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Mechanical properties of brick masonry cavity walls

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Abstract: The main objective of the research was to determine the compressive strength of brick masonry cavity walls using different wall thickness. Brick units were tested for absorption as well as direct compressive strength using Universal Testing Machine (UTM). Mortar cubes (2"x2"x2") having water-cement ratio (w/c) of 1.2 were cured for 7 and 28 days and tested in UTM. Three different combinations of cavity walls cured for 7 days and tested after 28 days under the increasing compressive load. Deflection gages were installed on both the external faces of the wall to measure vertical shortening of the specimen. Load-Deformation curves were plotted for three types of specimens. The Load-Deformation characteristics of the cavity walls were compared to that of solid brick masonry walls, it was concluded that the compressive strength and modulus of elasticity for cavity walls (K=172ksi) was relatively smaller than solid brick masonry wall (K=208ksi).

Keywords: *Cavity Wall, Universal Testing Machine, Deflection Gage, Load-Deformation Curve*

1. Introduction:

Typical Cavity walls consist of two distinct 'skins' which are parted by a hollow space i.e. cavity. These skins are generally masonry, such as brick masonry or concrete block masonry [1]. Masonry is a highly absorbent material which will drain rainwater slowly or even the external humidity within the wall structure. The presence of these cavities serves as a passage to drain-out this water back through weep holes in the base of the wall system [2]. A cavity wall that is having masonry on both the inner and outer skins is termed as Double Wythe wall [3].

The masonry skins present in the cavity wall can be brickwork, block-work. A variety of masonry materials can be used on either side of the masonry cavity wall [4]. The cavity is initially empty but can be filled with insulation by various methods. The construction and erection of Cavity walls is more time consuming (and therefore slightly more expensive) to build, than are walls with the two skins bonded together, but they provided better heat and sound insulation and most importantly resistance to the penetration of rain water.

Many buildings have been constructed using cavity wall since the early 20th century [5]. The cavity is usually just a few inches wide, and up until the end of the 20th century, this space was left empty. As the green building movement has gained momentum, the idea of adding insulation within this cavity has attained popularity in order to save energy [6]. Today, insulation in exterior walls is fairly standard, and many building owners are adding spray foam insulation to their existing walls in order to enjoy its many benefits.

Cavity wall filled with insulation has been investigated by various researchers for its thermal, water and water vapour resistance as in Fig 1 [7]. One special design advantage of the insulated cavity wall is to permit exposed masonry interiors with high thermal resistance at an economic level. This is evident if the results are compared to the cost and U-factor of a double Wythe of face-brick first as a solid 8" wall, second as a 10" cavity with a still air space, and third as an insulated cavity wall [8]. Exterior-wall insulation also offers a variety of lesser known benefits to building owners. Because it is placed inside the walls, it helps protect the pipes in these walls from freezing or bursting.

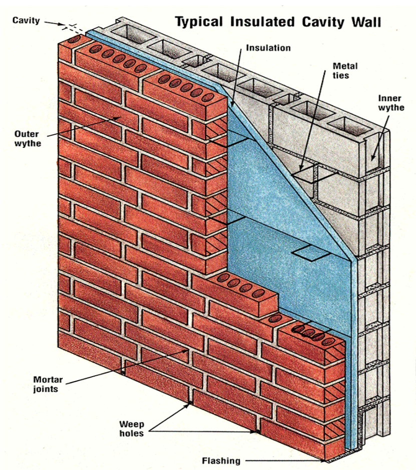

Fig 1. Typical insulated cavity wall

2. Selection of Geometry:

The main purpose of the vertical loading of the specimen is to determine its compressive strength by plotting stress-strain curve. Its modulus of elasticity 'K' is determined in accordance ASTM C1314 i.e. the slope of stress-strain curve between $F_{max}/20$ and $F_{max}/3$, where F_{max} is the maximum compressive stress obtained from the curve.

