Innovative Experimental Technologies in Earthquake Engineering – an Overview

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Challenges in the experimental simulation of earthquake effects and the use of innovative technologies to meet these challenges, will be overviewed in this short presentation. Ever since the digitally-controlled servo-valve revolutionized experimental structural dynamics, researchers have been pushing the boundaries of experimental mechanics to design structures for damaging earthquakes. From small-scale, elastic models we have progressed to large-scale, non-linear specimens in an attempt to capture the real world as accurately as possible in the laboratory. This is important if we are to validate our numerical models in the most credible manner possible. But, with increasing scale comes a family of challenges, some of which are reviewed below.

For a number of years the gold standard in laboratory testing has been the shake table (the closest we can come in the lab to an earthquake in the field). As these have become bigger to test large-scale specimens at high strokes and velocities, they have become expensive to build and operate. In response, arrays of shake tables have been constructed, in which multiple tables can be operated synchronously for large specimens, or independently of each other for smaller experiments. Also in response to high cost of a shake table experiments, hybrid testing has gained popularity. Once known as pseudo-dynamic testing with inherent errors and latency, it has the distinct advantage of being able to work with full-scale components at a fraction of the cost of a shake table test. An intense effort in the last decade has refined this technology and real-time hybrid simulation is now both reliable and affordable.

The principal experimental facility used by geotechnical engineers is the geotechnical centrifuge, in which an artificial gravity field is imposed on small-scale specimens of soil to simulate confinement and the insitu strength of soil. Even the largest of these in the world today, operate at about 1/40th scale and thus any structure embedded in the soil or supported thereon, is also limited to 1/40th scale. This is a significant challenge for meaningful soil-structure-interaction experiments, especially if nonlinear effects are to be investigated such as soil gapping, structure rocking, or structure yield. As a consequence, large-scale laminar soil boxes have been recently constructed, mounted on a large shake table and excited either uniaxially or biaxially. The advantage here is that a larger structural scale may be used (say 1:5), but the disadvantage is the inaccurate modelling of the soil strength. It is also true that boundary conditions influence the size of the shear deformation zone in the soil. To maximize this zone and minimize the effect of the wall, complementary shears in the soil need to be transferred to the box wall, where they become tensile forces in the wall. Resisting these forces while not restraining the soil laterally, is a challenge.

Coastal engineers have historically used wave flumes and wave basins for hydraulic studies of harbors and coastlines. More recently they have also been used to study tsunami inundation of coastal structures and validate load equations for their safe design. A typical scale for these experiments is of the order of 1:20 which raises concerns about the validity of the measured structural forces. Furthermore at this scale, hydraulic modelers do not attempt to represent structure flexibility and instead use rigid blocks for their models. This is a significant challenge for meaningful fluid-structure-interaction experiments, especially if nonlinear effects are to be investigated such as those incurred during progressive collapse. Furthermore the traditional wave flume was not intended to study tsunami waves. The solitary wave generated by most wave-makers is not truly representative of a tsunami bore (in shape or sustained flow) and new flumes are under construction that address this shortcoming.

This short overview would not be complete without saying something about innovations in instrumentation and data acquisition. Contact-less instrumentation has long been a goal of experimentalists, and a number of optically-based systems have now been developed and are under evaluation for use in earthquake engineering laboratories. These methods, including those based on digital image correlation, show great promise.

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