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Validation of 6DOF Shake Table for Testing of Half Scaled Reinforced Concrete Model

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Abstract — *Pakistan is located at the collision boundaries of Indian, Eurasian and Arabian plates. It is estimated that 8th October 2005 Kashmir Earthquake took 80,000 lives with the economic loss of US $6 billion. Pakistan is the 6th most heavily populated country of the world. Reinforced Concrete (RC) structures is a popular form of construction in rapidly developing world. Research regarding this type of construction is the need of hour. Keeping in view the capacity of 6DOF shake table a half scaled two stories RC model was constructed on 6-meter square shake table which is the largest shake table in the South Asia. Before finalizing the experimental setup, the capacity of shake table was checked with 18 and 48 tons service loads. For these loads different tabletop acceleration response histories and displacement response histories were plotted, from which the performance of shake table was evaluated. This paper mainly focuses on the rigorous process of validation of shake table, spanning over three months for the preparation of table for the test.*

Keywords- *Shake table, EEC UET Peshawar, Reinforced concrete model*

I. INTRODUCTION

Pakistan is located at the collision boundaries of Indian, Eurasian and Arabian plates. [1]. The plate boundaries are loci of earthquakes [2]. Quetta earthquake of magnitude 7.7 Mw was the first devastation which has killed between 30,000 and 60,000 people in 1935 [3]. In 2005 Kashmir earthquake of magnitude 7.6 Mw, due to damage of 450,000 buildings, more than 80,000 people were killed and about 2.8 million people were made homeless [4]. These earthquakes are still considered as moderate earthquakes in a regional setting because estimates of slip rates suggest an average slip of ˜ 18 mm/year [5] therefore great earthquake of magnitudes greater than 8.0 is susceptible in this region. Pakistan is a developing country and it is the 6th most heavily populated country of the world [6]. In cities of Pakistan like Islamabad, Karachi, Peshawar, Faisalabad and Lahore, RC structure is a popular form of construction. This is mainly due to higher population, economic condition in these cities and high cost of the land [7]. Research regarding this type of construction is the need of hour. Therefore, keeping in view local construction practice a two story half scale reinforced concrete model was constructed on shake table which is installed at Earthquake Engineering Centre (EEC) of University of Engineering and Technology Peshawar. Although the EEC was completed in June 2011 and equipment installation was started in July 2011, but it will be it first RC model test. Keeping in view the weight of the RC model, the performance of the shake table was evaluated with 18 tons and 48 tons service loads.

II. CHARACTERISTICS OF 6 DOF SHAKETABLE

In 2005 EEC has installed it fist shake table R-141, which has single degree of freedom and 1.5m x1.5m. In 2011 a new seismic lab was developed in which a new shake table was installed has six degree of freedom and 6m x 6m. Some of the characteristics of shake table are given below.

- Acceleration (in all the three directions) = ±1.5g
- Maximum payload = 60 tons
- Velocity (in all the three directions) = ±1.1m/s
- Overturning moment = 40ton-m
- Frequency range = 0-50 Hz
- Electric power to run the system = 1.2MW
- Cooling tower = 200 tons
- Hydraulic supply = 2044 litre/min as shown in Figure 1.
- 4 Dynamic Actuator 100 tons each

Figure 1: Hydraulic power supply

- Displacement = ± 400mm
- Frequency range = 0-50 Hz
- Peak velocity = ± 250 mm/sec
- Fatigue rated
  which can be
  displacement controlled,
  force controlled and
  strain controlled as shown in Figure 2.

Figure 2: Dynamic actuators

III. MODEL DESCRIPTION

RC frames structures are normally infilled with brick masonry to resist the surrounding moisture, temperature, fire and noise. In these structure the infilled walls are contemplate as non-structural elements and usually neglected in structural design and analysis because of a large number of variables such as relative infill to frame stiffness, strength and geometry of infills location of openings etc. However, under lateral loading the infilled walls can change the failure pattern and load resisting mechanism and of RC frames. In failure pattern and load resisting mechanism of URM infilled wall openings (door and window) play a very important role, therefore a half scaled RC model was constructed on shake table, in which infilled walls with different combination of window and door openings were provided as shown in Figure 3.

Figure 3: Half scaled RC building constructed on shake table

IV. PREPARATION OF SHAKETABLE

Before finalizing the experimental setup, performance of the shake table was evaluated in two tests, which are discussed in the following sections.

