Shear strength of Pond ash Mortar Brick Masonry

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Abstract

Masonry is one of the oldest method of construction in construction industry. We come across many monumental buildings like Palaces, Places of worship, forts, dams, and arches that have been built and survived for a very long time. Basically masonry is the assemblage of masonry blocks and a mortar. Generally mortar for masonry is prepared by using Portland cement and river sand. Here we study the shear strength of masonry using Pond ash mortar for wallettes of single and double openings.

Introduction

Masonry is unified mass obtained by systematic arrangement of laying masonry units and mortar. During early ages, mud blocks and stone blocks of different sizes were used in the construction of building and later on were replaced by manmade bricks of uniform size around 4000 B.C. Then shift took place from sun baked bricks to burnt bricks about 6000 years ago and later to soil stabilized bricks and latest being concrete blocks. Mortar influences structural properties of masonry assemblage. Chronologically mortars like mud mortar, lime mortar, soil cement mortar, and lime cement mortar have been used in construction of masonry. Whatever may be the combination used, aim was one and the same. To ensure that construction withstands largely the compressive loads; lateral loads to some extent; economical, locally available and durable.

Sand is a naturally occurring granular material composed of finely divided rock and mineral particles. River sand is one of the world's most plentiful resources and has the ability to replenish itself. As a resource, sand by definition is 'a loose, incoherent mass of mineral materials and is a product of natural processes. The most common constituent of sand is silica (silicon dioxide, or SiO2), usually in the form of quartz.

Sand Mining is a coastal activity referring to the process of the actual removal of sand from rivers, streams and lakes. Individuals and private companies are increasingly demanding sand for construction purposes and this has placed immense pressure on sand resources. Sand Mining in India is adversely affecting the rivers, sea, forests & environment. Mining of sand is depleting the waters of the rivers. Geologists know that uncontrolled sand mining from the riverbed leads to the destruction of the entire river system. The removal of sand from the river bed increases the velocity of the flowing water; the distorted flow-regime eventually erodes the river banks. Sand mining is regulated by law in many places, but is still often done illegally.

Now a days sand borrowing from most of our rivers has been temporarily stopped which created impasse and panic on construction Industry. This situation has warranted the need for exploring alternatives for granular sandy material. This situation has set alarms to explore alternatives for sand.
Hence steps are to be taken & alternate solution to be found out for sand, without disturbing the environment.

Earlier Studies:

Shear failure is characterized by combination of principal tensile and compressive stress as a result of applying combine shear and compression, and leads to typical diagonal cracks. In practice mainly two types of shear cracking can be observed, joint cracking by local sliding along the bed joint and diagonal cracking associated cracks running through bricks as well as the joints. Both kinds of shear failure must be considered in design. Shear failure mainly occurs if the ratio of height to length of the wall is relatively low, but this is a common situation in practice. The characteristic shear strength of masonry is mainly influenced by several factors which include the direction of applied shear (in-plane and out of plane direction), the strength of units, the normal stress in the joints (axial stresses due to preloading and self weight) and the mortar quality. Nagwa R. El-Sakhawy, **Malcolm Foss N.Sathiparan Vermeltfoort et** al, **R. H. Atkinson** studied the **s**hearing behaviour of joints in load-bearing masonry wall. Wind, earth pressure, and earthquakes acting on a building generate bending effects and produce shear stresses in load bearing masonry walls. Stress and strain responses during shearing of masonry joints indicate unrecoverable shear and normal deformation that demand use of a constitutive model specifically developed for joints. The study presented by them provides a basis for using an analytical method for determining shearing displacement response of brick-mortar bed joints by applying an elasto-plastic constitutive law for joints and determining its parameters from the shear testing of brick-mortar bed joints.

To satisfy the functional requirements, the masonry must possess sufficient shear strength in order to effectively transfer the structural loads to the adjoining supports. This requirement is vital in case of structures to resist in-plane lateral loads. Particularly in case of buildings located in the seismic region this requirement is much more important. Shear failure mainly occurs if the ratio of height to length of the wall is relatively low (short column effect), but this is a common situation in practice. To illustrate the fact that, the short column effect experienced by the masonry units near the openings usually manifested by development of diagonal shear cracks.

