IMPROVEMENT OF MASONRY STRUCTURES AGAINST SEISMIC FORCE

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ABSTRACT

In this paper, Plane and confined masonry specimens have been tested by Portable Structural Testing Equipment (PSTE). The shear strength and tensile strength of unconfined masonry increases by 1.34 times and 1.7 times respectively, using Plaster. Use of wire mesh and plaster in unconfined masonry increases the shear strength by 1.61 times and the tensile strength by 2.35. Confinement increases the shear strength by 1.65 times and tensile strength by 3.05. Confinement and plaster increases the shear strength by 1.79 times and the tensile strength by 3.35. Confinement with bamboo mesh and plaster increases the shear strength by 2.12 times and the tensile strength by 4.05. Confinement with wire mesh and plaster increases the shear strength by 2.73 times and the tensile strength by 5.40. Wall density ratio for confined masonry buildings in Pakistan has been proposed for different zones and soil type.

Keywords: unconfined masonry, confined masonry, modulus of elasticity, tensile strength, Shear strength, PSTE, wall density ratio

INTRODUCTION

A major earthquake of magnitude 7.6 on Richter scale struck Northern parts of Pakistan and Kashmir on October 8, 2005. Due to the deadliest earthquake of this region, more than 73,000 people lost their lives, 80,000 were left injured, and 3.5 million people were left homeless (WB & ADB, 2005). Most of the casualties were the direct result of buildings collapse, either partially or fully.

The Himalayan region is considered to have potential of creating an earthquake of magnitude 8.0 and greater once every 100 years (W.F Chin, 2003). In the recent past, several earthquakes of moderate magnitudes (i.e., M_w = 5.0 to 5.5) have struck northern parts of Pakistan. These earthquakes have proved that the northern part of Pakistan is a seismically active area.

Among the natural disasters, earthquake might be infrequent but more destructive. It is not possible to prevent this natural disaster but the losses can be mitigated. Buildings which are properly designed and detailed on the basis of modern seismic building codes are less affected because these buildings dissipate energy through inelastic behavior. Improper design of buildings can make these buildings vulnerable to earthquakes. The enormous losses inflicted by the October 8, 2005 earthquake in Northern Areas of Pakistan were mainly due to the fact that in the absence of a seismic building code, all the buildings were either non-engineered or designed for gravity loads only.

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This research aims to find the most important parameter of plane and confined brick masonry i-e compressive strength, diagonal compression strength and shear strength. Portable Structural Testing Equipment (PSTE), developed by Dr. Tetsuro Goto of National Institute for Land and Infrastructure Management (NILIM) Japan, has been used for testing masonry performance against earthquake force. As currently there is no enough experimental data available about various parameters for brick masonry work, it is extremely useful to find out such parameters in quantifiable terms for earthquake resistant design, risk zoning and damage assessment of such structures.

DIAGONAL COMPRESSION TEST FOR MASONRY TENSILE STRENGTH

P.Sheppard and S.Tercelj have performed diagonal compression test on masonry specimens with different arrangements. The following equations have been used for tensile strength calculation of the masonry specimen (P.Sheppard, 1980).

$$\sigma_n = \sigma_o \left[-1/2 + \sqrt{\left(1.5 \frac{\tau_o}{\sigma_o}\right)^2 + 0.25} \right] = 0.62\sigma_o \qquad \text{Eq. (1)}$$

$$\sigma_o = 0.83 \frac{P}{A} \qquad \text{Eq. (2)}$$

$$\tau_o = \frac{\sigma_o}{1.5} = 0.55 \frac{P}{A} \qquad \text{Eq. (3)}$$

$$\sigma_n = 0.49 \frac{P}{A} \qquad \text{Eq. (4)}$$

Where;

A = x-sectional area of masonry wall (mm^2), P = maximum applied Load on the specimen (N)
σ_0 = axial compression strength of masonry (N/mm^2), τ_0 = shear Strength of masonry (N/mm^2)
$\sigma_n = \sigma_t$ = tensile Strength of masonry (N/mm^2)
0.49 = factor of stress reduction due to corner holding (determined from Finite element analysis)

Tensile strength and lateral resistance of masonry specimen

By considering the masonry wall as an elastic, homogeneous and isotropic structural element, the basic equation for the evaluation of the shear resistance of plain masonry walls can be derived by taking into account the assumptions of the elementary theory of elasticity (Miha Tomazevic, 2000).

Compression strength of the specimen is calculated by following equation.

$$\sigma_c = \sigma_o / 2 + \sqrt{(\sigma_o / 2)^2 + (b\tau)^2} \qquad \text{Eq. (5)}$$

Tensile strength of the specimen is calculated by following equation.

$$\sigma_t = -\sigma_o / 2 + \sqrt{(\sigma_o / 2)^2 + (b\tau)^2} \qquad \text{Eq. (6)}$$

Shear strength of the specimen is calculated by following equation.

$$\tau = \sigma_t / b\sqrt{\sigma_o / \sigma_t + 1} \qquad \text{Eq. (7)}$$

The following equation is used for determining lateral resistance of plane masonry,

$$H_{s,w} = A_w \tau \qquad \text{Eq. (8)}$$

$$H_{s,w} = A_w \frac{\sigma_t}{b} \sqrt{\frac{\sigma_o}{\sigma_t} + 1} \qquad \text{Eq. (9)}$$

Where,

b = h/d, A_w = d x t, and t = thickness of wall (mm), d = width of wall (mm)

For lateral resistance of confined masonry specimen the following equation has been reviewed and used (Miha Tomazevic, 2000).

$$H_{s,c} = \frac{\sigma_t A_w}{C_I b} \left[1 + \sqrt{C_I^2 \left(1 + \frac{N_w}{\sigma_t A_w} \right) + 1} \right] + n.0.806 d_{rv}^2 \sqrt{f_{con} f_y} \qquad \text{Eq. (10)}$$

By knowing the tensile strength of masonry specimens from laboratory tests, the lateral resistance of specimens has been calculated by using the equation (9) and equation (10).