Three different types of specimens were fabricated as mentioned below:

2.1 Type A:

This type of specimen was prepared using half brick skins(walls) on both sides of a 3 inches thick concrete (1:2:4) pad providing 2 inches cavity between the two skins as in Fig 2. Dial gages were installed on the outer faces of both external skins of the cavity wall. The descriptions are as under:

Pad Dimensions:

- Length: Width: Height = 400mm(15.75in): 330.2mm(13in): 76.2mm(3in)

Wall Dimensions:

- Length: Width: Height = 400mm:280mm (including cavity) : 42mm

Sample # 01:

- Cavity width = 650 mm
- Gage # 01 (YS4280043)
- c/c distance = 320 mm
- Gage # 02 (YR8680004)
- c/c distance = 320mm

Sample # 02:

- Cavity width = 650mm
- Gage # 01 (YS4280043)
- c/c distance = 320mm
- Gage # 02 (YR8680004)
- c/c distance = 320mm

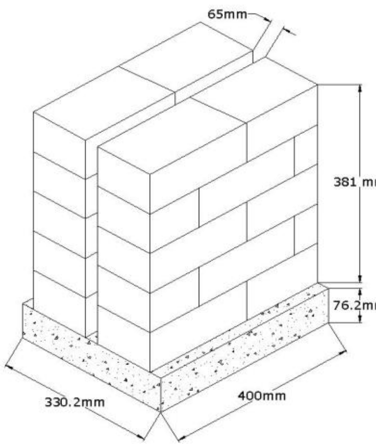

Fig 2. Type A specimen

2.2 Type B:

This type of specimen was prepared using half brick skin(wall) on one side and full brick on other side of a 3 inches thick concrete (1:2:4) pad providing 2 inches cavity between the two skins as in Fig 3. Dial gages were installed on the outer faces of both external skins of the cavity wall. Two specimens were prepared. The descriptions are as under:

Pad Dimensions:

- Length: Width: Height = 457.2mm(18in) :457.2mm (18in):76.2mm (3in)

Wall Dimensions:

- Length: Width: Height = 460mm: 390mm (including cavity):420mm

Sample # 01:

- Cavity width = 70 mm
- Gage # 01 (YS4280043)
- c/c distance = 25 mm
- Gage # 02 (YR8680004)
- c/c distance = 260 mm

Sample # 02:

- Cavity width = 70 mm
- Gage # 01 (YS4280043)
- c/c distance = 250 mm
- Gage # 02 (YR8680004)
- c/c distance = 260 mm

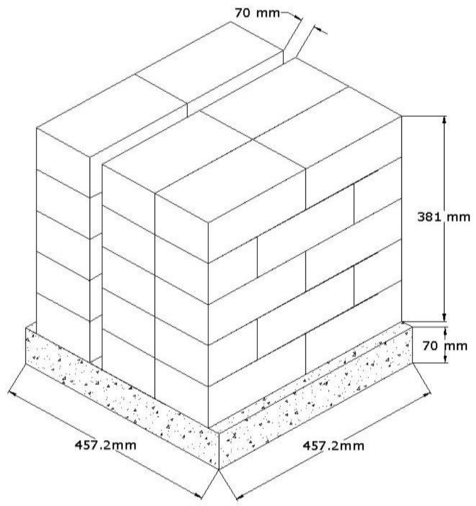

Fig 3. Type B Specimen

2.3 Type C:

This type of specimen was prepared using half brick skins (walls) on both sides of a 3 inches thick concrete (1:2:4) pad providing 2 inches cavity between the two skins. Dial gages were installed on the outer faces of both external skins of the cavity wall as in Fig 4. In this type of specimens shear ties were provided at 14 inches c/c. Two specimens were prepared, description as under:

Pad Dimensions:

- Length: Width: Height = 685.8mm(27in) : 330.2mm(13in) : 76.2mm (3in)

Wall Dimensions:

- Length: Width: Height = 710 mm :280 mm(including cavity) : 381 mm

Shear strips:

- Number of strips = 02
- Spacing = 14” c/c

Sample # 01:

- Cavity width = 70 mm
- Gage # 01 (YS4280043)
- c/c distance = 250 mm
- Gage # 02 (YR8680004)

- c/c distance = 250 mm

Sample # 02:

- Cavity width = 70 mm
- Gage # 01 (YS4280043)
- c/c distance = 250 mm
- Gage # 02 (YR8680004)
- c/c distance = 250 mm