In summary the main objective of this investigation is to produce an alternative mortar incorporating pond ash as a fine aggregate in order to gain an environmental benefit without possibly impairing the mortar performance and to evaluate shear strength characteristics of the masonry wall based on the lateral load tests on the wall specimens of moderate size. Also bond shear test and diagonal split tension test are performed on triplets and wallettes.

Burnt Clay Bricks

In India, burnt clay bricks are typically manufactured by employing a manual molding process and then are burnt in kilns. Locally available burnt clay bricks of a single make are used in the experiments. Details of the various properties of these bricks are given in Table 1. The results given in the Table 1 represent the mean of 8 specimens for compressive strength and 5 specimens for water absorption. The IS : 3495 - 1976 code procedure was adopted for determining the compressive strength (5.45 MPa) and water absorption (10.58 MPa) values.

Mortars

In this work, cement sand mortar is mixed in proportions of 1:6 and tested for fresh and hardened properties. Sand is replaced with pond ash for the proportions 1:6 by 25%, 50%, 75% and 100% by volume and tested for fresh and hardened properties. The water cement ratio the mortar is kept such that the flow is between 110 – 115 %. Ordinary Portland cement of 43 grade was used for the preparation of mortars, conforming to IS : 8112 - 1989. Natural river sand having a fineness modulus of 2.67 was used for the mortars.

Table 2 Properties of mortars (Cube size of 70.6 ± 2 mm)

Proportion C : S : PA	w/c ratio	Flow %	Compressive Strength 28 Days
1:6:0	1.2	114.48	7.88
1:3:3	1.4	111.33	6.66
1:0:6	2.7	115.58	4.55

Experimental program and methods of testing:

In this present study, three types of tests were conducted. They are, shear bond test using brick triplets, diagonal split tension test on wallettes and shear test on masonry wall. Pond ash based mortar of the ratio 1 : 6 of 100% replacement of sand by pond ash were used in the experimental investigation. And also cement sand mortar of the ratio 1 : 6 was used to compare the results with pond ash based mortar.

Shear bond test on brick triplets

In the present study a three brick assembly is used to obtain the shear bond strength of the brick mortar joints. The bottom two bricks of the triplet are rested on the bottom platform of the testing machine while the middle brick is not restrained against any movement. The vertical load is applied to the middle brick so as to impart shear force to brick-mortar interface at the joint. The test setup is shown in Fig 1. All the tests were performed with out pre-compression load. Hence the values of bond shear strength obtained are corresponding to zero pre-compression.

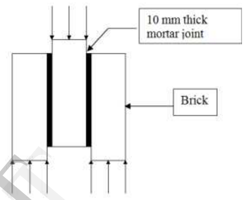

Fig 1 Loading of brick triplet specimen for shear bond strength

Diagonal split tension test on wallettes

In this work diagonal split tension test was conducted on the wallettes to assess the shear strength of the masonry wallettes. Since the objective is to validate the procedure for estimating shear strength, relatively small dimension specimen of one brick thick were prepared and tested. The specimens of size 1000 mm x 1000 mm were cast. A mortar joint thickness of 12mm was maintained. Totally six specimens of ratio C:PA 1:6 three specimens each of single opening of dimension 450mm X 450mm and double opening each of dimension 225mmX 225mm were constructed. In order to load the specimen diagonally a right angle bracket with flat top surface was fabricated. This loading bracket was placed in such a way that the flat surface of the bracket is in right angle to the diagonal axis of the specimen.

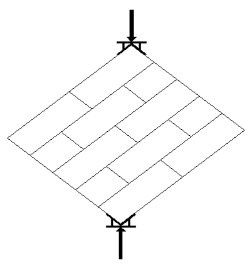

Fig 3 diagonal split tension test

The brackets were placed at top and bottom of the specimen. The test setup is shown in Fig 3. To ensure that the load distributed uniformly on the wallettes plywood sheets and steel plates were placed between loading platform and the specimen.

Shear test on walls

Experimental setup

In order to understand the shear strength characteristics of the full scale brick masonry wall it is intended to test schematic diagram of the testing procedure followed in this study is shown in Fig 4. The test setup consists of a brick masonry wall of dimension 1000 mm x 1000 mm x 220 mm constructed on a loading frame. The wall is constructed on 75mm thick concrete base slab. A vertical steel plate as wide as the wall is firmly fixed with help of angles and bolts to the loading end of the wall. At the bottom, the steel plate is fixed to a pair of steel angles which are in turn clamped down with the aid of horizontal member of the loading frame in order to avoid overturning of the test specimen upon loading laterally at the top edge. At the bottom of the other end the base slab is constrained against horizontal sliding using wedge blocks between far end vertical member of the frame and the base slab edge.

