Monitoring of expressway viaducts and comparative investigation of dynamic response variability

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1. INTRODUCTION:

There has been research on structural monitoring as structures of poor performance become a concern. Though many publications focus on chronological change of dynamic characteristics, the change is typically small. Also, the poor performance is not only due to chronological change. Some structures are poorly designed or constructed from the beginning. This paper presents a series of dynamic field tests performed on a twelve-span part of a viaduct located in downtown Tokyo to compare the dynamic characteristics among similarly-designed spans and investigate the possible causes of different characteristics. The tested viaducts are slab-on-girder bridges supported on elastomeric bearings which rests on concrete piers, carrying two lanes of traffic on each bound. Some span show variability in both pseudo-static and dynamic response levels. In this paper, the results for main girders and bearings are presented. The interpretation of the data from girder-ends and bearings (pier-tops) suggests a difference of stiffness of some bearings and thus, may contribute to the response variability among different spans. Though most of the results imply that the difference in dynamic characteristics is relatively small due to the well-maintenance record of the target viaducts, this study also holds importance for providing baseline for future monitoring programs of similar type of viaducts.

2. EXPERIMENTAL PROGRAM

Three spans consist of similarly-designed simply supported spans while the rest of the nine spans consist of three sets of three simply-supported spans connected with each other at the slabs. Each span is about 30 m in length and 16.5m in width. Plan view of spans and girder numbering is depicted in Figure 1. The dynamic field tests described herein includes traffic-induced vibration measurements during free-flow traffic. First, a preliminary test was conducted on the nine spans with a focus on the main girder response through tri-axial servo-type accelerometers array deployed on mid-span of exterior girders (Figure 2). The collected data is interpreted and response variability among similar design spans is observed. Further measurement is performed with several dense sensor array configurations (Figures 3 and 4) in order to investigate the reasons for the variability in detailed with a focus on the main girder and bearing responses. Wireless monitoring systems are employed for these dense arrays.

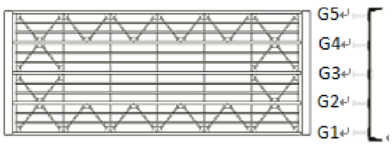


Figure 1. Plan view and girder #

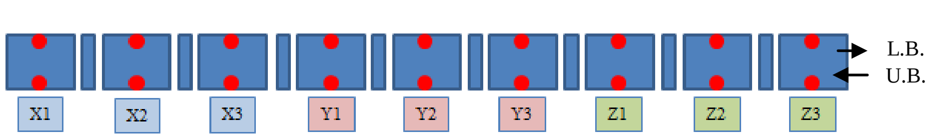


Figure 2. Preliminary test (Test 1) sensor installation plan

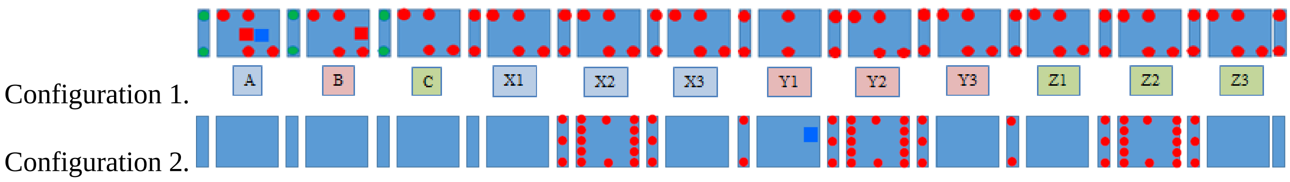


Figure 3. Test 2 sensor installation plans

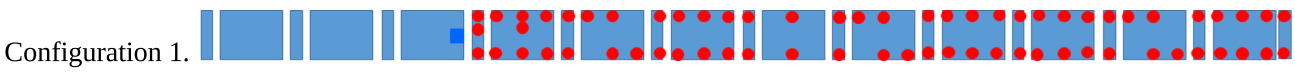


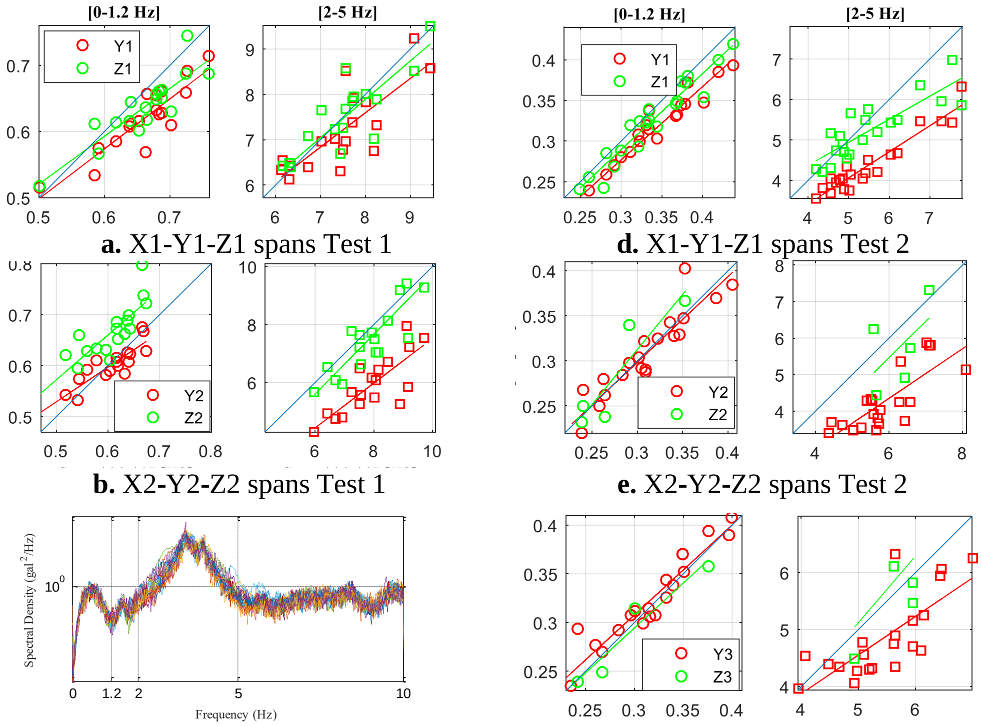
Figure 4. Test 3 sensor installation plan

