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Experimental Investigation to determine the Influence of cyclic loading on the Compressive strength and Modulus of Elasticity of Brick masonry

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Abstract
This paper presents the study on brick masonry that behaves differently under various patterns of static loading patterns. It is a common practice to determine the compressive strength of brick masonry under gradually increasing axial loading (known as monotonic loading) thus we generally ignore the effect of cyclic loading, which the real masonry structures experience during earthquakes. Experimental work carried out by researchers on masonry walls indicate that brick masonry is very sensitive to cyclic loading and undergoes relatively more damages under the action of cyclic loading compared to monotonic loading. Behavior of brick masonry will change under cyclic loading and there will be a definite effect on its mechanical properties. Due to contrast behavior of brick masonry under monotonic and static cyclic loading, it becomes a matter of concern to investigate the influence of loading types on mechanical properties of brick masonry. To investigate this phenomenon, 12 masonry prisms were cast in cement, sand and khaka (local stone dust). Six prisms were tested under both monotonic and cyclic load respectively. Compressive strength and modulus of elasticity were determined for each loading type and their value are compared. Tests have proven that the compressive strength of prisms tested under monotonic load was slightly lesser than cyclic load. So it is recommended that the monotonic tests may be used to determine mechanical properties of masonry such as compressive strength, elastic modulus used for seismic design.

Keywords
Compressive Strength, monotonic loading, Cyclic Loading, Modulus of Elasticity,

1. Introduction

Masonry construction is one of the oldest and common building technique in construction. The word "masonry" encompasses technique which may differ substantially depending on type and shape of material and construction method. A screening of the historical masonry heritage shows that the wide variety of construction systems which falls under the name of "masonry". Brick masonry is composite material consist of brick and mortar, to be able to predict the behavior of this composite material under various state of stress. The relevant characteristics of brick and mortar will be discussed in term that how they affect masonry behavior in general and the properties of the material used in the experimental program.

It is a common practice to determine the compressive strength of brick masonry under gradually increasing axial loading (known as monotonic loading) thus we generally ignore the effect of cyclic loading, which the real masonry structures experience during earthquakes. On the other hand, experimental work carried out by researchers on masonry walls indicate that brick masonry is very sensitive to cyclic loading and undergoes relatively more damages under the action of cyclic loading compared to monotonically increasing static loading. Behavior of brick masonry will change and there will be a definite effect on its mechanical properties. Due to this contrast behavior of brick masonry under monotonic loading and static cyclic loading, it becomes a matter of concern to investigate the influence of loading types on mechanical properties of masonry. The aim of this experimental work was to study the Influence of static cyclic load on the Compressive strength and Modulus of Elasticity of Brick masonry constructed in cement, sand and khaka mortar.

2. Materials

Materials used in the experimental work were bricks, sand, khaka and cement, which are very commonly used in Pakistan.

2.1 Brick:

Five samples of bricks having average compressive strength of 2000 psi being widely used in the region and were selected from three different kilns. The samples were tested under uniaxial compression in universal testing machine (UTM). The result of samples is provided in table 1.

2.1.1 Brick tests:

Several laboratory tests are performed on the selected sample of bricks selected from different kilns to determine the physical and mechanical properties of bricks.

Table 1: Average Compressive Strength of Bricks

Brick samples	Average Length (in)	Average Width (In)	Average Area $(in)^2$	Ultimate Load (tons)	Average compressive Strength (psi)
A	8.5	4.3	36.5	36.5	2201
B	8.7	4.4	38.2	32.6	1877
C	8.5	4.5	38.2	28.2	1625

Sample B was selected as the strength was near to standard selected for this research i-e 2000 psi.

Compression test:
The compressive strength test was carried out according to the specification mentioned in section 7 of ASTM C—67. 6 bricks of selected Sample **B** were caped with mortar on the bedding surface. The compressive Load was applied at right angle to the bedding surface until the crushing of brick. The compressive strength of the bricks is given below in the table.2.

Table 2: Compressive Strength of bricks as per ASTM C-67

Brick no	Area (in^2)	Compressive strength (psi)
1	37.41	2221
2	37.84	2068
3	39.6	2187
4	38.72	2174
5	39.6	1753
6	37.84	1887

Mean value = 2048.3 psi Standard Deviation = 188.9 psi Cofficient of variation = 9.22%

p: 0.75 inch., Bottom: 1 inch, Left: 1.25 inch, Right: 0.75 inch. The final text area must be 6.5 inch x 9.25 inch.

2.2 Mortar:
The mortar consisted of Cement: sand: khaka mortar (CSK) in 1:4:4 ratios. 15 cubes were prepared at different water cement ratio were cast to find the w/c that can produce mortar the required average compressive strength with 500 psi.

- A Sample 5 cubes of 1:4:4 at (w/c) = 1
- B Sample 5 cubes of 1:4:4 at (w/c) = 1.2
- C Sample 5 cubes of 1:4:4 at (w/c) =1.4

Mortar cubes were prepared and tested at the age of 7 days as shown in figure.1.Based on the assumption that after 7 days the mortar gains its 70% of its 28 days compressive strength. The 28 days strength was determined by dividing 7 days strength.

