Application of NetSLab for remote testing of bridge systems

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Introduction of NetSLab

NetSLab is the abbreviation of Networked Structural Laboratories, which enables the shared use of testing resources by integrating single structural laboratories into a powerful and networked laboratory with advanced capability.

Supported by the key project of National Natural Science Foundation of China, researchers at Hunan University and FutureNet Technologies Corporation have developed an Internet based remote hybrid platform for pseudo dynamic testing of substructures and structural elements.The testing platform, NetSLab, was developed based on client/server concept along with a proposed data model and communication protocols. It is capable of transferring control and feedback data among remote structural testing laboratories or computers connected by Internet. Based on NetSLab, several application programs have been developed to realize hybrid tests on various structural model.

Scalable Framework

NetSLab includes four types of modules with different functions: ControlCtr, PhysicalTester, VirtualTester, and Observer. ControlCtr is essentially the core of the system and it plays a transfer post dispatching information to all clients. Therefore, there is only one ControlCtr in a test, but multiple testers and observers are allowed to join the test. PhysicalTester operates the actual testing equipment to generate testing results. VirtualTester uses computation to provide restoring force of substructures instead of physical equipments. Observers monitor the process and share the testing results without any interference of the test and can join or quit monitoring a test at any time during testing.

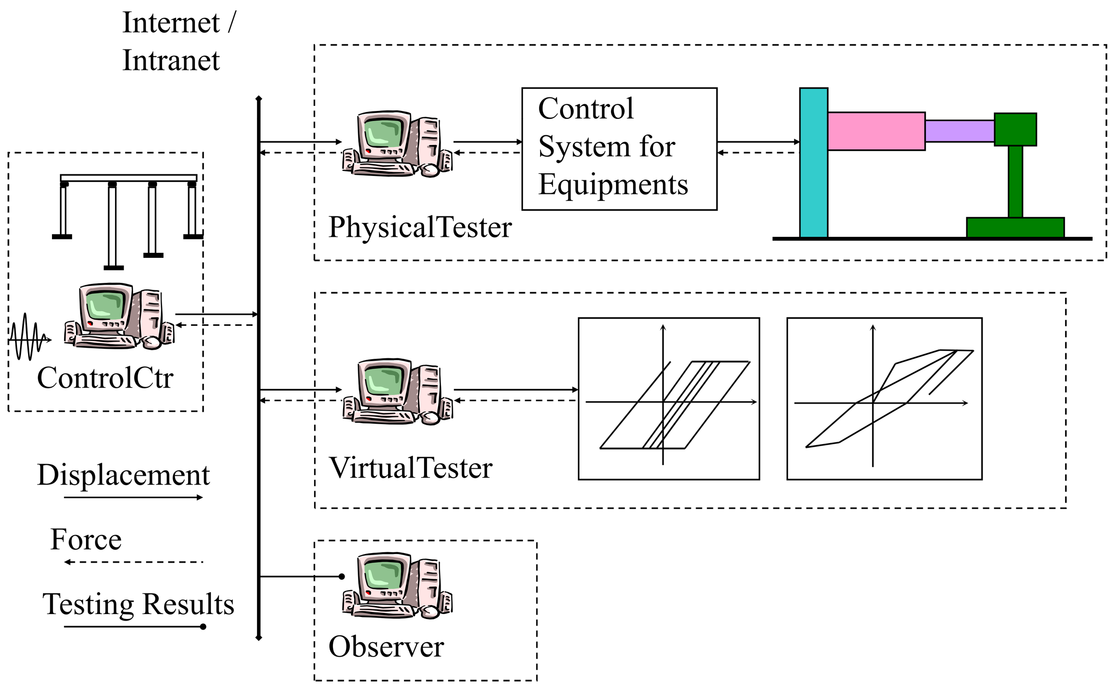


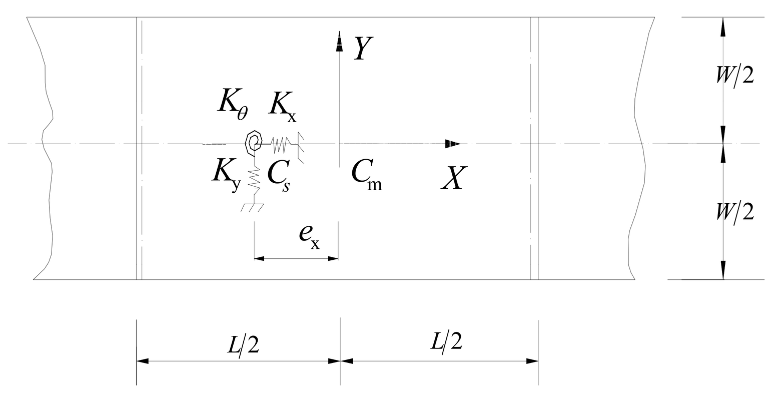
Fig.1 Framework of NetSLab

Torsional analysis

Considering an asymmetric bridge consisted of a rigid deck of mass subjected to unidirectional horizontal ground motions, the model shown in Fig. 2 is used for the analysis. Using the mass center of the deck as the point of reference, the coupled translational and rotational equations of motion can be written as

