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Shake Table Experiment on Reactor Vessel

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Abstract: *The importance of Nuclear Power Plants and the consequences of a nuclear accident require that the nuclear structures be designed for the most severe environmental conditions. As the Earth quake is one of the natural hazard that can cause extensive damage to human lives and property it constitutes major design consideration for the system structures and equipment of a Nuclear Power plant. In view of complex nature of analysis, experimental validation results on testing was done with 1/8th scale down model and main vessel with liquid on shake table (3m x3m, 10t capacity.*

Keywords: *Nuclear accident, structures, natural Hazard, main vessel, shake table*

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I. Introduction

Shake table tests are by far the best suited for studying the response of buildings, structures, structural components, equipment and machinery under simulated base excitation. Uni-axial, bi-axial and tri-axial tables are common. In a tri-axial shake table all six degrees of freedom can be reproduced. The shake table consistent with the performance requirements is actuated by multiple servo-controlled electro hydraulic actuators. A rigid mass to anchor the actuators and to support the shake table, a sophisticated electronic control system, and a foundation scheme with or without dampers complete the test facility. Compared to many other test facilities shake tables require a large dedicated building. Unlike many other equipment which can be directly installed once they are bought, shake table systems are custom built. The integration of the various components is to be done at site and large scale checking is necessary before eventual commissioning of shake table system. Even though the test runs for short duration, huge hydraulic power supply is usually required even for moderate size shake tables with reasonable performance criteria. Most civil engineering structures tested on the shake table are modelled to the scale ratios 1:2 to 1:100. Appropriate similitude analysis is used to scale the parameters. Smaller shake tables which are driven by electro dynamic shakers have high acceleration requirements and can support only limited mass. Typically shake tables used for R&D purposes have a payload capacity varying between 10 to 100 t. the acceleration levels are in the range of 0.8 to 2.0 g, velocity in the range of 0.8 to 2.0 m/sec, and displacement in the range of 50 to 200 mm. The performance of the shake table is governed by the performance envelope of the actuator.

II. Important Considerations Relating To Planning And Design Of Shake Table Facilities

Even though as a concept shake table appears simple, there are many critical points to be considered in planning of the shake table system. Some of these are indicated below.

5.2.1 Foundations For Shake Tables

Two types of foundations are common, namely the fixed type and the floating type. The floating type is nearly two to three times as costly as fixed type. The natural frequency of the foundation-soil system lies normally in the range of 20 to 40 Hz. The fixed foundation requires larger mass than floating foundation. Transmission of vibration in to the environment is extremely low in case of floating foundation. Floating foundations have problems at low frequencies, and hence may pose problems for large size models.

5.2.2 Table

Shake tables of the first generation were made with concrete, and several high performance shake tables were with special grade aluminium because of their strength to weight ratio. How ever present day shake tables are invariably made of steel. The table tops are to well machine. The first frequency of the table with actuators should be well above the frequency range of operation.

5.2.3 Acutators

The actuators are the heart of the whole shake table system, and the designs are extremely complex. Actuators should have very low friction, high lateral stiffness and high precision. High response and multi stage servo valves are required to ensure satisfactory performance. The present day designs of actuators tend to minimize the pressure seals included in the hydraulic circuit. Hydro static bearings, phosphor bronze bearings or poly-amide bearings are used by different manufacturers. The actuators have to be fatigue rated for large number of cycles of operation, typically 10^9 cycles. It is preferable to over size the piston rods to eliminate lateral deformations leading to unwanted loads on bearings. The actuators are usually filled with adequate capacity accumulators to provide for peak flow requirements and accidental over flow demands. The actuators accommodate the swivels, the manifolds, servo valves, LVDTs and load cells. Any component part whose natural frequency is in the range of operation of the actuator can distract/or create a hole in the performance in the actuator. The oil-column resonance frequency of the actuator must be as large as possible.

5.2.4 Htdraulic System

The seismic test requires large oil-flows for the first six to ten seconds. Even a highly used shake table facility may run only for about 600 hours per year. Single or modular hydraulic power packs are used depending on the system. The noise level generated is an important criterion in selection of power pack. For peak flow demands, generally accumulators systems are used. For very large test systems high pressure blow down accumulators which store hydraulic energy over a long period, and utilize the same during seismic testing have been employed. Special type of hydraulic oils which do not disintegrate with increase in temperature up to a given temperature level are to be used. The oil reservoir is usually integral with hydraulic power pack, and must have sufficient volume. Generally a minimum of three times the out flow volume is considered as requirement. Cooling of hydraulic oil is an important factor and efficient heat exchangers and cooling systems are to be planned and installed. Adequate care is also necessary in the design of hydraulic distribution system.

5.2.5 Control System

Servo controlled closed loop system is the essence of shake table testing. The controller configuration must be able to integrate, analyse and control the test system based on multiple signals received from transducers. The system shall have the capacity to store and retrieve assigned actions, and be in a position to abort program in case of limit over runs. The update rate for control shall be as high as feasible, usually around 5 k Hz per channel. The controller shall have multiple control and adaptive compensation to include degrees of freedom control, force balance control, amplitude-phase control, etc. the real time controller must have real time spectrum and analyser for PSD generation, transfer function estimates, information on coherence and suitable high and low noise digital filters. Adequate number of signal conditioners with high resolution and accuracy are needed. On line data acquisition at high speed is essential. The controller shall function and generate signals such that there is no cross-talk when than two experiments are in progress. User selectable resonance correcting notch filers to reduce distortion caused due to resonating specimen, oil column resonances, and other unforeseen mechanical and system resonances are to be included. Also sometimes servo valves exhibit non-linear characteristics, and the controller hence must provide for such an eventuality.

