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Dynamic response of prestressed masonry structure made of half reduced scale fly ash bricks excited by shake table

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ABSTRACT

Based on previous failure characteristics of masonry structures under earthquakes, and due to the fact that a considerable number of masonry structures have been built around the world, a strengthening strategy for improving seismic performance of masonry structures is adopted and justified in this experiment, namely, the pre-stressing technique. The principle of this strategy is to tension the pre-stressing tendons located on both sides of the walls in order to increase the in-plane shear strength and simultaneously to improve the out-of-plane bending resistance of masonry walls, thus allowing an overall improvement of masonry structures under seismic loadings. In this experimental investigation shake table tests were conducted on one reduced model that represent normal single room building constructed by clay burnt brick. Model was constructed with post-tensioning bars.to examine the seismic capacity of the model particularly when subjected to long period ground motion by large amplitude by many cycles of repeated loading. The test specimen was shaken repeatedly until the failure. The test results are calculated from Dewesoft & data Acquisition system.

1. Introduction

The idea of pre-stressing of a material to offset future loads (i.e., wind loads, floor loads, etc.) was first developed in concrete construction. Pre-stressing is commonly used in concrete construction, primarily in long span slabs, such as parking garages and building floors.

This is a new method of pre-stressing masonry construction which can offer an economical alternative to conventional reinforced masonry by greatly reducing the amount of grouting required. Pre-stressing is used in masonry structure to reduce or eliminated tensile stresses due to externally applied loads by using controlled pre-compression. The pre-compression is generated by pre-stressed tendons. In this experiment, tendon of 8 mm mild drawn wire is used with pre-stressing post-tensioning technique. In addition, this strategy enables multi-level pre-stressing to be applied to the walls of the structure, thus allowing optimized compressive pre-stress in the structure along the building height. In order to validate the effectiveness of this technique, shake table model tests is conducted.

2. Material & Properties

Fly ash brick of half scale is chosen for casting the test specimen of size 110 x 55 x 37.5 mm, Weight 0.403 kg, Water Absorption 15.39 % and Compressive Strength 4.9 Mpa. The strength properties of pre-stressing tendon is, Ultimate tensile strength σ = 548.7 N/mm^2, fracture strength σf = 409.05 N/ mm^2 and Yield strength σy = 383.11 N/ mm^2. Strain gauge is used to measure strain in tendon with the following specification.

Size: 5 mm x 3 mm
Resistance: 350±0.3%
Gauge factor: 2.1 (Normal)
Strain gauge type: Foil type

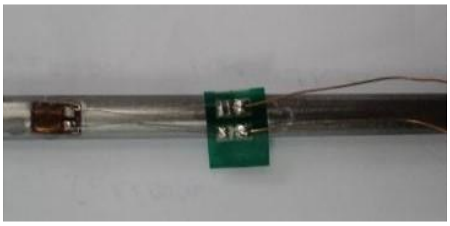


Figure 1 Strain gauge pasted on bar

Before pasting the strain gauge on the bar, the strain gauges are connected to wire and the other ends of wire are then soldering at the terminal tab. The strain gauges are then wrapped with silicon and aluminum foil to avoid damage and penetration of water. Having pasted the gauge on the bar, we have conducted a test to know the equation for change in resistance. The graph of resistance versus load is shown in figure 2

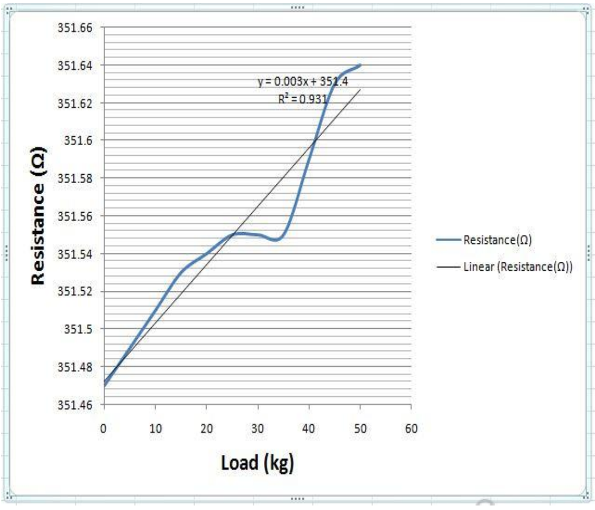


Figure 2 Resistance Versus load curve

$$R_f = 0.003X + R_0$$

Where, R_f = final resistance of strain gauge in (ohm)
X = load in kg
R_0 = initial resistance in (ohm)