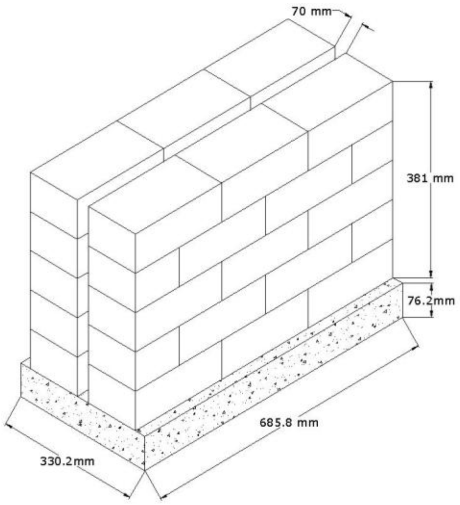

Fig 4. Type C Specimen

3. Instrumental Plan:

The instrumental plan for the specimens is elaborated by means of the Fig 5.

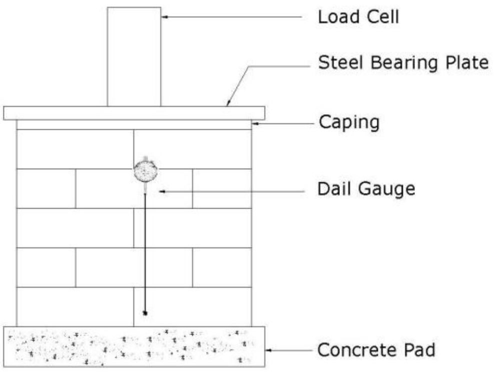

Fig 5. Instrumental Plan

The elements of the instrumental plan are discussed below:

Load cell:
Load cell unit is used to measure the load applied on the specimen.

Steel bearing plate:
Steel plate of sufficient thickness was used to uniformly distribute the load over the top surface of the specimen.

Capping:
Gypsum capping was done one day prior to the testing in order to ensure levelled surface below the steel bearing plate.

Dial gages:
Dial gages were installed on the outer faces of the cavity wall to measure the strain in the specimen under increasing loading conditions.

Concrete pad:
Plain Cement Concrete (PCC) 1:2:4 pads of 3 inches thickness were prepared for each specimen.

4. Experimental Program:

Brick Absorption (%):

To determine the water absorption, firstly the dry weight of each single brick was measured as W_d, then the brick re fully submerged in water for 24 hours and find the weight of t specimen as W_w. Find the absorption of the required specimens by using the formula. The absorption of the masonry units is listed in the Table 1.

Table 1. Absorption by masonry units

Sample	Absorption (%)
1	25.0
2	27.5
3	22.5
4	30.0
5	28.0
Average	26.6

Bricks Compressive Strength (ASTM C-67):

To determine the compressive strength of individual bricks, five bricks re selected and tested by Universal Testing Machine (UTM). The results are shown in Table 2.

Compressive Strength of Mortar Cubes:

Mortar is used to provide uniform bearing between units and to bond individual units into a composite assemblage that will withstand the imposed loads. The achievement of strength, durability, and weather tightness is the key requisite of hardened mortar. Cement-sand mortar ratios ranging from 1:4 to 1:6 are very common.

Table 2. Compressive strength of bricks

Sample	Compressive Strength(Psi)
1	2969
2	2762
3	2750
4	1936
5	3018
6	2843
7	2234
8	2014
9	2930
10	2550
Average	2602

In order to determine the compressive strength of mortar which was used in prisms, tests re carried out on mortar cubes according to the specification provided in ASTM C-109. The size of mortar cubes were 2”x2”x2”. The 7th and 28th day’s strength of these cubes are given in the Table 3 and these tests were conducted in UTM machine.

Table 3. Compressive strength of cubes

S.No	Strength (psi)
After 7 days	
1	253.46
2	248.00
3	225.91
After 28 days	
1	567.50
2	534.47
3	462.84

5. Fabrication:

Fabrication of specimen

Type A specimen

Type B specimen

Type C specimen

Hydraulic unit

Sample under loading

Sample after testing

Sample after testing

5. **Results and Discussion:**

Stress-strain curves:

After obtaining test data from Data Logger unit, it was analyzed and plotted with Strain at Abscissa while Load at Ordinate as shown in Fig 6, 7, 8.