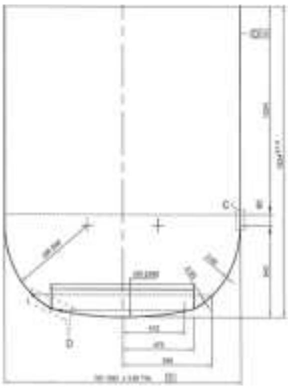
5.2.6 Instrumentation

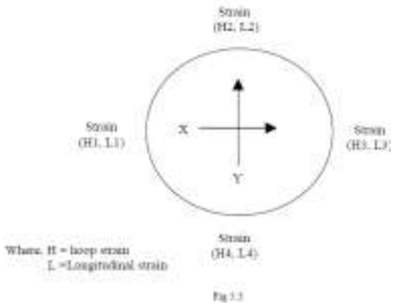
Varied type of instrumentation is used in seismic testing and evaluation. In servo controlled actuators normally transducers for load and displacement control in the form of load cells and LVDTs are used. For shake table control depending on degrees of freedom number of force balance accelerometers are used. Typically a three directional shake table facility includes nine force balance transducers. All transducers require signal conditioning. For measurement of response of the structure under test, LVDTs, accelerometers, pressure sensors, stain gauges, etc., are used. Present day data acquisition systems are digital, and hence A/D converters are necessary. The speed of data acquisition shall match with testing requirements.

III. Specifications Of Shake Table

Table Size: 3 m X 3 m
Payload 10 t
Degree of Freedom: 6
Maximum Displacement ± 100 mm
Maximum Velocity: 0.3 m/s
Maximum Acceleration (Horizontal): 1.5 g
Maximum Acceleration (Vertical): 1.0 g
Frequency Range of Operation : 0.1 – 100 Hz
Test capabilities: Sine, Sine Sweep, Time History, shock and Random Test.

Main vessel Specifications
All dimensions are in mm
Total height of the vessel= 1764 mm
Thickness of the vessel = 3 mm
Outer diameter of the vessel = 1565 mm





Shake Table Experimental Set up | Main Vessel Specifications | Starin Gauge location

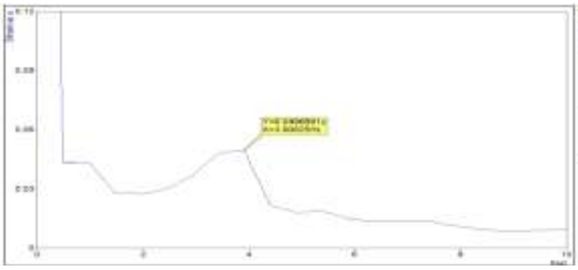
Strain Gauge:
Strain gauges are used in civil engineering to measure movement of buildings, foundations, and other structures.Both vertical and horizontal movement can be monitored over time.

The Linear Variable Differential Transformer (LVDT):
The Linear Variable Differential Transformer (LVDT) is a displacement measuring instrument and is not a strain-based sensor. The LVDT models closely the ideal Zeroth-order displacement sensor structure at low frequency, where the output is a direct and linear function of the input

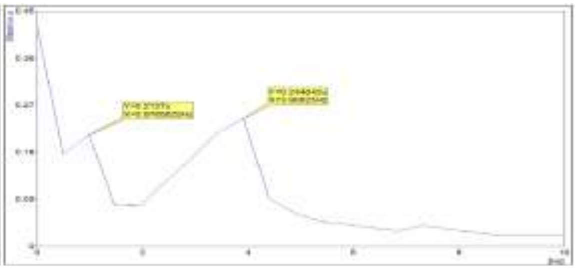
IV. Analysis Results

Sin X (0.1-4)Hz_2mm (frequency vs displacement)

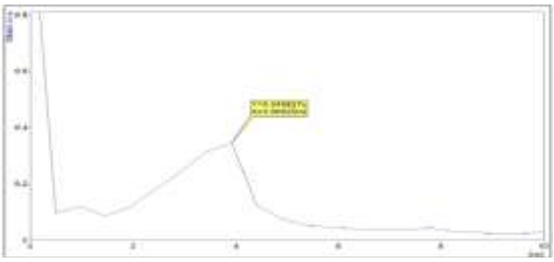
H1



H2



L1



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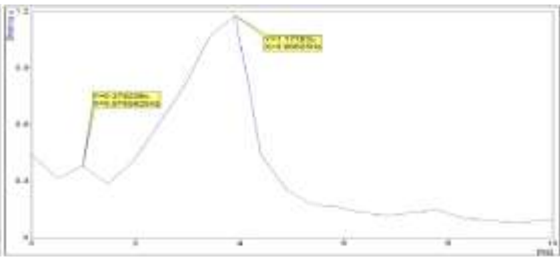
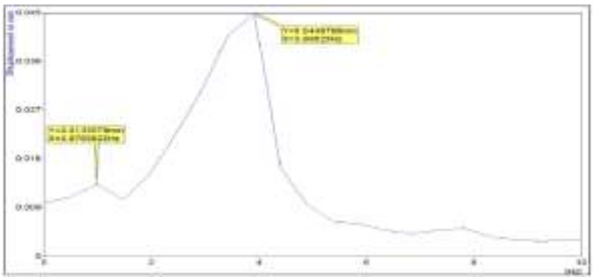


LVDT



From graphs it was found that the fluid structural interaction frequency of the main vessel is 3.90625 HZ.

V. Conclusion

From shake table experiment the fluid structural frequency of the main vessel was found to be 3.90625 Hz for the given model (Main vessel of 10 t capacity).Based on this result the structural features of main vessel are further modified if necessary.

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