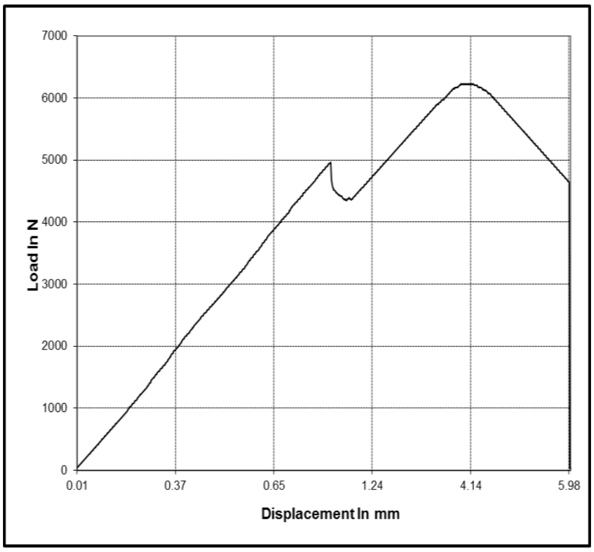
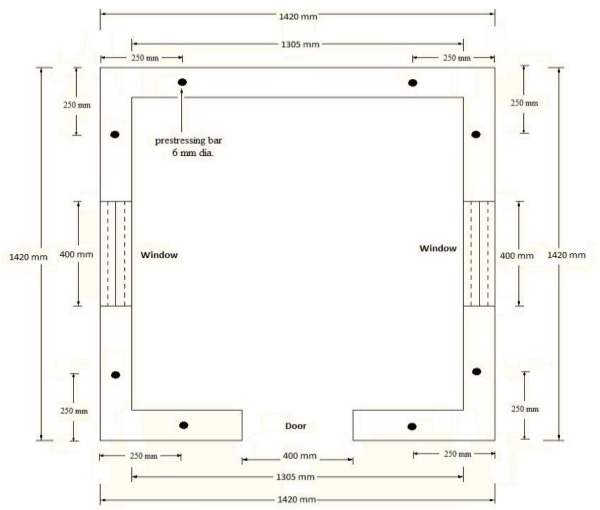


Figure 3 Stress-strain curve of pre-stressing bar

3. Description of Model

Fly ash bricks of 1:2 reduced scale of size 110 mm × 55 mm × 37.5 mm are used to construct the model. The dimension of reduced scale structure is 1.42 m × 1.25 m × 120 m. The base foundation on which super structure established is of dimension 1.5 m × 1.5m × 0.09 m. There are two windows of size (400×400) mm^2 on opposite side to each other and a door of size (900×400) mm^2. Tukri is used as a roof slab which is supported on steel angles. First window is on south wall, second window is on north wall and door of the structure is on east wall. The mortar grade MM-7.5 of 1:6 (cement: sand) is used for the brick work in the construction.



plan view of prestress model

Figure 4 Plan view of pre-stressed model

Calculation for weight of super structure:

Weight of west wall = 1.42 x 1.25 x 0.120 x 1700 = 362.1 kg

Weight of east wall = (1.42 x 1.25 x 0.120 x 1700) – (0.400 x 0.900 x 0.120 x 1700) = 288.66 kg

Weight of north wall + weight of south wall = 2 x [(1.18 x 1.25 x 0.120 x 1700) – (0.400 x 0.400 x 0.120 x 1700)] =536.6 kg

Weight of tukri = 1.300 x 1.300 x 0.050 x 2500 = 211.25 kg

Total weight of superstructure = 1398.61 kg

Total weight of the foundation = [2x (1.5m x 0.15m x 0.09 m) x 2500 kg / m^3] + [2x (1.2m x 0.15 m x 0.09 m) x 2500 kg/$m^{3]}$

= 182.25 kg

Total weight of structure = weight of foundation + weight of superstructure = (182.25+1398.61) kg = 1580.86 kg

4. Method of Pre-stressing:

Two high strength one end threaded bar of 6 mm diameter with an ultimate strength of 383 Mpa is introduced into each wall of the structure.

The pre-stress is applied to the structure at the age of 28 days after construction of the structure having assumed no pre-stress losses in the structure. A manual wrench is used for post-tensioning bar through the top anchorage plate; as its lower end is fixed with foundation. Pre-stress force is applied by the tighten of the bolt and pre-stress force is measured by relation of change in resistance of strain gauge and the original resistance of the strain gauge.

