Effective Seismic Assessment of Regional Transportation Networks Using an Image-Based Approach

PEER Transportation Systems Research Program

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Introduction

Modern urban areas are heavily dependent on transportation networks to sustain their economic life. Hence, when any of the vital components of a regional network are disrupted, economic losses are inevitable. As evidenced by 1989, Loma Prieta and 1994, Northridge earthquakes, the seismic damages experienced by bridges alone result in extensive traffic delays and rerouting, not only hindering emergency response but also causing indirect economic losses that surpass the direct cost of damage to infrastructure [1].

Traditional seismic risk assessment methods use bridge fragility curves computed for standard bridge classes to quantify damages to bridges comprising a transportation network [2]. An imminent consequence of this simplification is increased epistemic uncertainty in risk calculations. This study proposes a more granular image-based method for computing structure-specific fragility curves for bridges.

Methodology

Structure-specific fragility curves computed by image-based approach relies on bridge models generated based on images harvested from the Web, typically Google Street View images. Bridge geometries established using this method are founded on the measurement principles of single view metrology [3]. However, for model verification, data from the National Bridge Inventory (NBI) and Google Maps APIs are also utilized. The structural properties assigned to image-based bridge models are determined from material/design information in NBI. Figure 1 summarizes the components of image-based model generation method.

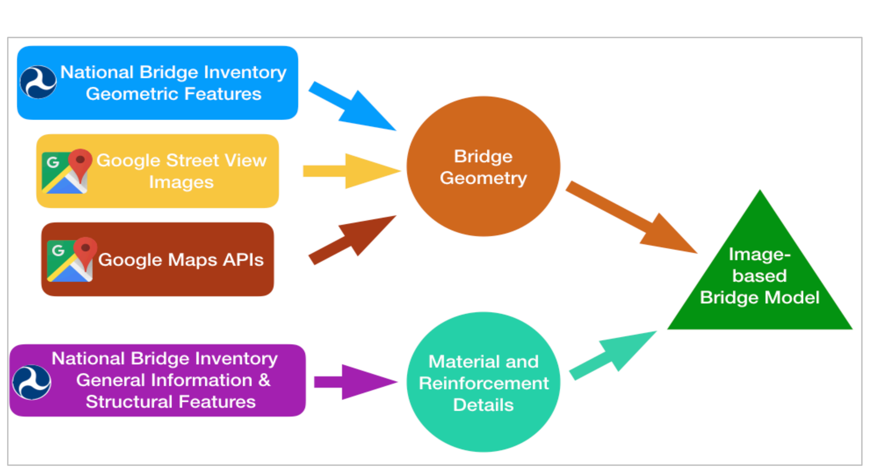

Figure 1. Image-based model generation method for bridges.

A critical ingredient of the image-to-model translations is identifying bridge dimensions. In simple terms, determining the size of bridge elements requires using fuzzy logic image segmentation, Canny-type [4] edge detection and measurement of distances from a reference plane by locating vanishing points. Figure 2 visualizes the enhancements in an image after segmentation and edge detection.

Methodology (continued)

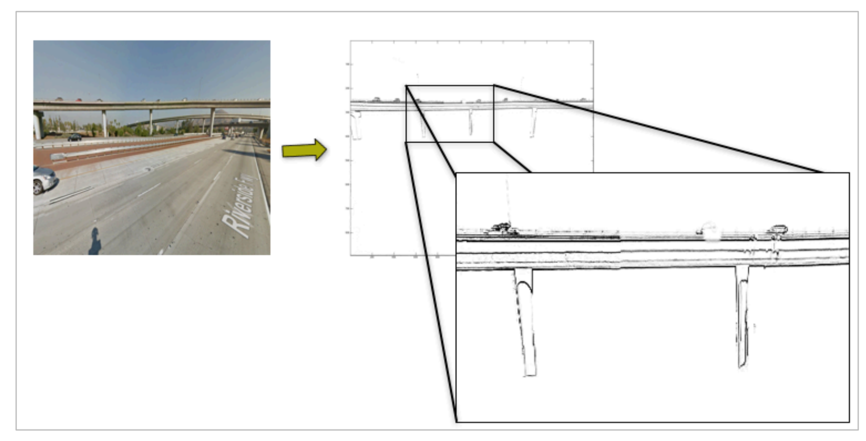

Figure 2. A Street View image after segmentation and edge detection.

Results

In order to illustrate the accuracy of the models generated using image-based approach, results of an analysis performed for I-10W/I-215N interchange bridge in San Bernardino, CA are shown below. Figure 3 shows the 3-D model generated for the bridge based on Street View images.

Figure 3. Image-based model of I-10W/I-215N interchange bridge.

Figure 4 provides a comparison of image-based column dimensions. The structure consists of 15 tapered, circular columns. In Figure 4 (b), both the diameter of the widest part (top) and the cylindrical part (bottom) of bridge columns are compared against image-based results.