Table 3: Compressive Strength of Mortar cubes (Plain)

S.NO	Sample A	Sample B	Sample C
1	827	835	464
2	866	780	402
3	1040	780	536
4	1307	827	480
5	1126	670	402

Sample	**A**	**B**	**C**
Mean value	1033.2	778.4	456.8
Standard deviation	196.3	65.8	56.7
Cofficient of variation	18.9 %	8.4 %	12.4 %

2.2.1 Mortar test:

Five samples of mortar of different water cement ratio were cured for 28 days. Mortar test is carried out in order to get the normal strength of mortar of a specific water cement ratio. The compressive strength of mortar that was used in prism preparations were determined by testing the mortar cubes under uniaxial compression in UTM.

Compressive strength of mortar;

In order to determine the compressive strength of mortar used in masonry assemblage as per ASTM C –109 specifications. Five cubes each having 2 inch side was tested in UTM.CSK mortar used in masonry assemblage was having a ratio of 1:4:4 by weight and water cement ratio 1.4, in the preparation of 12 prisms as shown in the figure.1. Brick used in the prisms had average strength of 2000 psi. The average dimensions of prism were

2.2.2 Monotonic load test:

In this test masonry assemblage were tested under the monotonic load. Load was applied through loading cell in UTM and the load displacement data was recorded in the data logger. 4 holes were made in each prism (**2** on front face and **2** on back face) .one hole on each face was made to mount the dial gauge while second hole on each side was made to place a nail. As shown in the figure 3.6. The nail was tied to a chord which was connected at the other end at a fixed distance. Steel plate of 2 ‘x 2 ‘with a thickness of one inch was placed on the top of the prism. Started applying load on the prism. The dial gauge shows the strain encountering in the prism by the revolution of needle around, the Values of which will be saved in the Data Logger**.** When the wide Cracks appeared, stopped applying load. Data saved in the floppy disk of data logger. Convert the floppy files to the numeral data.

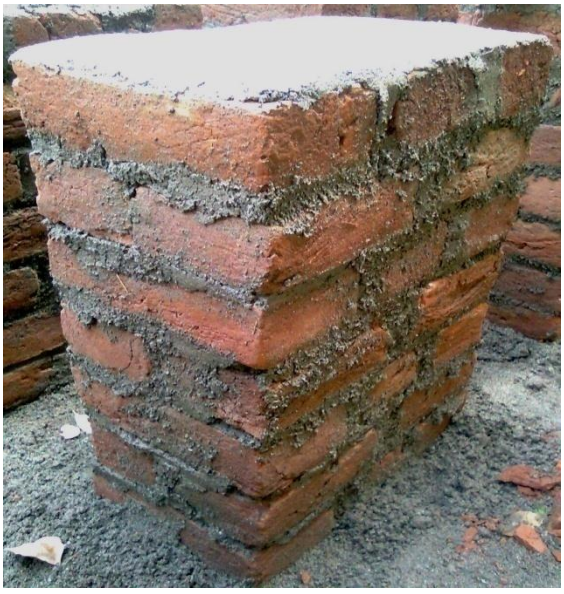

Figure 1: CSK mortar Prism
Length =14.5 inch Width = 8.5 inch Height = 22.5 inch

2.2.3 Modulus of elasticity:

The modules of elasticity can be determined by using the stress strain data of the masonry prism used to determine the compressive strength of masonry. ASTM E—447 specification were followed to determine the modulus of elasticity of the masonry.

E_m = (fm/3 -- fm/20) / strain

Figure 2: Testing of Masonry Assemblage

Table 1: Compressive strength and Modulus of Elasticity of Masonry Assemblage under Monotonic Load

Prism No	Compressive Strength f'_m (psi)	Modulus Of Elasticity (psi)	E_m/f'_m
1	242	46091	190
2	238	55132	232
3	245	103750	427
4	263	-------	-------
5	208	41556	200
6	234	--------	--------
Mean value	238.3 psi		262
Std. dev.	17.9 psi		111
% COV	7.5		42.4

Em of prism 4 and 6 were highly deviated from the practical range and were, therefore discarded.

2.2.4 Cyclic load test:

A load which, once in each period or stress cycle, fluctuates in respect to zero in one of alternating load; repeated load; pulsating load. In cyclic loading the value of load is increasing from zero up to certain value for three times. Detail data of cyclic test is given in table 5.

A load that is applied slowly and gradually in the direction opposite to each other is known as static cyclic load. In our case cyclic load was not possible to be applied due to the resulting tensile stresses. Therefore semi cyclic load (causing only compressive stresses) was applied.

Table 2: Compressive strength and Modulus of Elasticity of Masonry Assemblage under Semi cyclic Load

Prism No	Compressive Strength fm (psi)	Modulus Of Elasticity Em (psi)	Em/fm
1	241	112337	466.2
2	238	130377	545
3	292	133435	457
4	300	166100	550
5	226	75329	335
6	214	111280	520
Mean value	251.8		478.8
Std. dev.	35.61		80.57
% COV	18.6		22.2

As discussed in table above the mean compressive strength of both loadings are almost equal, so both systems should yield similar results.

Conclusions:

Following conclusions were made from the results of experimental work

1. The compressive strength of prisms tested under cyclic load was slightly higher than monotonic load.
2. E_m/f_m ratio for cyclic load was unexpectedly higher than that for monotonic prisms

Recommendations

It is recommended that the monotonic tests may be used to determine mechanical properties of masonry such as *compressive* strength, *elastic* modulus etc in seismic design. However these observations are based on limited tests further tests in future shall be carried out.

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