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Capital University of Science and Technology, Islamabad Pakistan

EXPERIMENTAL DETERMINATION OF THE MECHANICAL PROPERTIES OF BRICK MASONRY AND LOW STRENGTH CONCRETE BLOCK MASONRY

[a] Raheel Asghar, [b] Asif Shahzad, [c] Syed Uzair Amjad, [d] Ali Akhtar

a: Department of Civil Engineering, COMSATS University Islamabad, Abbottabad Campus, raheelasghar68@gmail.com
b: Department of Civil Engineering, COMSATS University Islamabad, Abbottabad Campus, shahzaasif@gmail.com
c: Department of Civil Engineering, COMSATS University Islamabad, Abbottabad Campus, uzairshah197@gmail.com
d: Department of Civil Engineering, COMSATS University Islamabad, Abbottabad Campus, aliakhtarglt@gmail.com

Abstract- A practice of constructing reinforced concrete frame structures with unreinforced masonries is being followed all over the world. In the past, these masonries were considered as the non-structural elements of the building, but recent researches have shown their importance during seismic events where they greatly enhance the performance of the building. The most common type of masonries used in Abbottabad are brick masonry and low strength concrete block masonry. These masonries are the composite materials that generally consist of individual units of the bricks or concrete blocks bonded together with the help of mortar. Mortar is also the mixture of cement, sand and water. Due to this heterogeneity in the composition, mechanical properties of infill masonries are not the same as that of the individual units. Moreover, there are variety of materials available in the construction market, a most widely adopted material in one region may not be used entirely in other regions e.g. low strength concrete blocks that are most widely used masonry material in Pakistan especially in Abbottabad but are not considered outside the Asian sub-continent. Therefore, it is desirable to find out the mechanical properties of these infill masonries experimentally at the local level in order to assess their response under different types of loading e.g. seismic loading. This research aims at the experimental determination of mechanical properties of two types of infill masonries i.e. brick masonry and low strength concrete block masonry. The research is further focused on the establishment of empirical relationships between different mechanical properties and making their comparison with those given by other researchers and international standards. For this purpose, masonry prisms for both these types of infill masonries were constructed and tested in the concrete laboratory of COMSATS University Islamabad, Abbottabad Campus and the results were reported in terms of compressive strength, elastic modulus, shear modulus, Poisson's ratio. From the outcomes of this research it was found out that compressive strength of masonry depends on the compressive strength of masonry units and number of joints in a square unit. Greater the compressive strength of masonry unit, greater will be the compressive strength of masonry whereas greater the number of joints in a square unit, lesser will be the compressive strength of masonry and vice versa. Moreover, compressive strength, elastic modulus, shear modulus and Poisson's ratio were found to be 790 psi, 410 ksi, 166 ksi and 0.2383 for brick masonry whereas 400 psi, 250 ksi, 97 ksi and 0.3127 in case of concrete block masonry respectively.

Keywords - Infill Masonries, Compressive Strength, Elastic Modulus, Shear Modulus, Poisson's Ratio.

1 INTRODUCTION

In the present time, a practice of constructing reinforced concrete frame structures with masonry infill walls is being followed all over the world [1]. In the past, these masonry infill walls were considered as the non-structural elements of the building [1], but recent researches have shown their importance during seismic events where they greatly enhance the performance of the building. The most common type of masonries used in Abbottabad are either the brick masonry or low strength concrete block masonry. These masonries are the composite materials that generally consist of individual units of the bricks or concrete blocks bonded together with the help of mortar. Mortar is also the mixture of cement, sand and water. Due to this heterogeneity in the composition, mechanical properties of the infill masonries (i.e. compressive strength, elastic modulus, Poisson's ratio etc.) are not the same as that of the individual units. Individuals units of brick or concrete block masonries usually carries greater compressive strength and modulus of elasticity as compared to their masonries. The mechanical properties of the infill masonries generally depend upon the mechanical properties of individual units, quality of the binding material being used in the joints and workmanship. Though different building design codes provides empirical relationships for the determination of these parameters, but the quality of the material and workmanship being the major influencing factors for these parameters do not remain same in all parts of the world. Moreover, there are variety of material available in the construction market, a most widely adopted material in one region may not be used entirely in other regions e.g. low strength concrete blocks that are most widely used masonry material in Pakistan especially in Abbottabad but are not considered outside the Asian sub-continent. Therefore, it is desirable to find out the mechanical properties of these masonries experimentally at the local level in order to assess their response under different types of loading e.g. seismic loading.