A. Test # 1

In this test the performance of the shake table was evaluated with 18 tons service weight as shown in Figure 4. Two concrete pads of weight one ton each, were place at each corner through bridge crane of capacity 60 tons. Two pads of weight four tons and two pads of weight one ton at the centre.

B. Test # 2

In this test the performance of the shake table was evaluated with 48 tons service weight as shown in Figure 5.

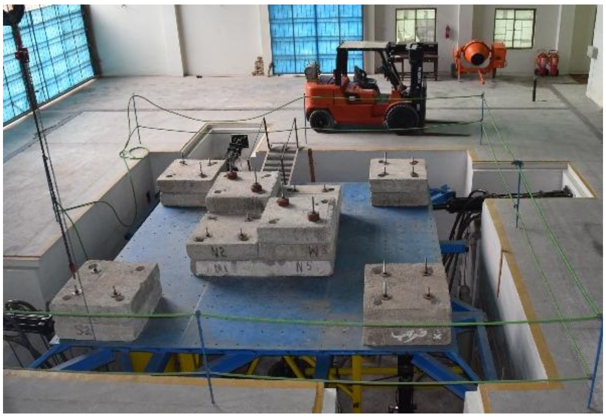

Figure 5: Shake table with 48 tons service dead load

Figure 4: Shake table with 18 tons service dead load

C. Instrumentation Plan

Two displacement transducers and five accelerometers were installed at different locations of shake table as enumerated in Table 1 in both the tests. Schematic diagram of instrumentation plan is shown in Figure 6. Before the installation, accelerometers and displacement transducers were properly calibrated as shown in Figure 7.

Table 1: Details of instruments

Channel No	Serial No of Sensor	Sensitivity	Type	Location
a01	323	509.0 (mv/g)	Accelerometer	AC-WS
a02	340	510.1 (mv/g)	Accelerometer	AC-ES
a03	6516	510.1 (mv/g)	Accelerometer	AC-NW
a04	6515	501.1 (mv/g)	Accelerometer	AC-SW
a05	6514	492.2 (mv/g)	Accelerometer	AC-CU
a06	1708-01	8.5305 (mv/mm)	Displacement transducer	DT-H4
a07	1708-02	8.5332 (mv/mm)	Displacement transducer	DT-H2
a08			Actuator	H2
a09			Actuator	H3
a10			Actuator	H4

Notation

- AC-WS: Accelerometer located at West face of Shake table facing towards south
- DT-H4: Displacement transducer located at actuator H4

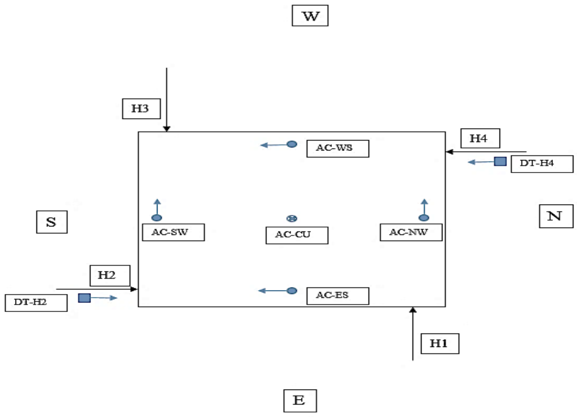

Figure 6: Schematic diagram of instrumentation plan

Figure 7: Calibration of Accelerometers and Displacement transducers

D. Purpose of Instrumentation

In order to detect the twisting in the shake table, two accelerometers (AC-WS and AC-ES) were installed at the west and east face of the shake table facing towards south. Similarly, to detect the out of plan acceleration in the shake table, two accelerometers (AC-SW and AC-NW) were installed at south and north face on the shake table facing towards west. To measure the vertical acceleration of shake table one accelerometer (AC-CU) was installed at the centre of the shake table. In order to measure that actuators are displacing at same amount, one displacement transducer (DT-H2) was installed at H2 and one (DT-H4) at H4 actuator as shown in Figure 8. If there is difference between the two displacement, then there will torsion in the shake table.

Figure 8: Displacement transducer installed at actuator H2

E. Data acquisition system and Servo controller

The Data acquisition system consist of rack, in which four ADC (ANALOG TO DIGITAL CONVERTER) boards are mounted, in these boards 48 channels are available. In the rack 24 channels ICP power supply for accelerometer, for anti-Aliasing and Data clarification there is 64 channels Filters, 24 channels power supply for Displacement transducers, one Dance control PC and one ANIPC Control PC are mounted as shown in Figure 9.

