Chapter 14
Interlocking in Mud Blocks for Improved Flexural Strength

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14.1 Introduction

Buildings associated with the construction of dwellings up to G + 3 stories can be built as load-bearing masonry structures. An important parameter for load-bearing construction is compressive strength. Another important parameter for such a type of load-bearing wall construction is flexural strength. Flexural strength of a masonry wall is that strength which resists the horizontal components of forces so as to ensure the stability of structure against overturning.

Flexural strength deserves special attention since adequate knowledge on strength parameters can allow structural design engineers to check the adequacy with suitable design methods. Such an approach is gradually becoming a necessity as disaster resistance of dwellings is given considerable attention these days in order to minimize causalities and damages. High lateral loads are generally caused under unusual conditions such as cyclones, floods and earthquakes. Hence, flexural strength is a useful property in resisting lateral loads.

In normal plain blocks, the flexural strength is mainly governed by the bond strength between the mortar and the block. But by providing interlocking in blocks, flexural strength can be improved because here not only the bond strength governs but also the interlocking effect.

Mortar used for masonry structures consists of sand, cement and water. General masonry mortars used are cement mortar, cement–lime mortar, soil–cement mortar, cement–pozzolana mortar, lime–pozzolana mortar, mud mortar-Jagadish (2007).

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Cement mortars are widely being used for masonry construction. Very often, such mortars are not satisfactory due to lack of plasticity, high suction from bricks and fast-setting character. Combination of mortars like cement–lime mortars and soil–cement mortars eliminates these problems of cement mortar.

14.2 Literature Review

Venu Madhava Rao et al. (1996) examined the effect of mortar composition and strength of masonry flexural bond strength using stabilized mud blocks, stabilized soil–sand blocks and burnt brick, and they concluded that the increase in mortar strength increases flexural bond strength for cement mortar, irrespective of the type of masonry unit. They also found that combination mortars, such as soil–cement mortar and cement–lime mortar, give better bond strength compared to cement mortars.

Anand and Ramamurthy (2000) studied on durability and performance aspects of interlocking block masonry and concluded that the flexural capacity of interlocking block masonry normal to bed joint is higher than parallel to bed joints.

Sarangapani et al. (2005) studied enhancing the bond strength of brick–mortar and masonry compressive strength with and without bond-enhancing parameters, and they have concluded that using regular cement mortars of 1:6 proportion leads to low flexural bond strength of less than 0.10 Mpa; however, it can be increased by coating the surface of the brick with cement slurry/epoxy resin, increasing area of frog.

Venkatarama Reddy et al. (2007) studied on enhancing the bond strength and characteristics of soil–cement block masonry, and they have concluded that by providing a rough textured surface, surface coatings like cement slurry and epoxy resin increase the bond strength.

Konthesingha et al. (2007) attempted to understand bond and compressive strength of masonry for three different types of sand and bricks locally available in Sri Lanka, and also, the effect of soaking time of bricks was studied, and they have concluded that higher shear bond strength can be achieved by increasing the tensile bond strength depending upon type of brick.

Jayasinghe and Mallawarachhi (2008) studied on flexural strength of compressed stabilized earth masonry materials such as compressed stabilized earth bricks, plain solid blocks, interlocking solid blocks, interlocking hollow blocks and rammed earth with low levels of pre-compression load, and they concluded that CSE bricks, blocks and rammed earth can be considered as a safe alternative up to two-storied buildings.

14.3 Experimental Programme

14.3.1 Raw Materials

14.3.1.1 Soil

The locally available soil sample was used which was red in colour with semi-hard lumps, and its grain size distribution was determined. For doing grain size distribution analysis, soil passing through 4.75-mm sieve was used. The sand content was found to be 63% in the soil sample when wet sieve analysis was carried out.