Similar works have already been done on the determination of mechanical properties of infill masonries in different parts of the world. Saroj Phajju and Prachand Man Pradhan [2] have conducted an experimental research on the determination of mechanical properties of brick masonry. The results of this research yielded a value of 2.5 MPa, 2703.2 MPa, 915.1 MPa and 0.32 for compressive strength, shear strength, elastic modulus, shear modulus and Poisson's ratio of given masonry respectively. Another researcher T.C. Nowofor [3] as a result of his experimental work have found out a value of 11.86 MPa, 7420 MPa and 0.33 for compressive strength, elastic modulus and Poisson's ratio of brick masonry respectively. Zeljke Radovanovic et. al. [4] on the basis of his experimental findings suggested a value of 2.89 MPa and 3190 MPa for compressive strength and elastic modulus of clay block masonry whereas 2.9 MPa and 6600 MPa for compressive strength and elastic modulus of concrete block masonry respectively. Another research made by Mohamad Gihad et. al. [5] found out the compressive strength and elastic modulus of concrete block masonry to be 10.56 MPa and 10145 MPa respectively. In another research made by Sayari Arash [6], compressive strength and elastic modulus of brick masonry were found out to be 3.7 MPa and 3751.3 MPa respectively.

This research aims at the experimental determination of mechanical properties of two types of infill masonries i.e. brick masonry and low strength concrete block masonry. The research is further aimed at the establishment of empirical relationships between different mechanical properties and making their comparison with those given by other researchers and international standards.

2 RESEARCH METHODOLOGY

Two different types of infill masonries (i.e. brick masonry and low strength concrete block masonry) were considered in the research for the investigation of mechanical properties i.e. compressive strength (f'_m), elastic modulus (E_m), shear modulus (G_m) and Poisson's ratio (ν). In order to do so, masonry prisms for both these wall types were constructed in the concrete laboratory of Comsats University Islamabad (CUI), Abbottabad Campus. These masonry prisms were then given proper curing for 28 days after which they were tested in universal testing machine (UTM) for compressive strength test. During the compression strength test along with the axial deformation, lateral deformation was also observed in order to determine Poisson's ratio. Due to the inability of testing device shear test was not conducted on the masonry prisms. Therefore, shear modulus was determined by using an empirical relationship as given in (1). Although this equation was derived assuming the material to be isotropic, but it can give reasonable results for masonry material as well. Most of building design programmers like ETABS and SAP 2000 use the same relationship for the determination shear modulus from elastic modulus and Poisson's ratio.

$$G_m = \frac{E_m}{2(1+\nu)} \quad (1)$$

2.1 Construction of Masonry Prisms

A total number of 3 masonry prisms for both these types of infill masonries were constructed on a relatively flat or levelled surface. These prisms were constructed with height to thickness ratio of 2 in case of brick masonry and 2.7 for concrete block masonry. The construction of these prisms was undertaken as per the standard procedure of ASTM C1314 [7].

Table 1: Physical Characteristics of Masonry Prisms

Prism Type	**Length**	**Width**	**Height**	**Top Area**
	(in)	**(in)**	**(in)**	**(in^2)**
Bricks Masonry	18	9	18	162
Concrete Block Masonry	18	6	16	108

2.2 Curing of Masonry Prisms

All the masonry prisms were kept at a normal room temperature of 24 ± 8 °C in moisture tight bags after the initial normal curing of 48 hours. The prisms were extracted from these bags two days before the test. The guidelines of ASTM C1314 [7] for the curing of masonry prisms were followed in their full spirit.

2.3 Testing of Masonry Prisms

All the masonry prisms were tested in accordance with the standard procedure of ASTM C1314 [7], and the results were reported in the form of compressive strength, elastic modulus, shear modulus and Poisson's ratio. Compressive strength was obtained as a maximum axial stress taken by the prism before undergoing failure whereas elastic modulus was obtained as the slope initial elastic region of stress strain curve. Moreover, during the compressive strength test a dial gauge was also installed at one side of the prism to observe its lateral strain. The results obtained were then plotted in the form of lateral vs longitudinal strain curve. The slope of linear curve between lateral and longitudinal strain gives the Poisson's ratio for the prism. Shear modulus was determined using (1).

Figure 1: Testing of Masonry Prisms

2.4 Testing of Masonry Units

For the sake of making comparison between compressive strength of masonry (f'_{m}) and masonry units (f'_{mu}), compressive strength test was also conducted on masonry units. For this purpose, 3 samples of both bricks and mortar were prepared. Mortar samples were prepared in the form of 2-inch cubes with cement to sand ratio of 1:3 whereas brick samples were prepared by filling the frog of Class-A bricks with mortar. After the preparation of test samples, compressive strength test was conducted in compression testing machine (CTM) in the concrete laboratory of Comsats University Islamabad, Abbottabad Campus. This test was conducted in accordance with the standard guidelines of relevant standards.

3 RESULTS

At the end of specified curing period of 28 days, all the masonry prisms were tested for compression test in UTM whereas masonry units in CTM. All the results obtained from the compression test were reported to the nearest 10 psi for compressive strength and 1000 psi for elastic and shear modulus. The Poisson's ratio was reported to the four decimal places. A more detailed description of average test results is given in table 2 and table 3. On the basis of test results, a comparison was made between different mechanical properties of masonry and masonry units. Analyzing the results, compressive strength of masonry was found to be some fraction of masonry unit. This loss of strength is due to the presence of weaker mortar and interface elements in the joints. Greater the number of joints, greater will be the loss of strength which can be observed from the test results of brick masonry prism where greater loss of strength was seen due to the greater number of joints. Compressive strength of mortar used in the joints was found to be 1720 psi. In table 2 and 3, the symbol f'_{mu} refers to the compressive strength of major masonry unit i.e. either bricks or concrete blocks.

