A System for Multi-Axial Subassemblage Testing (MAST): Initial Developments

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Introduction

The University of Minnesota Multi-Axial Subassemblage Testing (MAST) system, to be housed in a new laboratory on the Minneapolis campus, is one of four large-scale structural testing facilities awarded through the National Science Foundation George E. Brown, Jr. Network for Earthquake Engineering Simulation (NEES) program. The MAST system enables multi-axial cyclic static tests of large-scale structural subassemblages, including portions of frames, walls, and bridge piers. The six-degree-of-freedom control technology employed by the MAST system advances the current state of technology by allowing the experimental simulation of complex boundary effects through its multi-axial capabilities, which can impose multiple-degree-of-freedom states of deformation and load. The system is unique in size and scope and will greatly expand the large-scale earthquake experimentation capabilities both nationally and internationally.

Description of Experimental Testing and Computational Simulation Facility

The MAST system and laboratory is shown schematically in Figure 1. A stiff steel crosshead in the shape of a cruciform will be controlled with six-degree-of-freedom digital control technology. Four ±1470 kN (±330 kip) vertical actuators, capable of applying a total force of ±5870 kN (±1320 kips) with strokes of ±510 mm (± 20 in.) will mount between the crosshead and the strong floor. Two sets of actuator pairs with strokes of ± 400 mm (±16 in.), will provide lateral loads up to ±3910 kN (±880 kips) in the horizontal orthogonal directions. The actuator pairs will be secured to an L-shaped strong wall with universal swivels. The vertical clear distance permits specimens up to 7.6 m (25 ft.) in height to be tested. The horizontal clear distance between the vertical actuators can accommodate specimens up to 6.1 m (20 ft.) in length in the two primary orthogonal directions.

The stiff steel crosshead and six-degree-of-freedom control technology enable the precise positioning of a plane in space. This feature makes it possible to apply pure planar translations, as well as the possibility of applying gradients to simulate overturning (e.g., axial load gradient in the columns of a multi-bay frame, or wall rocking). Any degree-of-freedom may be programmed in either displacement control or load control, and degrees-of-freedom may be constrained in a master-slave relation to be a linear combination of the values of other degrees-of-freedom. As an example, it will be possible to program any biaxial lateral displacement history while controlling the axial load on the test specimen with the mixed-mode control capabilities. The system will also be equipped with four ±980 kN (±220 kip) ancillary actuators with strokes of ± 400 mm (±16 in.) which can be used to apply lateral loads at intermediate story levels, gravity loads, or simulated specimen boundary conditions.

In conjunction with the contributions of the NEES System Integrator (SI) at the University of

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Illinois at Urbana/Champaign, the telepresence infrastructure of the MAST Laboratory will provide all relevant information needed for both monitoring and interpretation of the experiments. As such, this facility will incorporate real-time (or, for some components, near real-time) telepresence of acquired sensor data and visual monitoring information during an experiment.

Teleobservation will be achieved primarily through a set of eight remotely-controllable high-resolution digital audio/video cameras and eight remotely-controllable digital still cameras spaced uniformly around the perimeter of the three-dimensional specimen, and through an array of sensors (e.g., strain gauges, position sensors). Limited real-time teleoperation of hydraulic equipment will also be developed where possible, under the assumption that an on-site research fellow will participate in the execution of all experiments to ensure safety and accuracy. Teleobservation and teleoperation of the video and still cameras will be controlled through a set of high-end PC systems configured as Video and Camera Servers. Teleobservation of sensor data and teleoperation of the hydraulic system will be through a single high-end PC system configured as the Control and Data Acquisition Server. All information gathered during an experiment will be collected on these associated servers and fed to a remote Client Machine for teleobservation and teleoperation. It is anticipated that an intelligent web browser on the Client Machine will serve as the primary graphical user interface for all telepresence functions of the MAST Facility.

It is also envisioned that the MAST facility will fit into an integrated data-centric approach for experimentation, computation, theory, databases, and model-based simulation facilitated through the NEES System Integration. To achieve this functionality, this facility includes a Visualization and Archiving Server on which will reside an accumulated database of experimental results, and which will feature the ability to "replay" tests and to couple experimental responses with computer simulations. A complete archive of all data (e.g., video, audio, still images, sensor data, actuator settings, materials properties, and structural dimensions) will be stored both on this server and in the national data repository at the SI for subsequent access.

Conclusion

As part of the George E. Brown, Jr. Network for Earthquake Engineering Simulation (NEES) program, sponsored by the National Science Foundation, and coupled with the establishment of the national NEES Collaboratory in 2004, the Multi-Axial Subassemblage Testing (MAST) System at the University of Minnesota will be a national facility available for use by researchers for large-scale testing and computational research of structural subassemblages subjected to multi-directional loading. To house this facility, the MAST Laboratory is being constructed in a new building on the University of Minnesota campus, and is due to open October 1, 2004.

Figure 1 MAST Laboratory

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