14.3.1.2 Sand/Quarry Dust

For the production of blocks and prisms, sand or quarry dust may be used to reduce the clay content in the soil. Here, quarry dust was used by considering the availability and economy. Ten percentage of total weight of soil taken was added so as to reduce the clay content in the mix. Sand was used in the construction of prisms (mortar joints).

14.3.1.3 Cement

Cement has been used as a stabilizer for preparing the blocks and also as binder for various mortar combinations in mortar joints. Seven percentage of cement was used as stabilizer for the production of blocks. In present work, ordinary Portland cement of 53 grade was used both as stabilizer and binder.

14.3.1.4 Lime

Lime was used only for the mortar joints in preparation of masonry prisms. Locally available fresh lime was procured and slaked. Slaked lime passing through I.S. 1-mm sieve was used.

14.3.1.5 Blocks

Interlocking blocks are shown in Figs. 14.1 and 14.2. The depth of interlocking provided is 20 and 30 mm. These blocks have projections in bottom and recess at the top so that one projection of the block will accommodate at the bottom recess of another block. The area of projection and recess is 100 × 190 mm and 90 × 190 mm for 20- and 30-mm-depth interlocking blocks, respectively. The projections and recess

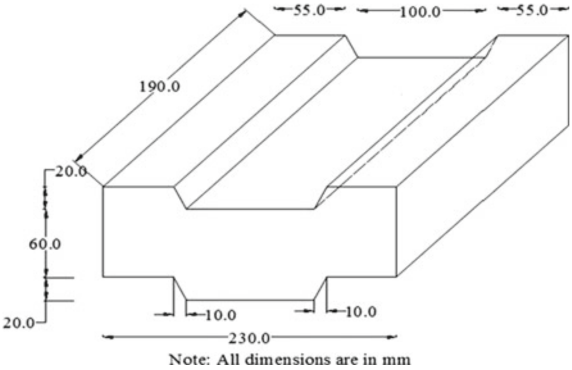

Fig. 14.1 Details of 20-mm-depth interlocking blocks

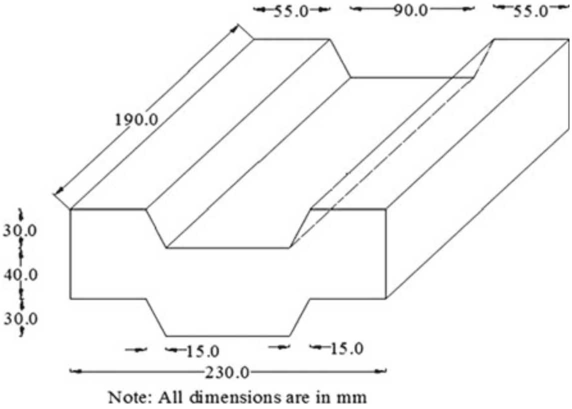

Fig. 14.2 Details of 30-mm-depth interlocking blocks

Fig. 14.3 Wooden pieces used in mould for preparing interlocking blocks

Fig. 14.4 Prepared blocks using Mardini press

are tapered with 10 mm for 20-mm-depth and 15 mm for 30-mm-depth interlocking blocks. These blocks were used to determine both flexural and compressive strength.

Normal plain blocks were made using the machine called “Mardini press”. The interlocking blocks were also made using the same machine by making slight modifications to it. These modifications can be done by using steel or wood. In present work, wooden pieces have been used since they were cheaper and the number of blocks production was less. The modifications used in the machine are as shown in Fig. 14.3, and all the three types of blocks produced using the machine and wooden pieces used in the mould are shown in Fig. 14.4.

14.3.2 Casting of Prisms

The prisms for a height of 1 m and 3 block prisms were cast and cured for 28 days in moist condition by covering the prisms with gunny bags. The masonry mortars used for casting of prisms were cement mortar (1:6), cement–lime mortar (1:1:6), cement–soil mortar (1:2:6). For each type of mortar, two sets of prisms were cast. Totally 18 prisms for flexural strength test and 18 prisms for compressive strength test were cast. In order to maintain consistency in the construction of prisms, the prisms were cast by the same mason.

