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Investigating the Mechanical Properties of Concrete Block Masonry Units (CBMU)

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Abstract —*Concrete block masonry are nowadays a common practice to be provided as infill walls in Reinforced Concrete structures as well as load bearing walls due to their improved sound and fire proofing properties. Moreover, its low cost and easy and robust construction has also boosted their use in construction industry. This research focusses on finding the mechanical properties of concrete block masonry units and the mortar used during its construction. Water absorption test on CBMU, compressive strength test on CBMU, compressive strength test on mortar cubes and compressive strength test on concrete block masonry prisms has been conducted and has shown promising result.*

Keywords-*Concrete block masonry units, water absorption, compressive strength, mortar cubes, masonry prisms*

I. INTRODUCTION

The usual practice adopted for the construction of the structure in earthquake affected areas of Pakistan is an assemblage of unreinforced concrete block masonry or brick masonry load bearing walls and reinforced concrete walls. This concrete block masonry and brick masonry are normally designed to support the gravity load. In the calamitous earthquake of October 8, 2005, in Kashmir and northern areas of Pakistan, in which thousands of people lost their lives due to either partial or full collapsing of buildings in these areas. These areas were later on inspected by various professionals and field related experts who came to the conclusion that main causes for these huge losses were use of low-quality construction material, absence of seismic building code, and improper workmanship. Moreover, it was also observed that most of the buildings in these areas were either non-engineered or were not designed for lateral load. From the inspections of the earthquake affected areas of Pakistan, it was observed that the masonry units used in the construction of masonry buildings were mostly stones and burnt clay bricks. However, it was also noticed that the concrete blocks were also used as in both as infill and load bearing walls. The masonry units' demand has increased due to the large-scale destructions and afterwards huge reconstruction in the earthquake affected areas. Due to huge demand, carriage cost, and fuel cost, the cost of a unit burnt clay has increased manifold in those areas. The experts have rejected the use of stone masonry because they performed poorly during the earthquake. Resultantly, the request for concrete block masonry increased, which was accomplished by the local factories established in those areas. Due to low cost and readily availabilities of this block masonry in areas struck by earthquake and its surroundings, its use increased as a major construction unit. The performance of these concrete blocks was not properly investigated before the earthquake in Pakistan.

This research work focusses on evaluating the mechanical properties of concrete block masonry units, i.e. initial rate of absorption, compressive strength of masonry units, modulus of rupture, compressive strength of mortar to be used in the construction of block masonry, block masonry prisms test to compute masonry compressive strength and modulus of elasticity etc. The tests to compute the mechanical properties of concrete block masonry and their results are discussed in the following sections.

II. WATER ABSORPTION TEST

The block selected for water absorption test were first dried in the oven for 24 hours in electric oven. The oven dry blocks were weighted and the weight was noted as Wd, after that this block were put in water for 24 hours and the weight was again noted as Ww, the water absorption was calculated from the following formula:

$$\text{Absorption (\%)} = (Ww-Wd)/Wd\times 100$$

In the above equation,
Wd is the dry weight of block (gm)
Ww is the wet weight of block (gm)
The computed value for the water absorption of concrete blocks were found to be 4.88%.

III. INITIAL RATE OF ABSORPTION

Initial rate of absorption for the concrete block calculated based on the procedure given in ASTM C-140**[1]**. The following equation was used for calculating IRA of different blocks.

$$IRA = 30\,(Ww-Wd)/Ac \quad g/min/30\ in2$$

In the above equation,
Wd = Weight of oven dried block (gm).
Ww= Block weight when placed in water for one minute as per ASTM C 67.
Ac= Surface area of block in contact with water
The computed value for the initial rate of absorption was found to be 0.81 (g/min/30 in^2).

IV. COMPRESSIVE STRENGTH(Fc□) OF CONCRETE BLOCK MASONRY UNITS

The compressive strength of the block was checked by testing 20 blocks in UTM machine as per ASTM C-140 standard. The surface was made uniform by gypsum capping and the load on the block was increased till the failure of the block in crushing occurred as shown in **Figure 1.**

Figure 1: Concrete block under compression test in Universal Testing Machine

An average compressive strength for the concrete blocks was calculated as 1050 psi.