GS2000 Servo controllers also consist of rack mounted card cages (for each controlled channel one cage). Each cage contains modular circuit cards for program input to the load cell conditioning, the actuator, strain gage bridge completion and conditioning, command vs. feedback comparison, LVDT conditioning, and program error and limit detection as shown in Figure 9.

Figure 9: Data acquisition system and Servo controllers

F. Data processing tool:

For the signal processing DADisp (Data Analysis and Display) was used which includes a series based programming language called Series Processing Language (SPL) [8] used to implement custom algorithms.

V. VAIBRATION STUDY

Shake table was vibrated with different frequency and amplitude through signal generator manually. To check the performance of shake table different combination of frequency and amplitude were applied to the shake table. Details of which are given below.

- In the initial stage frequency was kept 0.5 Hz and the amplitude of vibration was kept ±2.5 mm.
- In the second stage frequency was kept the same i.e 0.5 Hz but the amplitude of vibration was increased to ±5.0 mm.
- In the third stage frequency was increased to 1 Hz and the amplitude of vibration was kept the same i.e ±5.0 mm.
- In the fourth stage frequency was increased to 2 Hz and the amplitude of vibration was kept the same i.e ±5.0 mm.
- In the fifth stage frequency was increased to 3 Hz and the amplitude of vibration was kept the same i.e ±5.0 mm.
- In the sixth stage frequency was increased to 4 Hz and the amplitude of vibration was kept the same i.e ±5.0 mm.
- In the seventh stage frequency was increased to 5 Hz and the amplitude of vibration was kept the same i.e ±5.0 mm.
- In the eight stage frequency was increased to 6 Hz and the amplitude of vibration was increased to ±10.0 mm.
- In the ninth stage frequency was increased to 10 Hz and the amplitude of vibration was kept ±5.0 mm.
- In the tenth stage frequency was Kept 1 Hz and the amplitude of vibration was increased ±20.0 mm.
- In the eleventh stage frequency was kept 1 Hz and the amplitude of vibration was increased to ±30.0 mm.

VI. RESULTS AND DISSCUSION

A. Displacement transducers Results

Displacement response history from DT1708-02 is shown in Figure 10 while displacement response history from DT 1708-01 is shown in Figure 11. These two displacement response histories were plotted over each other as shown in Figure 12.