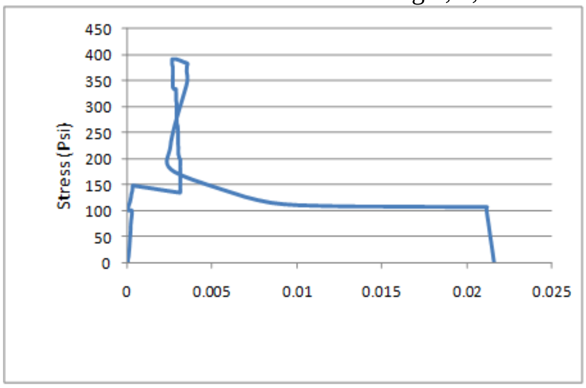

Fig 6. Stress-strain curve of Sample A

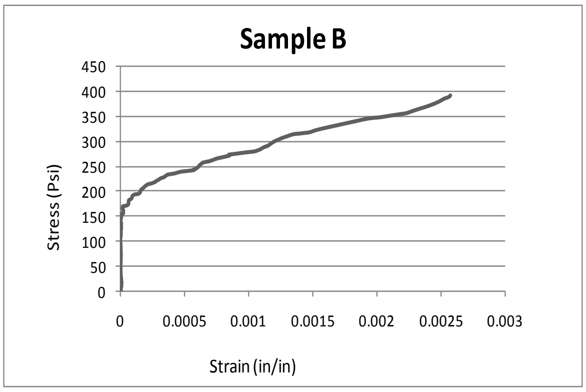

Fig 7. Stress-strain curve of Specimen B

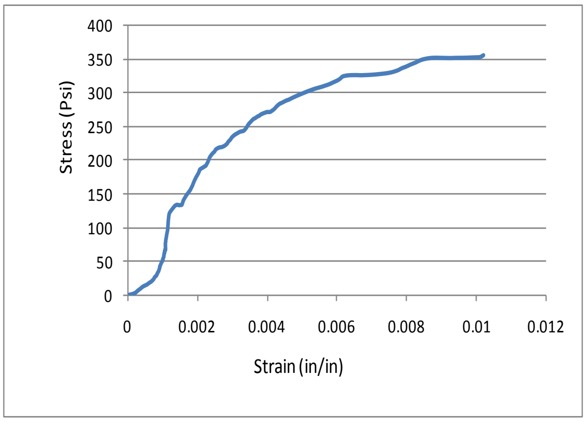

Fig 8. Stress-strain curve of Specimen C

Maximum Stress= 352 Psi
Maximum Strain = 0.0100 in/in
Fmax/3=117.33 Psi
Strain=0.00118in/in
Fmax/20=17.60 Psi
Strain=0.00060in/in
Difference of Stress=100 Psi
Difference of Strain=$5.8x10^{-4}$ in/in
Using ASTM C1314
Modulus of Elasticity=K
K=100/0.00058 =172413 Psi
=172.4ksi

6. Conclusions and Recommendations:

The Load-Deformation characteristics of the cavity wall were compared to that of solid brick masonry wall, it was concluded that the compressive strength and modulus of elasticity for cavity wall (K=172ksi) is relatively small than solid brick masonry wall (K=208ksi).

The various causative reasons may be enlisted as:

- Load cell used was of less loading capacity.
- Capping may not be appropriate
- May be due to initial bending of steel plate.
- Dial gage on one side was not properly installed.

In future the research may be upgraded by new fellows with:

- Usage of specially manufactured heat resistant materials like Mineral Fiber, Cellulose Fibre, Glass Fibre, Mineral Wool (Slag and Rock Wool), Expanded Polystyrene, Polyurethane and Polyisocyanurate Boards, Phenolic Foam Boards, Spray-Foam Insulation, Polyurethane Foam etc.
- Providing cavity protection.
- Providing different types of Shear Connectors between the two Wythe.
- Performing many other types of test besides compression test.
- Research and development, training and capacity building. Especially training courses for architects, engineers, and consultants in the use of energy simulation software such as ‘Energy plus’.

7. References:

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