Mechanical properties of materials

The material properties were determined and the results are given in the table as follows;

Table 2 Mechanical Properties of Materials

Material	Concrete	Mortar	Bamboo	Brick unit	Brick Prism
Compressive strength MPa)	27.3	21.53	NA	8.9	2.43
Tensile Strength (MPa)	2.56	2.2	234.5	NA	NA
Modulus of Elasticity (GPa)	19.368	14.782	NA	NA	28.182

Failure pattern of masonry specimens

The following figures explain the failure pattern of masonry specimens.

Figure 1 Behavior of Specimen J10B after testing

Figure 2 Behavior of Specimen J10B after testing

Figure 3 Behavior of Specimen J10BCTP after testing

Figure 4 Behavior of Specimen J10BCWP after testing

Diagonal compression strength of masonry specimens

Seven types of different specimens were prepared and tested. In the specimen names J, stands for Japan, 10 for compressive strength of brick unit in MPa, B for brick, P for Plaster, W for wire mesh, C for confined, T for Take (in Japanese) Bamboo, and W for wire mesh. Diagonal compression test of wall specimens were performed by using PSTE. Test results are given in the table;

Table 3 Diagonal Compression Strength of Brick specimens

Specimen Designation	Sectional area of specimen (A) (mm^2)	Maximum Load (P) (KN)	Diagonal Compression Strength = P/A (N/mm^2)
J10B	48792	20.02	0.41
J10BP	71920	70.53	0.98
J10BWP	71920	97.25	1.35
J10BC	100920	125.28	1.24
J10BCP	100920	138.65	1.37
J10BCTP	100920	166.35	1.65
J10BCWP	100920	219.43	2.17

Result shows that a specimen with confinement and wire mesh gives higher value of diagonal compression strength.

Tensile strength of masonry specimens

Tensile strength has been calculated from Diagonal compression test by using Equation (4) and the results are given in the table as follows;

Table 4 Tensile strength of masonry specimens

Specimen Designation	Sectional area of specimen (A) (mm^2)	Maximum Load (P) (KN)	Tensile Strength $\sigma_t = 0.49P/A$ (N/mm^2)
J10B	48792	20.02	0.20
J10BP	71920	70.53	0.34
J10BWP	71920	97.25	0.47
J10BC	100920	125.28	0.61
J10BCP	100920	138.65	0.67
J10BCTP	100920	166.35	0.81
J10BCWP	100920	219.43	1.08

Test results shows that application of plaster, confinement, Bamboo and chicken mesh increases the Tensile strength of brick masonry specimens.

Shear strength of masonry specimens

Shear strength has been calculated by using Equation (2) and Equation (7); where b = 1 for h/l = 1 and the results are given in the table as follows;

Table 5 Shear strength of masonry specimens

Specimen Designation	Compression Strength $\sigma_0 = 0.83$ P/A (N/mm^2)	$\sigma_t = 0.49P/A$ (N/mm^2)	Shear Strength (τ) (N/mm^2)
J10B	2.02	0.20	0.67
J10BP	2.02	0.34	0.90
J10BWP	2.02	0.47	1.08
J10BC	2.02	0.61	1.11
J10BCP	2.02	0.67	1.20
J10BCTP	2.02	0.81	1.42
J10BCWP	2.02	1.07	1.83

Test results shows that shear strength of brick masonry increases with Plaster, chicken mesh, confinement, Bamboo and Chicken mesh.

WALL DENSITY RATIO FOR BUILDINGS IN PAKISTAN

There are no rules and regulations for wall density ratio of confined masonry structures in Pakistan. To have safe masonry structures against earthquake, wall density ratio for masonry structures is of prime importance. On comparing with the seismicity of different zones of Peru and the corresponding wall density ratio of each zone the following wall density ratios are proposed for confined masonry buildings in Pakistan (UNI, March, 2004).

Table 6 Wall Density ratio for confined masonry buildings in Pakistan

Soil Type	Zone-I	Zone-II	Zone-III	Zone-IV
S1	3%	1%	1%	1%
S2	3%	2%	2%	1%
S3	4%	2%	2%	1%
Damage level	Very high hazard	High hazard	Moderate hazard	Low hazard

CONCLUSIONS

From test results which were carried out to determine the Diagonal compression strength, shear strength and tensile strength of different specimens the following conclusions are made.

1. The shear strength and tensile strength of unconfined masonry increases by 1.34 times and 1.7 times respectively using Plaster.
2. Use of wire mesh and plaster in unconfined masonry increases the shear strength by 1.61 times and the tensile strength by 2.35.
3. Confinement increases the shear strength by 1.65 times and tensile strength by 3.05.
4. Confinement and plaster increases the shear strength by 1.79 times and the tensile strength by 3.35.
5. Confinement with bamboo mesh and plaster increases the shear strength by 2.12 times and the tensile strength by 4.05.
6. Confinement with wire mesh and plaster increases the shear strength by 2.73 times and the tensile strength by 5.40.
7. Wall density ratio for confined masonry buildings in Pakistan has been proposed.

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