparable with conventional brick masonry.
- The foundation blocks are heavier which can be overcome through adoption of lightweight high strength blocks.

References

Anand, K.B. and K. Ramamurthy, 2003, Water Permeability Assessment of alternate masonry systems, Building and Environment, 2003, 38, 947-957.

Anand, K.B. and K. Ramamurthy, 2003, Laboratory based productivity study on alternative masonry systems, ASCE Journal of Construction Engineering and Management, 129(3), 237-242.

Crofts, F.S, 1993, State of Art of Mortarless Concrete Masonry in South Africa, Proceedings of the 6th North American Masonry Conference, Philadelphia, 875-884.

Drysdale, R.G and E.A Gazzola, 1991, Strength and Deformation Properties of a Grouted Dry-stacked, Interlocking, Concrete Block System, Proceedings of 9th International Brick/Block Masonry Conference, Berlin, October, 164-171.

Drysdale R.G, Hamid A.A and Baker L.R, 1994, Masonry Design- Behaviour and Design, Englewood Cliffs, Prentice Hall.

Hendry, A.W, 1990, Structural Masonry, Macmillan Press, United Kingdom.

Oh, K.H, 1994, Development and Investigation of Failure Mechanism of Interlocking Mortar less Block Masonry System, PhD Thesis, Drexel University, Pennsylvania.

Ramamurthy, K and K B Anand, 2001, Influence of Construction Method on the Behaviour of Interlocking Block Masonry, Journal of Institution of Engineers (India), Civil Engineering Division, 81, 167-173.

Ramamurthy, K, and E.K.Kunhanandan Nambiar, 2004, Accelerated Masonry Construction- Review and future prospects, Progress in Structural Engineering Materials, 6, 1-9.