Table 2: Average Test Results for Brick Masonry Prisms

Parameters	**Values**	**Parameters**	**Relationship/Values**
	(psi)		
f'_m	790	**ν**	0.2383
f'_{mu}	1880	$f'_m - f'_{mu}$	$f'_m = 0.4202 * f'_{mu}$
E_m	410000	$E_m - f'_m$	$E_m = 520 * f'_m$
G_m	166000	G_m - E_m	$G_m = 0.405 * E_m$

Table 3: Average Test Results for Concrete Block Masonry

Parameters	**Values**	**Parameters**	**Relationship/Values**
	(psi)		
f'_m	400	**ν**	0.3127
f'_{mu}	820	f'_m - f'_{mu}	$f'_m = 0.4878 * f'_{mu}$
E_m	250000	E_m - f'_m	$E_m = 625 * f'_m$
G_m	97000	G_m - E_m	$G_m = 0.388 * E_m$

A comparison between mechanical properties of masonry infill walls determined experimentally during this research is made with that of previous researches in table 4. From the comparison it can be seen that Nowofor [3] has overestimated the mechanical properties of infill masonry whereas Randovanovic [4] has underestimated the results among all. The mechanical properties determined by all other researches lie in between that of Nowofor [3] and Randovanovic [4]. It was also observed that mechanical properties determined during this research neither lies very close to someone else's nor deviates too much from any other presented. A comparison between empirical relationships proposed by each of the researcher is also made in table 5. From the comparison it can be observed that empirical relationship of mechanical properties of infill masonries proposed by this research comply with most of the other researches. The relationship between compressive strength and elastic modulus lies closer to that recommended by FEMA 356 [8] whereas relationship of compressive strength of masonry and masonry unit lies closer to that proposed by Nowofor [3]. The relationship among elastic and shear modulus is almost the same as proposed by all the researcher. Poisson's ratio was slightly overestimated by Phajju [2] and Nowofor [3] as compared to that presented in this research.

Table 4: Comparison of Mechanical Properties of Masonry

Research	**Masonry Type**	**f'_m**	**E_m**	**G_m**	**ν**
		(psi)	(ksi)	(ksi)	
This Research	Brick Masonry	790	410	166	0.2383
	Conc. Block Masonry	400	250	97	0.3127
Phajju [2]	Brick Masonry	360	392	133	0.32
Nowofor [3]	Brick Masonry	1720	1076	404	0.33
Radovanovic [4]	Clay Block Masonry	420	463	-	-
	Conc. Block Masonry	421	957	-	-
Gihad [5]	Conc. Block Masonry	1530	1471	-	-
Arash [6]	Brick Masonry	540	544	-	-

Table 5: Comparison of Empirical Relationships Between Different Mechanical Properties

Research	**Masonry Type**	**f'_m - f'_{mu}**	**E_m - f'_m**	**G_m - E_m**
This Research	Brick Masonry	42.02%	$E_m = 520 * f'_m$	40.5%
	Conc. Block Masonry	48.78%	$E_m = 625 * f'_m$	38.8%
Phajju [2]	Brick Masonry	22.5%	$E_m = 1085 * f'_m$	34%
Nowofor [3]	Brick Masonry	51%	$E_m = 626 * f'_m$	37.6%
Radovanovic [4]	Clay Block Masonry	44%	$E_m = 1104 * f'_m$	-
	Conc. Block Masonry	89%	$E_m = 2276 * f'_m$	-
Gihad [5]	Conc. Block Masonry	58%	$E_m = 961 * f'_m$	-
Arash [6]	Brick Masonry	-	$E\ m = 1014 * f'_m$	-
FEMA 356 [8]	-	-	$E_m = 550 * f'_m$	-

4 CONCLUSION

Following conclusions can be drawn on the basis of results of this research study:

- Compressive strength of masonry depends on the compressive strength of masonry units and number of joints. Greater the compressive strength of masonry unit, greater will be the compressive strength of masonry whereas greater the number of joints in a square unit, lesser will be the compressive strength of masonry and vice versa.
- Compressive strength of masonry was found to be 42% of that of masonry unit in case of brick masonry whereas 49% in case of concrete block masonry respectively.
- Elastic modulus of masonry was found to be 520 times its compressive strength in case of brick masonry whereas 625 times in case of concrete block masonry respectively.
- Shear modulus of masonry was found to be 41% of that of elastic modulus in case of brick masonry whereas 39% in case of concrete block masonry respectively.
- Poisson's ratio was found to be 0.2383 for brick masonry whereas 0.3127 for concrete block masonry.

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