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Scientific and engineering studies of systems, structures, and components important to safety for a potential repository at Yucca Mountain, Nevada

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BACKGROUND

The seismicity of Yucca Mountain is a major factor in determining its feasibility as a repository for nuclear waste. Advances in seismology and earthquake engineering in the last decade have greatly improved the state-of-the-art to the point where significant reductions in risk are now feasible despite high hazard levels. Nevertheless most of the advances in earthquake engineering have been in numerical simulation rather than in experimental modeling and analysis. This is due in large measure to the lack of sophisticated test facilities with high-performance simulators of
sufficient capacity and stroke to permit experimental work at large-scale. As a consequence, it is generally not possible to confirm advances in numerical simulation with experimental evidence and the limitations on numerical solutions cannot be determined with objectivity.

In 1995 the Large-Scale Structures Laboratory at the University of Nevada Reno (UNR), installed one of the largest earthquake simulation facilities in the United States, comprising a pair of 50-ton payload tables capable of high accelerations at typical earthquake frequencies, and large strokes (24 in (600 mm) peak-to-peak). But the tables were limited to unidirectional motions and thus unable to reproduce more than one component of ground motion at a time. Multiple components of ground motions, which are characteristic of actual earthquakes, could therefore not be imposed simultaneously, and thus approximations were necessary to infer three-dimensional response of test specimens.

Recognizing this deficiency, the Department of Energy requested the University’s earthquake facilities be upgraded from uniaxial to biaxial motions to allow rigorous experimental analyses of systems, structures and components (SSCs) important to the safety of the potential repository at Yucca Mountain.

Other federal agencies were also supportive of the upgrade, and in particular agreed to fund the purchase and installation of a third biaxial table, to enable the study of long, spatially-linear systems with multiple support excitation. The National Science Foundation (NSF) made an award of $4,398,450 million for this purpose and the Department of Housing and Urban Development (HUD) provided an additional $1,618,750. The total investment in this project, including the DOE contribution under the subject task, was therefore $7,017,200.

Furthermore the NSF Award was made under the George E. Brown Jr. Network for Earthquake Engineering Simulation (NEES) Program at NSF, and the facility will become a node in the NEESgrid when it is completed in September 2004. Using broadband internet-2 connectivity, teleobservation and teleoperation activities will be possible in the laboratory by the end of 2004, thus enabling shared-use access by remote users.

OBJECTIVE

The objective of this Task was to purchase, install and commission the equipment necessary to upgrade two existing shake tables in the Structures Laboratory at UNR, from uniaxial to biaxial motion.

It was recognized that a parallel effort, funded by NSF and HUD, to add a third biaxial table with identical properties to the upgraded existing tables, would be undertaken at the same time.

RESULTS

The existing tables have been upgraded to biaxial motion and a third table installed in the laboratory. Figure 1 shows the third table being lowered into position onto base plates previously post-tensioned to the laboratory strong floor. Figure 2 shows the completed 3-table installation. Also seen in both figures are the servo-controlled actuators, which drive the tables in biaxial motion. A pair of actuators is provided for each table, aligned in the North-South and East-West directions respectively.
Figure 1. Installation of third shake table in Large-Scale Structures Laboratory (8/02)

Figure 2. Multiple shake table facility in Large-Scale Structures Laboratory (9/02)
All three tables in this facility are:
- 14 ft (4.25 m) square, have 50-ton (445 kN) payload capacity and 24 inch (600mm) peak-to-peak stroke in both the X- and Y-directions,
- relocatable on the strong floor of the Laboratory, so that a variety of table configurations may be assembled to meet present and future research needs, and
- operable independently of each other, in-phase with each other (thus forming a single large table), or differentially with each other (for the simulation of spatial variation effects in earthquake ground motions).

Each table was designed, manufactured and installed by the Advanced Engineering Solutions Division of MTS Systems Corp of Eden Prairie, Minnesota. Performance characteristics are as follows:

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Table size</td>
<td>4.25 m square (14 ft)</td>
</tr>
<tr>
<td>Max specimen weight at 1.0g acceleration</td>
<td>445 kN (50 ton)</td>
</tr>
<tr>
<td>Max specimen weight at 0.5g acceleration</td>
<td>890 kN (100 ton)*</td>
</tr>
<tr>
<td>Max acceleration with 445 kN payload</td>
<td>+1.0g (both long. and lateral directions)</td>
</tr>
<tr>
<td>Max acceleration with 890 kN payload</td>
<td>+ 0.5g (both long. and lateral directions)</td>
</tr>
<tr>
<td>Max velocity during blowdown cycle</td>
<td>1 m / sec (40 in/sec)</td>
</tr>
<tr>
<td>Max velocity after blowdown cycle</td>
<td>750 mm/sec (30 in/sec)</td>
</tr>
<tr>
<td>Max displacement</td>
<td>+300 mm (+12 in) (long. and lateral directions simultaneously)</td>
</tr>
<tr>
<td>Dynamic vertical load</td>
<td>+135 kN (+30,000 Lb)</td>
</tr>
<tr>
<td>Max overturning moment (pitch)</td>
<td>+542.5 kNm (+400,000 Lb-ft)</td>
</tr>
<tr>
<td>Max overturning moment (roll)</td>
<td>+542.5 kNm (+400,000 Lb-ft)</td>
</tr>
<tr>
<td>Max overturning moment (yaw)</td>
<td>+542.5 kNm (+400,000 Lb-ft)</td>
</tr>
<tr>
<td>Dynamic force rating of actuators</td>
<td>667.5 kN (150,000 Lb)</td>
</tr>
</tbody>
</table>

* assumes center of gravity of payload less than or equal to 1.83 m (6 ft) above table and directly above table centerpoint.

Each table is relocatable on the laboratory strong floor within the following constraints:
- maximum length-wise spatial separation between tables is approximately 32 m (105 ft)
- maximum width-wise spatial separation between tables is approximately 9.1 m (30 ft)
- minimum spatial separation between tables is approximately 6.7 m (22 ft)
- maximum clearance from table platform to raised hook of overhead crane hook is 9.4 m (31 ft)
- lifting capacity of overhead cranes is 2 x 222.5 kN (25 tons) = 445 (50 tons)

Figure 3 shows dimensions of a typical biaxial table, and Figures 4 through 6 show the overall dimensions of the laboratory in which the tables are housed.

This facility is believed to be the only one of its kind in the United States and will enable a range of experiments to be undertaken that are currently not possible. This include studies of spatial variation in earthquake ground motions on critical lifeline systems, the biaxial response of structural systems and their components, and the behavior of very large-scale systems which are either physically too large for existing, single-table, facilities or too heavy, or both.

Examples of such studies of relevance to the potential Yucca Mountain Repository, include:
- the integrity of the drip shield for both water tightness and overall stability,
Figure 3. Plan view and side elevations of a typical biaxial table

Figure 4. Longitudinal section through Large-Scale Structures Laboratory
Figure 5. Floor plan of Large-Scale Structures Laboratory, UNR

Figure 6. Section through Large-Scale Structures Laboratory showing strong floor and overhead cranes
examination of fuel pool sloshing, which may cause flooding of adjacent safety components and loss of inventory, and

performance of the waste handling building and associated fuel racks, handling baskets, and canister handling operations.

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