$$y_{i+1} = \left(m + \frac{\Delta t}{2} C_{yy}\right)^{-1} \left[2my_i + \left(\frac{\Delta t}{2} C_{yy} - M\right) y_{i-1} - \Delta t^2 (\bar{K}_i^I d_i + \bar{r}_i + C_{y\varphi}\dot{\varphi}_i - f_i)\right]$$

$$\varphi_{i+1} = \left(J + \frac{\Delta t}{2} C_{\varphi\varphi}\right)^{-1} \left[2J\varphi_i + \left(\frac{\Delta t}{2} C_{\varphi\varphi} - J\right) \varphi_{i-1} - \Delta t^2 (\bar{K}_i^I D_i + C_{\varphi y}\dot{y}_i + x\bar{r}_i)\right]$$



$\bar{K}^I$ = the stiffness vector of analytical substructures
r^E = the restoring force of experimental substructures
y = lateral displacement relative to the ground
φ = rotation relative to the ground
J = the torsional mass moment of inertia about a vertical axis through the center of mass for the deck
d = translation-torsion coupling displacement, $d = y + x\varphi$
D = no mathematical meaning, $D = x(y + x\varphi)$
C_m = the center of mass
C_s = the initial center of stiffness

Fig.2 Bridge model with stiffness eccentricities

Applications of NetSLab

- Full-scale model of precast prestressed concrete pile to pile-cap (Fig.3)
- Seismic response of single column bent bridges (Fig.4)
- Transverse response of multi-column bent bridge system with different column length (Fig.5)
- Torsional effects of asymmetric bridge system(Fig.2)

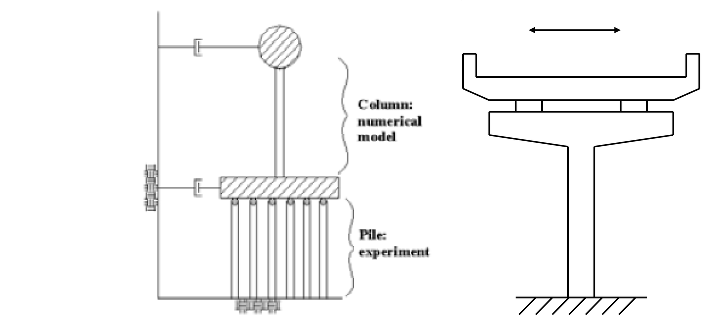


Fig.3 Precast concrete pile to pile-cap assembly model

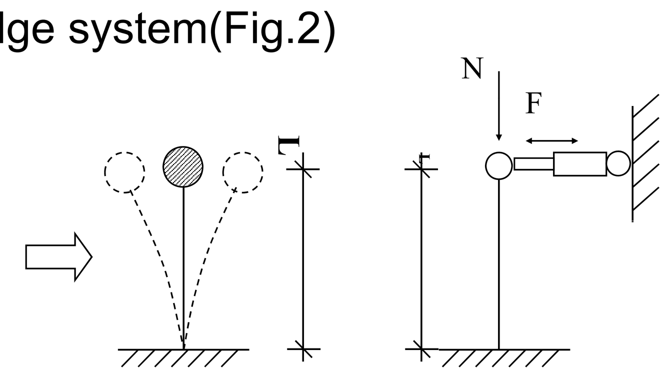


Fig.4 Single column bent bridge model

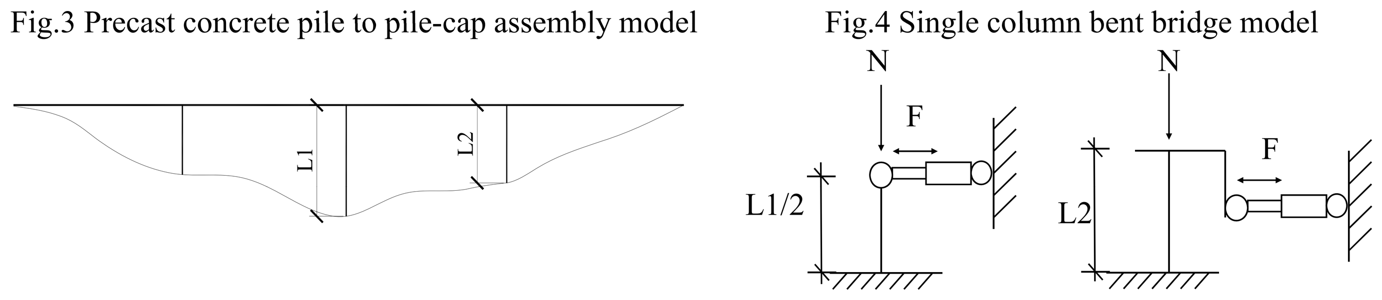


Fig.5 Bridge system

Remote hybrid tests

The bridge system, as shown in Fig. 6 is simulated by ControlCtr in networked structural laboratory of Hunan University. Pier 1 and Pier 5 are respectively tested physically by PhysicalTester in Hunan University and Harbin Institute of Technology. The structural model in Hunan University is a reinforced concrete bridge bending column. Pier 5 is retrofitted with CFRP in order to prevent brittle shearing damage which is one of the most dangerous damage modes of RC bridge short columns. The other piers are respectively simulated by VirtualTester with bilinear model in University of Southern California, Tsinghua University and Hunan University. Testing results indicate CFRP can prevent brittle shearing damage of RC short column and improve the capacity of stable ductility and energy dissipation effectively. It is also found that the pier in Hunan University is still elastic.