Testing procedure

The lateral load is applied at the top of near end (at which the steel plate is provided) vertical face of the specimen using 350 kN capacity screw jack. The load is measured using 50 kN capacity proving ring. To measure the lateral deflection during loading, the dial gauge is fixed at the top of the far end vertical face of the wall at the same height as the loading point on the other end. A mechanical dial gauge of range 0.001 – 25 mm was used.

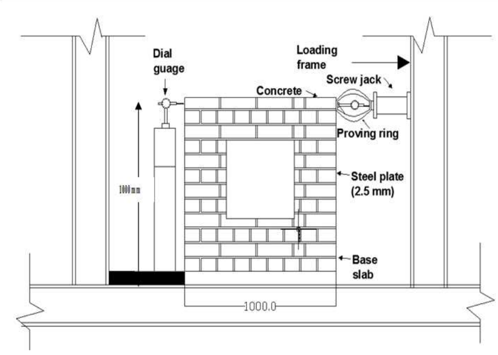

Fig 4 Test set up for testing wall specimen

Casting and Curing of triplets, wallettes and walls

The bricks used for casting triplets and wallettes were prewetted before laying. The duration of prewetting of the bricks was 20 min for all cases, so that adequate water was available for complete hydration of the cement in the fresh mortar. A mortar joint thickness of 12mm was maintained for all the cases. The triplets, wallettes were cured for 28 days by keeping them in moist condition under wet gunny bags. Three specimes were cast for each mortar type for all the tests.

Results and discussion

Shear bond test on brick triplets

Nine triplet specimens were cast with different mortar types and proportions, that is C : S – 1 : 6 ; C : S : PA – 1 : 3 : 3 (PA 50%) and C : S : PA – 1 : 0 : 6 (PA 100%). A mortar joint thickness of 12mm was maintained. The triplet was casted and cured for 28 days. The specimens were tested on 1000 kN capacity Universal Testing Machine. The test results are tabulated in Table 4.

The failure of specimens could be classified into three types:

- Type 1: failure of one joint throughout the complete length
- Type 2: shear bond failure at one joint and brick failure at other joint
- Type 3: failure of both joints throughout the complete length

The failure of specimens with C : S 1: 6 were shear bond failure of both joints throughout the complete length, shear bond failure of one of the joint throughout complete length.The average shear bond strength for C: S 1:6 triplets are found to be .330 MPa.

Table 4 Shear bond strength test results for brick triplets

Specimen No	Area mm^2	Load N	Shear bond strength MPa
Proportion C : S 1 : 6			
1	28350	9319.5	0.328
2	29400	9810	0.330
3	34000	112815	0.332
Average shear bond strength			**.330**
Proportion C : S : PA 1 : 3 : 3 (PA 50%)			
1	34000	8829	0.26
2	31500	8829	0.28
3	32000	6867	0.215
Average shear bond strength			**.251**
Proportion C : S : PA 1 : 0: 6 (PA 100%)			
1	32000	4905	0.15
2	29400	5395.5	0.18
3	28350	3924	0.138
Average shear bond strength			**0.156**

Fig 6 Failure pattern of brick triplets with C : S 1 : 6 mortar

The specimens cast with the pond ash based mortar of the ratio C : S : PA 1 : 3 : 3 (PA 50%**)** failed due to shear bond failure of one of the joints throughout the complete length. The average shear bond strength was found to be .251 MPa. The specimens cast with the pond ash based mortar of the ratio C : S : PA 1 : 0 : 6 (PA 100%**)** failed due to shear bond failure of both joints throughout the length and brick failure at one joint and shear bond failure of one of the joints in the complete length The average shear bond strength was found to be 0.156 MPa.