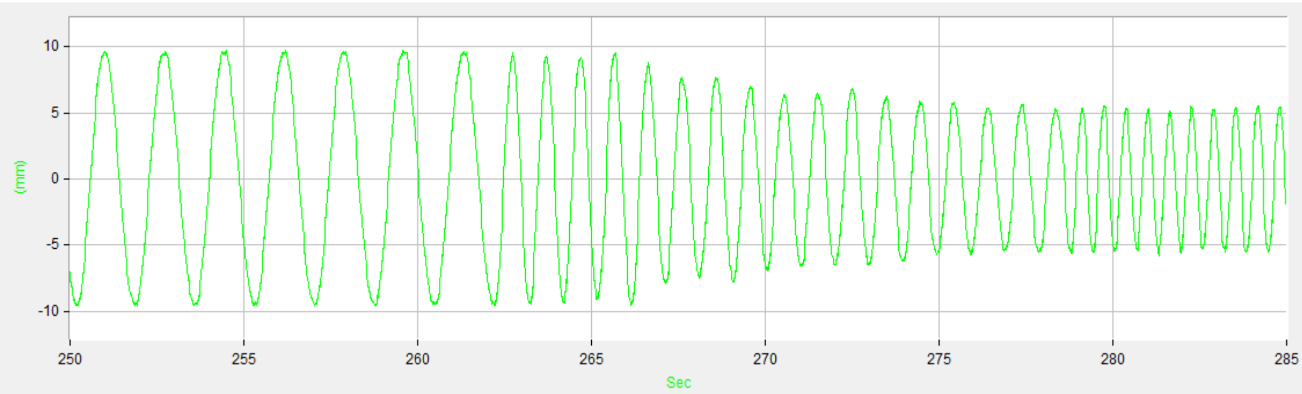

Figure 10: Displacement response history from DT 1708-02

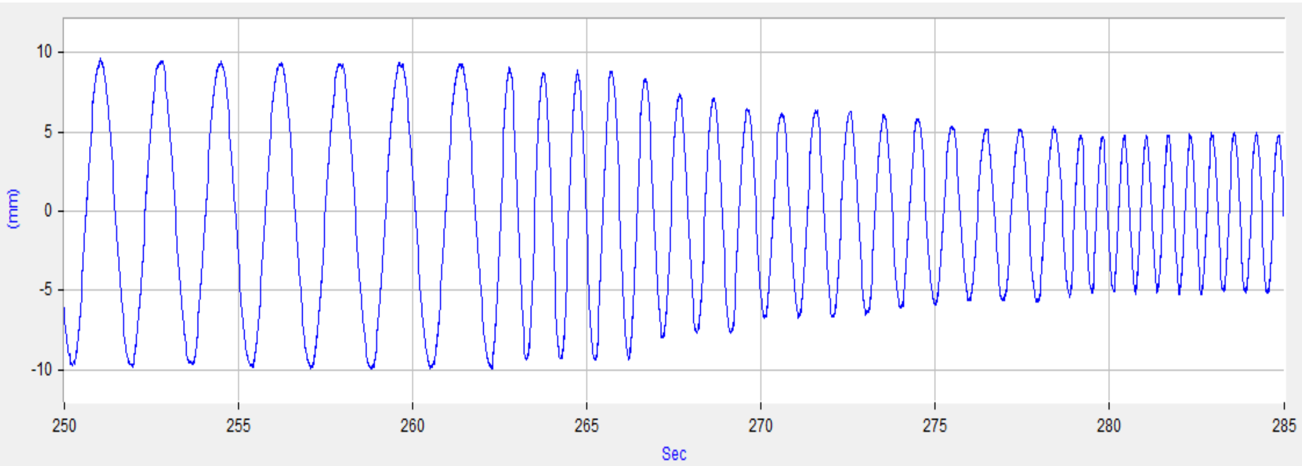

Figure 11: Displacement response history from DT 1708-01

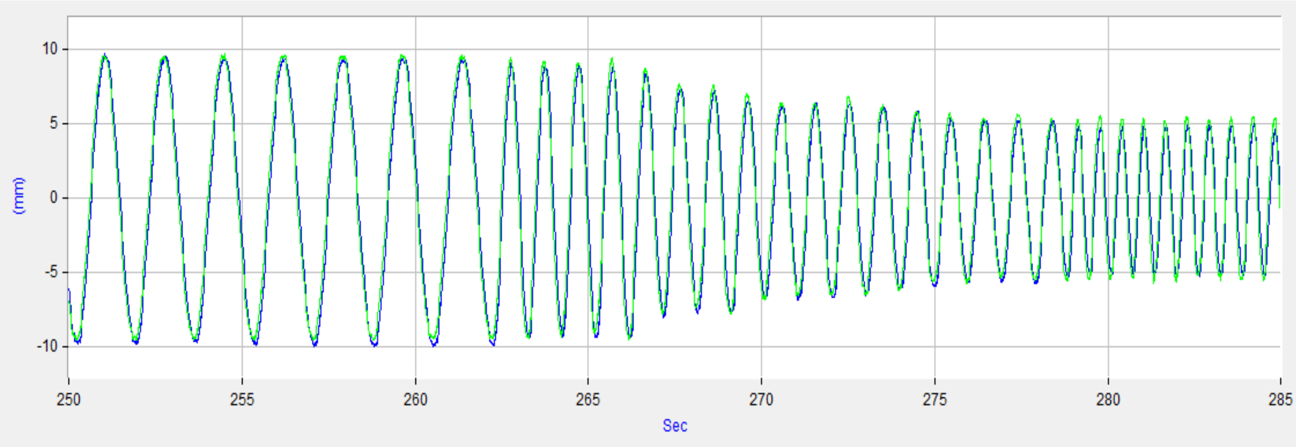

Figure 12: Over plot of displacement response histories

From the Figure 12 it was observed that displacement in actuators H2 and H4 were same from which it was detected that shake table was vibrated only in the in-plane direction and there were no out of plane vibration in the shake table.

B. Accelerometers Results

Acceleration response history from acc. 340 is shown in Figure 13. Similarly, the acceleration response history from acc. 323 is shown in Figure 14. These two acceleration response histories were plotted over each other as shown in Figure 15.