3. RESPONSE COMPARISON OF SPANS

3.1 Main girder response

Main girder dynamic responses are compared among similarly-designed spans by employing two frequency bands, namely pseudo-static and dominant dynamic ranges. The considered cut-off frequencies (Figure 4) are selected through investigation of power spectra of all spans and verified based on the finite element model. Test 1 consists of two separate measurements with durations of about 2 hours during night time when the heavy vehicles are expected on the viaducts. Five-minute root-mean-square (RMS) acceleration values are calculated for both measurement data sets and compared. Since both measurement results were similar, the summary of results is shown for only one of the two-hour data sets for Test 1. In addition, the results from G1 and G5 side measurements were also similar, thus for the purpose of brevity only the results from G1 side is presented in Figure 4. Note that, in Figure 4, x-axes correspond to X spans where y-axes correspond to Y and Z spans five-minute acceleration RMS values. Results from Test 1 suggested that only Z2 span shows higher response levels when pseudo-dynamic frequency range, corresponding to deflection, is considered.

However, when the results from day time measurements are examined, no clear difference is observed in this frequency range. In 2-5 Hz frequency range, Y spans generally showed smaller response levels than X and Z spans which may be attributed to joint and profile conditions.



a. X1-Y1-Z1 spans Test 1 **d.** X1-Y1-Z1 spans Test 2

b. X2-Y2-Z2 spans Test 1 **e.** X2-Y2-Z2 spans Test 2

c. Selected frequency bands **f.** X3-Y3-Z3 spans Test 2

Figure 4. RMS acceleration [gal] comparison among spans for Test 1 and Test 2 (configuration 1)

3.2 Bearing response

In order to study the bearing condition variability among spans dense sensor arrays, namely Test 2 – configuration 2 and Test 3, are installed on the girder-end and pier top locations. Relative motion between pier top and girder-end measurements are studied. Z2 span, again, showed a clear response difference in pseudo-static range when compared to its counterparts. Thus the summary of results from XYZ-s spans is depicted in Figure 5. Z2 span has large components in the pseudo-static frequency range on both G1 and G5 sides, which suggests differences in some bearings.

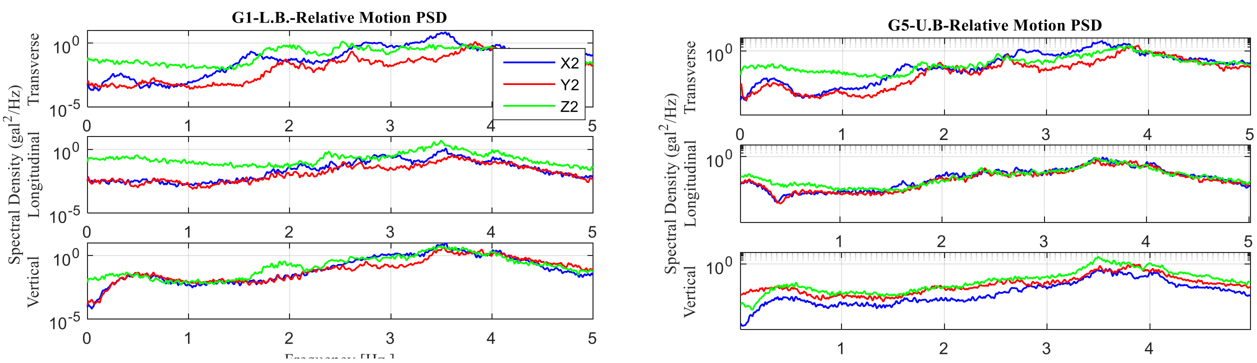


Figure 5. Bearing relative motion spectral density comparison for X2-Y2-Z2 spans

4. CONCLUSIONS AND FUTURE WORK

In order to investigate the response variability among spans, a series of field experiments were carried out. Summary of some results considering main girder response and bearing conditions are presented in this paper. Z2 span shows clear difference from the other spans when main girder acceleration RMS and bearing motion are considered. Although no significant difference and no corresponding possible damage is found, this study holds importance as it provides a baseline for similar type of bridges which will be studied in the future.

5. ACKNOWLEDGEMENTS

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