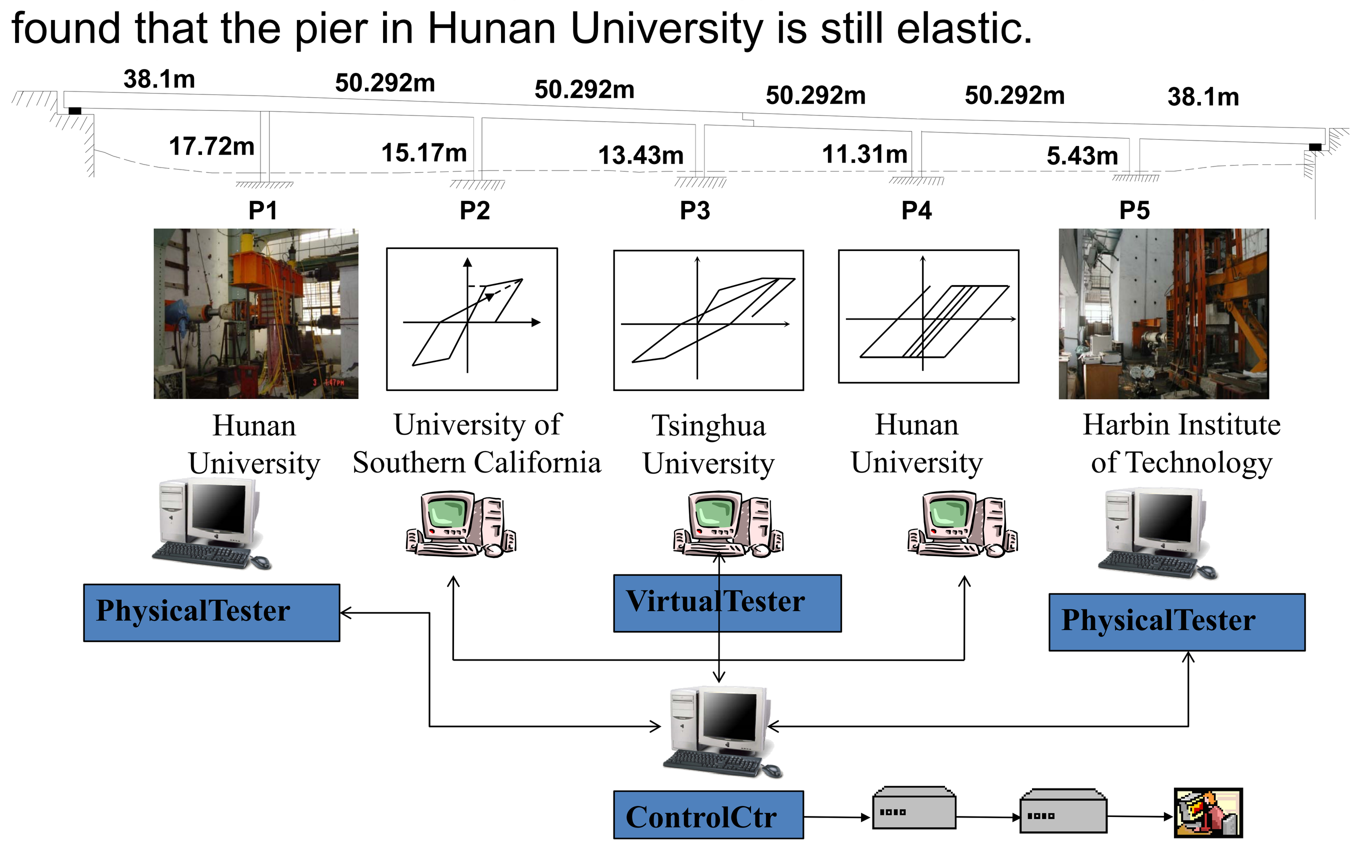


Fig.6 Six-span bridge model for remote hybrid test

Conclusion

1) A standardized platform is developed for efficient data exchange, test equipment remote control and collaborative multi-site hybrid tests.
2) A remote hybrid testing method for asymmetric-plan bridge system considering torsional effects is described.
3) The successful application among four universities realize the possibility of integrating exiting structural laboratories at geographically different locations into networked structural laboratory with strong function aiming at improving testing capability and resource share.

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