14.4 Results and Discussions

14.4.1 Compression Test

The average compressive strength of individual normal plain blocks was 6.65 Mpa. The average compressive strength of two prisms is given in Table 14.1. Prisms were tested in partially saturated state by pouring water over the prisms 10 min prior to testing.

From the tests, it is observed that the strength of three block masonry prisms is less than that of individual blocks. This difference in strength is being observed because of the presence of mortar between the blocks.

14.4.2 Flexural Strength Test

14.4.2.1 Initial Set-up

For conducting the test, a rigid bottom support was made with reinforced cement concrete of dimensions 24 × 20 × 15 cm. The height of the support was maintained such that only a single joint of prism was restrained inside the support. Arrangements were made to apply load by using wooden bracket, bag and cable wire over a pulley. One end of the cable was tied to wooden bracket which was fixed to the top most block of the prism and the other end to the bag. The arrangement done is as shown in Fig. 14.5.

Table 14.1 Compression test of three block prisms

S. No.	Mortar proportion (by weight) C:L:So:Sa	Type of prism	Compressive strength of prism (Mpa)
1	CM (1:0:0:6)	Plain block	2.63
2	CM	Interlocking block of 8 cm depth	1.95
3	CM	Interlocking block of 7 cm depth	1.95
4	CLM (1:1:0:6)	Plain block	2.63
5	CLM	Interlocking block of 8 cm depth	2.39
6	CLM	Interlocking block of 7 cm depth	2.3
7	CSM (1:0:2:6)	Plain block	2.39
8	CSM	Interlocking block of 8 cm depth	2.39
9	CSM	Interlocking block of 7 cm depth	2.39

Note *C* cement, *L* lime, *So* soil, *Sa* sand, *M* mortar

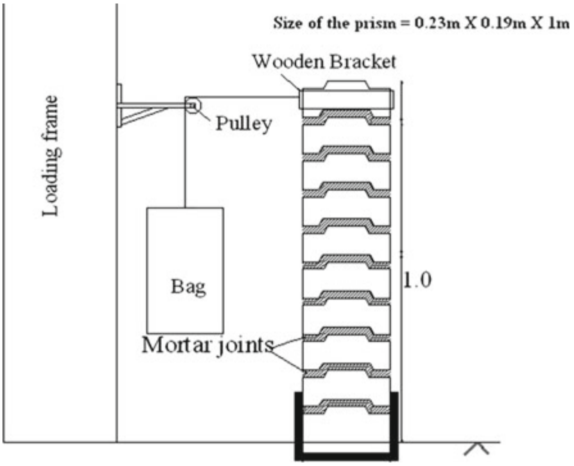

Fig. 14.5 Typical sketch of the arrangement

14.4.2.2 Test Procedure

Prisms were placed as a cantilever over the rigid bottom, and the load was applied (without pre-compression) in the horizontal direction at the free end. Sand was poured into the bag till there was a failure in the prism. The failure load was measured by weighing the quantity of sand in the bag (self-weight of the arrangement was not considered).

Table 14.2 gives the flexural strength of normal plain block prism. The data for cement–lime mortar mix is not available since the specimens failed while handling. The combination of cement–soil mortar mix has given better flexural resistance when compared with cement mortar mix. All the failures have occurred at bond–mortar interface.

The test results of the 1-m-height masonry prisms with 20-mm-depth interlocking are tabulated in Table 14.3. Prisms cast using cement–lime mortar mix proportion gave better flexural resistance compared to cement mortar mix proportion and cement–soil mortar mix proportion which has resulted in better bond strength between the blocks. It can also be observed that there is an improvement in flexural strength

Table 14.2 Flexural strength of normal plain block prisms

S. No.	Mortar proportion	Flexural strength (Mpa)	Average flexural strength in Mpa	Type of failure
1	CM	0.031	0.032	Bond
2	CM	0.033		
3	CSM	0.046	0.048	Bond
4	CSM	0.049		