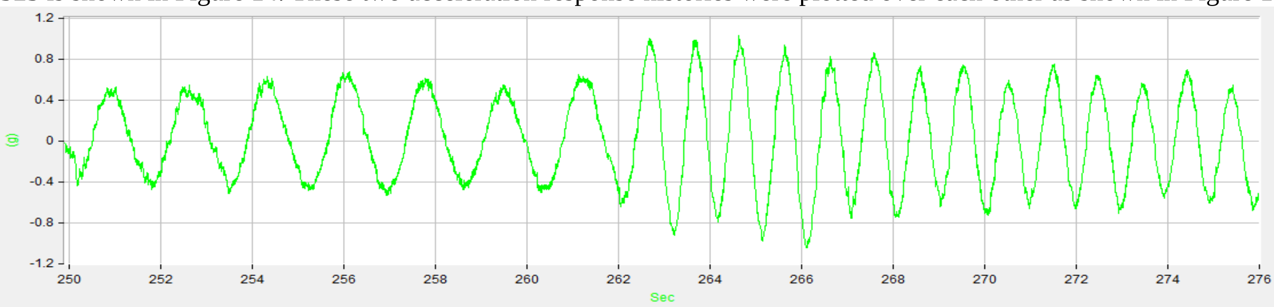

Figure 13: Acceleration response history from AC. 340

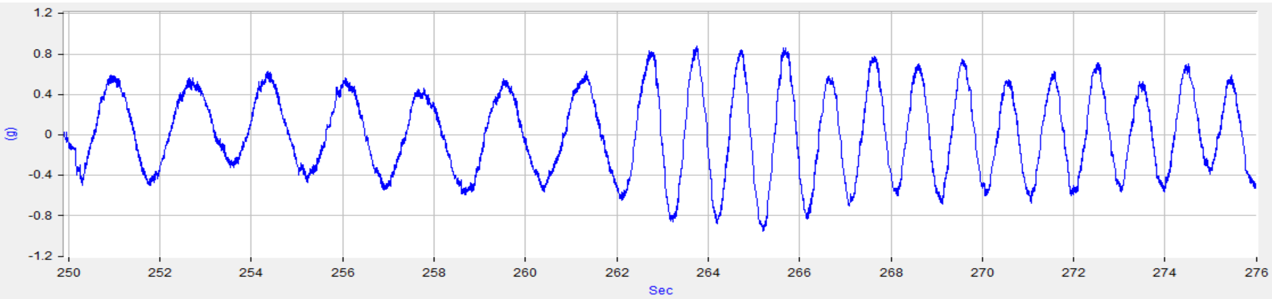

Figure 14: Acceleration response history from AC. 323

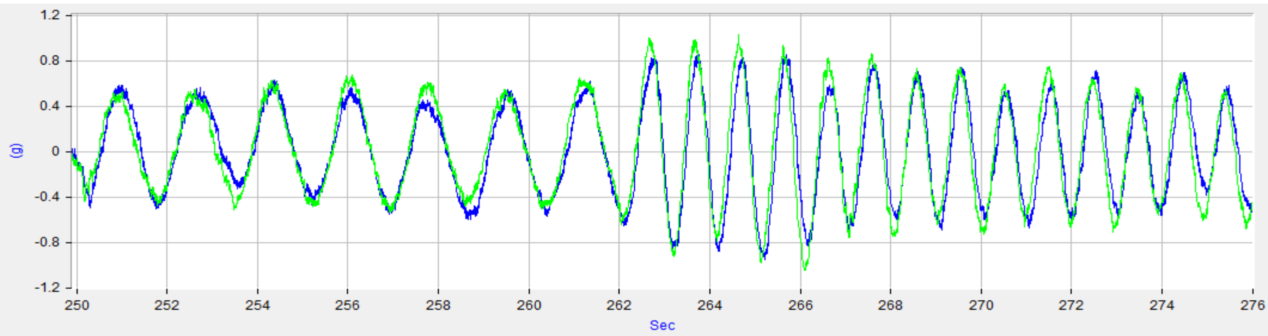

Figure 15: Over plot of acceleration response histories

From the Figure 15 it was observed that there is a slight difference of acceleration of AC-ES and AC-WS, but it is negligible. Because from the pattern it may be recognize that one accelerometer is more sensitive than the other.

VII. CONCLUSION

After careful analysis of the displacement response histories and acceleration time response of displacement transducers and accelerometers for 18 tons and 48 tons service loads it was concluded that shake table is properly validated. Although there was slight difference of acceleration of AC-ES and AC-WS but it was concluded it is because the sensitivity of the two instruments.

The half scaled RC building total weight was 16.2 tons. As the performance of the shake table with 48-ton service load was very good, therefore in future the scale of the RC building can be increased.

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