Table 1 Pre-stressing force in bar

Bar no-	Initial resistance (Ω)	Final resistance (Ω)	Yield strength (f_y) N/mm^2	20% pre-stress of f_y (N/mm^2)	Initial pre-stress force (N)
1	355.40	356.04	383	76.6	2164.76
2	352.84	353.48	383	76.6	2164.76
3	352.07	352.72	383	76.6	2164.76
4	351.70	352.35	383	76.6	2164.76
5	353.82	354.47	383	76.6	2164.76
6	352.40	353.05	383	76.6	2164.76
7	351.89	352.54	383	76.6	2164.76
8	354.62	353.27	383	76.6	2164.76

5. Experimental Setup

Instrument used:

- Shake Table
- Accelerometer
- Shake table speed controller
- Sixteen channel vibration analyser instrument

***Procedure*:**

After construction of foundation, 10 mm thick mortar mix of 1:3 is laid on the top surface of foundation. English bond is used in the construction of superstructure. Lintels are provided above every opening of concrete mix with reinforcement bar of 6 mm diameter. The structure is tested by means of shake table. The motion of shake table is simple harmonic. The shake table is adjusted at ±45 mm base displacement. Dewesoft software is used for calculating the various results e.g. displacement, velocity and acceleration at particular frequency. Four accelerometers are pasted on two walls, which are along the axis of the motion of shake table. These all accelerometers are connected to data logger device and this device is connected to the monitor e.g. laptop. The excitation given to the model is only in one direction. There is a control panel of shake table to apply the desired frequency. The structure is applied an initial frequency of 0 hertz and then increases up to 1.99 hertz.

Figure 5 Model on Shake Table Before Test

6. Result of Experiment

At frequency of 1.91 hertz, initial cracks are developed at base level on north, west, and south walls of the structure and also at sill level on south wall. The width of the crack is 1 mm at base level of north wall, west wall, and south wall and 1mm on south wall at sill level. Length of the crack at base level on north wall is 1135 mm from corner of east-north walls and length of crack on west wall at base level is 1090 mm from corner of north-west walls. Also the length of crack on south wall at base level is observed approximately 1090 mm from corner of west-south walls.

Figure 6 Crack on east wall at base level

Figure 7 Crack on north wall

Figure 8 Crack on south wall

Figure 9 @frequency=0.67 Hz

Figure 10 @frequency= 0.96 Hz

Figure 11 @frequency= 1.49 Hz

Figure 12 @frequency= 1.96 Hz

Table 2 Result at Base Level

S.no	Frequency (Hz)	Acceleration (g)	Velocity (mm/s)	Displacement (mm)
1	0.46	0.0089	0.8632	0.0958
2	0.67	0.0638	4.0639	1.1090
3	0.83	0.1599	20.9201	0.8990
4	0.96	0.1215	37.5912	0.6862
5	1.26	0.0158	26.3854	8.9786
6	1.49	0.0921	11.1458	7.9261
7	1.67	0.0371	2.1042	2.1284
8	1.76	0.1093	2.1928	16.8930
9	1.91	0.2543	112.7404	21.6915

Table 3 Result at Sill Level

S.no	Frequency (Hz)	Acceleration (g)	Velocity (mm/s)	Displacement (mm)
1	0.46	0.0151	0.8267	0.0434
2	0.67	0.0444	4.0306	1.1060
3	0.83	0.1555	21.2229	0.8499
4	0.96	0.0598	39.2672	0.7339
5	1.26	0.0998	26.6959	9.0171
6	1.49	0.0378	133.4015	8.1295
7	1.67	0.0799	2.1411	2.1731
8	1.76	0.1082	2.2541	17.1511
9	1.91	0.5840	87.9213	21.8193

Table 4 Result at Lintel Level

S.no	Frequency (Hz)	Acceleration (g)	Velocity (mm/s)	Displacement (mm)
1	0.46	0.0089	0.6340	0.0373
2	0.67	0.0493	3.9868	101518
3	0.83	0.1717	21.8827	0.8738
4	0.96	0.0636	41.8665	0.7739
5	1.26	0.0648	28.1365	9.4247
6	1.49	0.1108	148.1921	8.5252
7	1.67	0.0389	2.2526	2.2468
8	1.76	0.0767	2.3764	18.0536
9	1.91	0.7374	81.5482	22.8051

Table 5 Result at Roof Level

S.no	Frequency (Hz)	Acceleration (g)	Velocity (mm/s)	Displacement (mm)
1	0.46	0.0244	0.8298	0.0341
2	0.67	0.0376	4.2746	1.2557
3	0.83	0.2084	23.7789	0.9549
4	0.96	0.0677	46.8156	0.8567
5	1.26	0.0850	31.8199	103234
6	1.49	0.1816	169.7886	9.3864
7	1.67	0.0402	2.4973	2.4576
8	1.76	0.1014	2.6338	19.9857
9	1.91	1.2046	81.4573	25.2155

7. Conclusion

1. The modal is collapsed at the frequency of 1.91 Hz as compared to plain structure @1.62 Hz.
2. The pre-stressed structure performed better than plain structure without pre-stress as tested earlier.
3. The maximum displacement at frequency 1.91 Hz was at roof level of 25.21mm and minimum at base level of 21.6mm.
4. Pre-stressed structure shows more resistance to external force than plain structure.

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