V. MODULUS OF RUPTURE TEST

The Concrete block were tested as per ASTM C-140. Load was applied at midspan of the block making the end of the block simply supported and the load was increased by UTM until the rupture of concrete block occurred as shown in **Figure 2**.Modulus of rupture was calculated from Popov and Balan 1998**[2]**, formula as given below:

$$F_{bt} = M_{cent}\delta b$$

Where,
M_{cent} = Flexure moment at the center of the sample.
δ_b= Section modulus of block

Figure 2: Concrete block specimen under tensile strength

The computed value for the modulus of rupture was found to be 479.20 psi.

VI. COMPRESSIVE STRENGTH TEST FOR MORTAR CUBES

Since, the bonding material for the masonry unit is mortar, therefore, mortar's compressive strength effects the overall behavior of masonry structure. The mortar compressive strength was conducted as per ASTM C-109 **[3]** specification. About 50 mortar cubes having cement sand ratio 1:6 (one part cement and six parts sand) were tested in this study with an average compressive strength of 1100 psi. The test of these cubes is shown in **Figure 3** below.

Figure 3: Mortar cubes under compression test

VII. COMPRESSIVE STRENGHT TEST OF BLOCK MASONRY PRISMS

Compressive strength of masonry unit and mortar cubes are necessary for checking the properties individually but for predicting the behavior of masonry assemblage prism compressive strength must be find out. For this purpose, prism of concrete block with average size 16" x 16"x 8" (406mm x 406mm x 203mm) were tested compressively after curing for 28 days to find out the compressive strength of masonry assemblage. Therefore 10 prism prepared by placing of blocks in staggered manner so as to avoid continues vertical joint and joint thickness was approximately 3/8 inch. The test on the prism were performed in UTM by applying uniaxial load on the prism. To ascertain the value of fm', highest load resisted by prism was divided by the cross sectional area. (Shahzada 2011**[4]**). **Figure 4** shows procedure of prisms test.

Figure 4: Concrete block masonry prims under compression test

The modulus of elasticity of block masonry was obtained from the test conducted on the prism and for this purpose twodial gauges one on the front and the 2nd on the back side of the prism for detecting the displacement of the bock were installed. The deformation detected by the dial gauges were obtained from the record in the data acquisition system. By using the following equation, the modulus of elasticity was found for the concrete masonry prism.

Modulus of Elasticity, Em =(Difference of Longitudnal Stress)/(Difference of Longitudnal Strain)

=
Where,
Longitudinal stress difference= compressive strength/3- compressive strength/20= fm'/3-fm'/20
Longitudinal strain difference = difference in strains corresponding to fm'/3 and fm'/20 respectively.

The average compressive strength of concrete block masonry prims was found to be 436 psi.

VIII. COHESION C AND COEFFICIENT OF FRICTION μ

ASTM does not give any standard procedure for determination of cohesion c and coefficient of friction μ from triplet test. Therefore, EN-1052-3 **[5]**Specifications were availed for finding out shear strength of masonry based on triplet tests. **Figure 5** shows the framework of Triplet test. The shear strength from the test was established from the formula designed by Popov and Balan in 1998 as;

$$tu = \frac{Vus}{2Abm}$$

Where,
Vus = The amount of force that causes shear sliding in triplet test &
Abm = Brick mortar joint total shear area.
The computed value for the cohesion was calculated as 2.73 psi and coefficient of friction of 0.07.

Figure 5: Test setup for cohesion and coefficient of friction calculation

IX. CONCLUSIONS AND RECOMMENDATIONS

Pakistan is situated in seismically active region of the world. It has been hit by moderate earth quakes every year, however, the Hamalaya region has the potential of generating earthquakes of magnitude 8 and greater once in every 100 years which triggers severe losses to public and private properties and precious human lives. Pakistan is a poor country, especially the Northern areas which are prone to high seismic activities are living below the poverty base-line. The inhabitants of the region use economical but non-engineered means of building construction, mostly of unconfined stone, brick and concrete masonry, which though efficiently resist gravity loads but are very weak against earthquake loadings. Concrete block masonry units are nowadays common to be provided in RC structures which are having good sound and fire proof properties.

The mechanical properties tests conducted on concrete block masonry have shown promising results and hence further tests needs to be conducted on masonry wallets and piers to get information about their diagonal shear strength and lateral load resisting capabilities.

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