I – Research Problem Title (04-EQ104)

Verification of Computer Analysis Models for Suspension Bridges

II - Research Problem Statement

Question: Can Caltrans verify that computer models used for the retrofit and analysis of suspension bridges are able to accurately determine bridge seismic and service load response using data collected from sensors installed on the bridge?

There are a limited number of suspension bridges in the State of California. The long structure period of a suspension bridge makes this kind of structure substantially different from traditional ordinary rigid frame type of bridges, both in its dynamic response and analysis techniques. Previous studies on suspension bridges were subjective to the specific bridge since most of them are important structures across major waterways. There is a need to develop a common methodology in system identification to verify finite element model of all Caltrans' suspension bridges for future structure safety evaluation.

III - Objective

To establish a clearly defined systematic methodology in system identification for suspension bridges to verify its finite element model. The procedure should use the Vincent Thomas Bridge as its base since data is available. It should be applicable to other suspension bridges as well, such as the East and West SFOBB and the new Carquinez Bridge.

IV - Background

A review of the consultant submitted Vincent Thomas Bridge retrofit computer model indicates a fundamental frequency that may be inconsistent with data collected from sensors installed on the bridge during research completed in the last twenty years. The difference is large enough that it can not be explained by various modeling techniques and structure modifications. Studies from other bridges indicate the difference in measurement and computed period should be within 5%. A suspension bridge inherits a long response period by its nature. Sensors used to collect vibration data and techniques to analyze it need to be able to capture the low frequency vibration response. Little is known about the data's accuracy after double-integration from acceleration to displacement by its long period. In addition, modes with periods longer than 5 seconds are harder to pickup by sensors and to be identified.

The Vincent Thomas Bridge was retrofitted with viscous dampers to reduce the seismic response of the decks and towers. After two years in service, some of those dampers are leaking fluid and others suffer with sheared nuts on their protective covers. This may indicate the service environment is largely different from what was originally expected. Replacement of those dampers will require re-analysis of the current structure. However,

the computer model cannot be used at current stage before it is verified and modified as determined by results of this research.

A recent report from California Geology Services indicated a large vertical motion was observed at the Carquinez Bridge. It is not clear if such a motion was expected. However, this incident indicates that similar computer modeling uncertainties may exist at the San Francisco Oakland Bay suspension Bridge and the new Carquinez Bridge.

V - Statement of Urgency and Benefits

A. Support of the Department's Mission /Goals:

(Improving Mobility: Safety and Reliability)

A consistent standardized methodology for the verification of suspension bridge model needs to be developed to address the uncertainties of the seismic and service load response.

B. Return on Investment:

Most of the suspension bridges across major waterways and generally their functions are vital to their surrounding societies. In addition, we spent $600,000 to upgrade all Toll bridge computer models recently. It is the time to verify revised suspension bridge model to ensure the suspension bridge model can be used to evaluate bridge conditions after a major earthquake.

VI - Related Research

1. Lawrence Rubin of Princeton University studied 3 suspension bridges in the Western US in 1983.
2. After the 1987 Whittier Earthquake, Caltrans funded research to the University of Southern California to study the seismic response of the Vincent Thomas Bridge.
3. In 1994, the Washington Department of Transportation did an ambient vibration survey and spectral analysis of the Tacoma Narrows Bridge.

VII - Deployment Potential

The immediate result can be used to re-analyze the Vincent Thomas Bridge for its damper replacement. Further implementation can be extended to the SFOBB and Carquinez Bridge.