Diagonal split tension test on wallettes

In order to determine the shear strength of masonry wallettes, specimen of relatively small dimension were cast. Totally nine wallettes were cast each of size 750 mm x 750 mm and one brick thick, with different mortar types and proportions, that is C : S 1 : 6 ,C : S : PA 1 : 0:6 (PA 100%) . All the specimens were cured for 28 days prior to testing. The wallettes were tested in the loading frame of 50 T capacity. All the specimens except one failed at ultimate load along the diagonal. One of the cement sand specimens failed at the second coarse from bottom. The shear stress is calculated based on the failure load divided by the area along the diagonal. Table 5 shows the results of the diagonal tension test of wallettes.

Table 5 Diagonal Split Tension Test Results

Sp No	L mm	H mm	Th mm	Area	Load	Shear stress	Side
1	700	700	105	73500	31.4	0.302	
2	700	700	105	73500	36.1	0.347	
3	700	700	105	73500	30.9	0.297	
0.315							
1	700	700	105	73500	14200	0.130	
2	700	700	105	73500	17000	0.163	
3	700	700	105	73500	14770	0.142	
0.145							

Fig 9. Experimental set up and Failure of the wallettes

Shear test on walls

For determining the shear strength characteristics of the brick masonry wall it is intended to test moderately size wall. Totally four moderate size wall specimens of size 1000mm (length) × 1000mm (height) × 220mm (thick) were cast. The walls were cast with the English bond pattern. The mortar used for these wall specimens is C : PA 1 : 6. The omparison was made for wallettes constructed using pond ash mortar having single opening of size 450mm X 450mm placed centrally in wall and double opening of size 225mm X 225mm aligned equidistant from centre. The central alignment was done in order to make the stress distribution equal in the wall.

In single opening all the specimens failed with the development of cracks near the openings in all the four edges of openings. The load at the failure and deflection of different specimens are listed in the table.

The failure of specimens having double openings was cracking from the corners of opening till the edge of the wall and in between the two openings. The ultimate load and deflection is tabulated in the table.

The shear strength of the masonry is estimated using beam theory. The maximum shear stress for the shear force (failure load) is given by $\tau_{\max} = 6.09\times10^{-6}V$.

Failure of wall specimens C:S 1:6 single and double opening

Table-06 Summary of the test results on wall specimens

Specimen	Failure Load KN	Deflection mm	Maximum shear stress(MPa) $\tau_{max} = 6.09 \times 10^{-6}$
Single opening wall-1	11.360	20.461	0.069
Single opening wall-2	10.220	17.882	0.066
Single opening wall-3	10.790	19.633	0.066
Double opening wall-1	9.650	10.026	0.058
Double opening wall-2	8.520	10.227	0.052
Double opening wall-3	10.220	11.380	0.062

Table 7 Tabulated summary of results obtained from experimental tests for shear

Proportion	Average shear bond strength MPa	Average shear strength MPa		
	Shear bond test	Diagonal split tension test	Shear test	
			Single opening	Double opening
C : S 1 : 6	0.273	0.315	---	
C :PA 1 : 6	0.230	0.145	0.067	0.057

Concluding Remarks

- The shear bond strength obtained from triplet test is comparable for triplets with cement sand mortar of the ratio C : S 1 : 6 and triplets with pond ash based mortar of the ratio C : PA 1:6 at 28 days of curing.
- The shear strength obtained by diagonal split tension test indicates that the shear strength of wallettes with cement sand mortar of the ratio C : S 1 : 6 is comparable with pond ash based mortar of the ratio C : PA 1:6.
- The shear strength of masonry walls constructed with pond ash based mortar of the ratio 1:6 with single openings is comparable with that constructed of double openings
- The shear strength values of diagonal split tension and shear bond test is comparable with the values obtained by shear test on walls. Hence pond ash based mortar can be satisfactorily used in brick masonry.
- In conclusion pond ash may be replaced for sand in cement sand mortar.

Scope for further Study

- Study of shear strength of the walls with openings of combinations of different sizes can be carried out.
- Study on pond ash mortar can be carried out by treating pond ash prior to use to increase compressive strength of mortar.
- Investigation can be carried out to increase the workability of mortar at a lower water cement ratio by addition of plasticizers.
- Study of compressive strength, flexural strength and shear strength for full size walls with and without openings can be carried out.
- Only a handful of specimens are tested in this study. Hence it is required to test more number of specimens to arrive at more pertinent conclusions based on statistics.
- The experimental investigations on shear strength can be carried out on the specimen of same sizes with different testing procedures.
- Study of shear strength with a combination of main wall and cross wall system with openings and without openings can be carried out

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