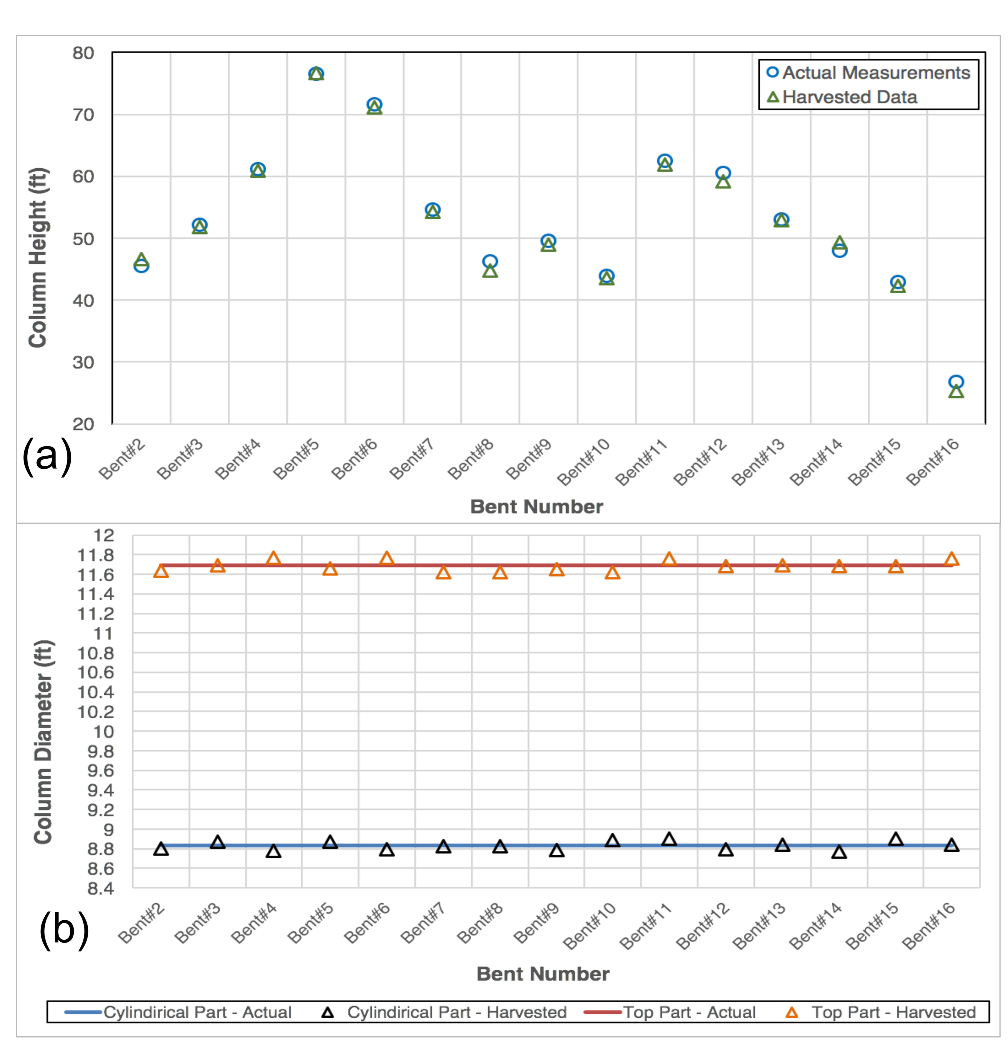

Figure 4. A comparison of column heights and diameters of I-10W/I-215N interchange bridge image-based model against as-built dimensions.

Figure 5 demonstrates the accuracy of image-based approach in approximating bridge deck geometry.

Results (continued)

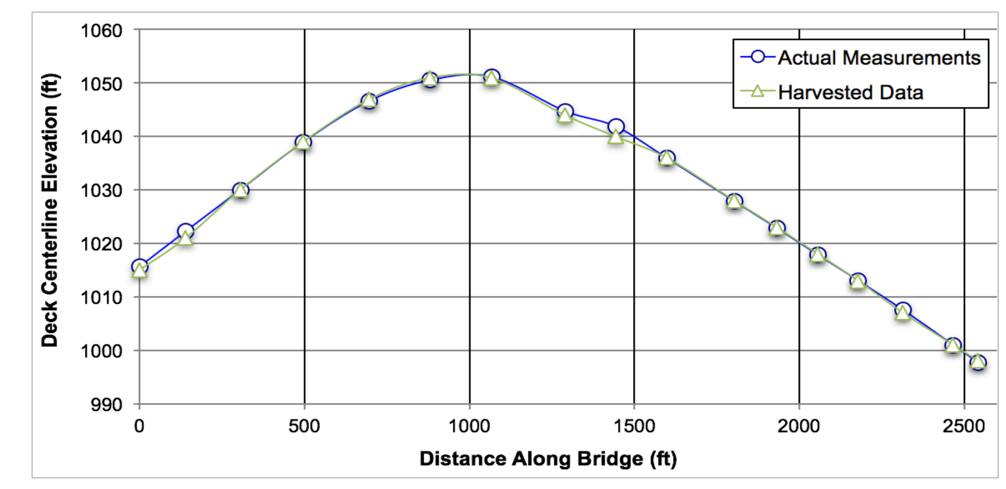

Figure 5. A comparison of deck centerline elevation of I-10W/I-215N interchange bridge image-based model against as-built centerline elevations.

Figure 6 summarizes the modal analysis result for the image-based model and how first 8 frequencies of the model compares against frequencies of the bridge model based on as-built drawings.

	$T_{Image\text{-}Based}$ (sec)	$T_{As\text{-}Built}$ (sec)
Mode 1	1.357	1.528
Mode 2	1.182	1.294
Mode 3	1.028	1.091
Mode 4	0.947	1.019
Mode 5	0.892	0.942
Mode 6	0.836	0.881
Mode 7	0.784	0.807
Mode 8	0.746	0.788

Figure 6. Modal analysis results for first 8 frequencies of the I-10W/I-215N interchange bridge for image-based model and the model based on as-built drawings.

Discussion

Accuracy associated with the image based approach presented here can be quantified in many different ways. In this presentation, authors selected the most intuitive one. A comparison of bridge geometry information computed using image-to-model conversions shows that the procedure effectively captures geometric features. Furthermore, modal analysis results indicate that the minor deviations from as-built geometry have limited effect on elastic behavior.

Acknowledgments

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References

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