Fig. 14.6 Failure at bond–mortar interface

Table 14.3 Flexural strength of interlocking blocks with an interlocking depth of 20 mm

S. No.	Mortar proportion	Flexural strength (Mpa)	Average flexural strength in Mpa	Type of failure
1	CM	0.13	0.14	Bond
2	CM	0.14		
3	CLM	0.18	0.25	Bond
4	CLM	0.31		
5	CSM	0.27	0.21	Bond
6	CSM	0.15		

between normal plain block prisms and 20-mm-depth interlocking prisms. All the failures have occurred in bond–mortar interface. These failures can be observed in Fig. 14.6.

The test results of the 1-m-height masonry prisms with 30-mm-depth interlocking are tabulated in Table 14.4. Cement–lime mortar mix gave better flexural strength compared to cement–mortar mix and cement–soil mortar mix which results in better bond strength between the blocks. It can also be observed that there is further improvement in flexural strength of masonry prisms as the depth of interlocking was increased to 30 mm. The failures have taken place at bond and mortar interface, but in the case of cement–lime mortar mix, failure has occurred in the block. The failure is as shown in Fig. 14.7.

Maximum flexural strength of normal block prism in CSM is 0.048 Mpa, whereas in CM is 0.032 Mpa.

Flexural strength with 20-mm-depth interlocking block prism in CLM is 0.25 Mpa, whereas in CSM and CM is 0.21 and 0.14 Mpa, respectively. Flexural strength with 30-mm-depth interlocking block prism in CLM is 0.45 Mpa, whereas in CSM and

Fig. 14.7 Failure in block

Table 14.4 Flexural strength of interlocking blocks with an interlocking depth of 30 mm

S. No.	Mortar proportion	Flexural strength Mpa	Average flexural strength Mpa	Type of failure
1	CM	0.25	0.21	Bond
2	CM	0.17		
3	CLM	0.51	0.45	Block
4	CLM	0.39		
5	CSM	0.22	0.31	Bond
6	CSM	0.27		

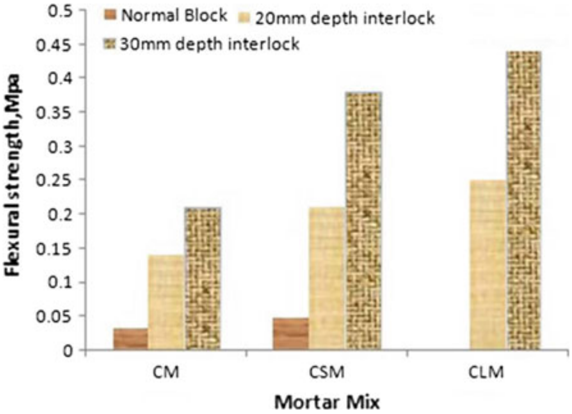

Fig. 14.8 Comparison of flexural strength

CM is 0.31 and 0.21 Mpa, respectively. CLM has given better strength compared to other two mortar proportions. The interlocking blocks have better flexural strength than normal blocks. The details can also be observed in Fig. 14.8.

14.5 Conclusions

Normal plain blocks have a flexural strength of less than 0.1 Mpa which has also been concluded by Sarangpani et al. (2005). There is an interlocking effect on flexural strength which has produced the values of 0.14–0.25 Mpa in case of 20-mm-depth interlocking block and 0.21–0.45 Mpa in case of 30-mm-depth interlocking blocks; thus, interlocking blocks can be used to improve flexural strength of masonry structures.

Bonding between cement–lime mortar mix and stabilized mud blocks functions well when compared to cement–soil mortar mix and cement mortar as the failure has occurred in the block not at bond–mortar interface which clearly indicates the maximum flexural strength. Thus, interlocking blocks with 30 mm depth along cement–lime mortar (1:1:6) can be used in earthquake areas where out of flexure failure occurs.

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