Observed variability in dynamic response of same-designed expressway bridges under moving truck load

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1. Introduction

Constructed since mid 1960, many viaducts in the Tokyo Metropolitan Expressways have undergone increased service loads, both in number and weight. The current loads, especially heavy vehicles, may induce higher excitation to the viaducts than in the past. This will lead to more severe fatigue problem, pavement wear[1]. Therefore, understanding the effects of the current heavy vehicles to the dynamic behavior of the expressway bridges is deemed necessary in order to prevent unexpected bridge failure.

On the other hand, same-designed bridges are expected to behave similarly to each other during the passage of vehicles with the same type, the same weight, the same traveling speed and lane, provided that these bridges are located close to each other and have no damage. Hernandez (2007)[2] and Su et.al. (2008)[3], however, revealed that in the case of same-designed railway viaducts located near to each other, considerable variation may exist in their response when subjected to the same vehicles. This study attempts to experimentally investigate the response variability of same-designed expressway bridges under the same moving truck load. This full-scale experimental result will be used to gain insights about the mechanisms behind the observed variability in the future.

2. Description of selected bridges

A total of six (6) full-scale, same-designed bridge spans (Fig. 1) were selected and measured in 2009 for their dynamic response under the passage of road vehicles. The selected bridges are a part of elevated viaducts in Shibuya route of Tokyo Metropolitan Expressways, which connects Shibuya and Yoga. Each bridge carried four lanes of road traffic: two for Shibuya-bound, and the other two for Yoga-bound. However, due to the space limitation, only the first three spans (Spans A, B, and C) will be discussed.

All of the bridge spans (Spans A, B, and C) were equally designed as non-skew, simply-supported, and non-composite spans. The bridge deck is composed of a reinforced concrete slab 210-mm thick, 31,900-mm long, and 16,500-mm wide. Expansion joints were provided at both ends of the slab to facilitate contraction and expansion of the spans. A total of five main steel I-girders (denoted as Ga to Ge in Fig. 2) spaced uniformly at 3,500-mm interval, carried the weight of the bridge deck and the traffic load above for each span. All main girders were supported by rubber bearings, which allow rotational displacements in any directions and certain amount of transverse displacements of superstructure.

3. Measurement program

The measurement employed wired servo accelerometers and velocimeters distributed over all spans and the adjacent piers. The strain measurement was also conducted: 19 strain gauges were attached at the selected location of steel girders for each bridge span, as shown in Fig. 2. All gauges, expect gauges no. 2,7,18 and 19, were placed on the top surface of the bottom flange of main girders. Gauges no. 2 and 7 were on the web of main girders, about 100-mm from the top flange of main girders. Gauges no. 18 and 19 were placed on the top surface of the top flange of transverse steel girders. Dynamic loads were produced by a moving 25-ton test truck (Fig. 3) at 50 to 70 km/h. All strains and accelerations of the tested spans were measured during the passage of the test truck, as well as that of arbitrary vehicles for about 24-hour.

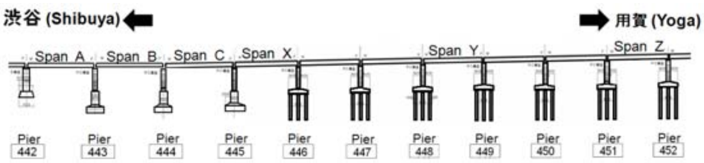


Fig.1 – Selected bridge spans with same design

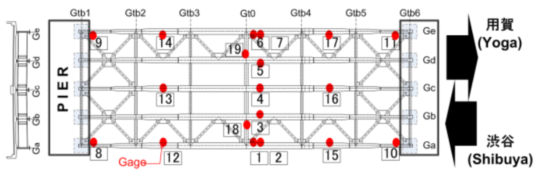
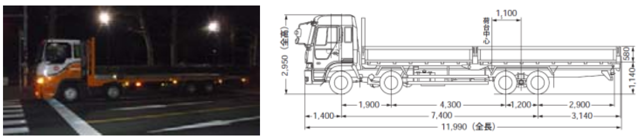


Fig.2 – Location of strain gauges over each span



(a) view (b) dimension

Fig.3 – 25-ton test truck

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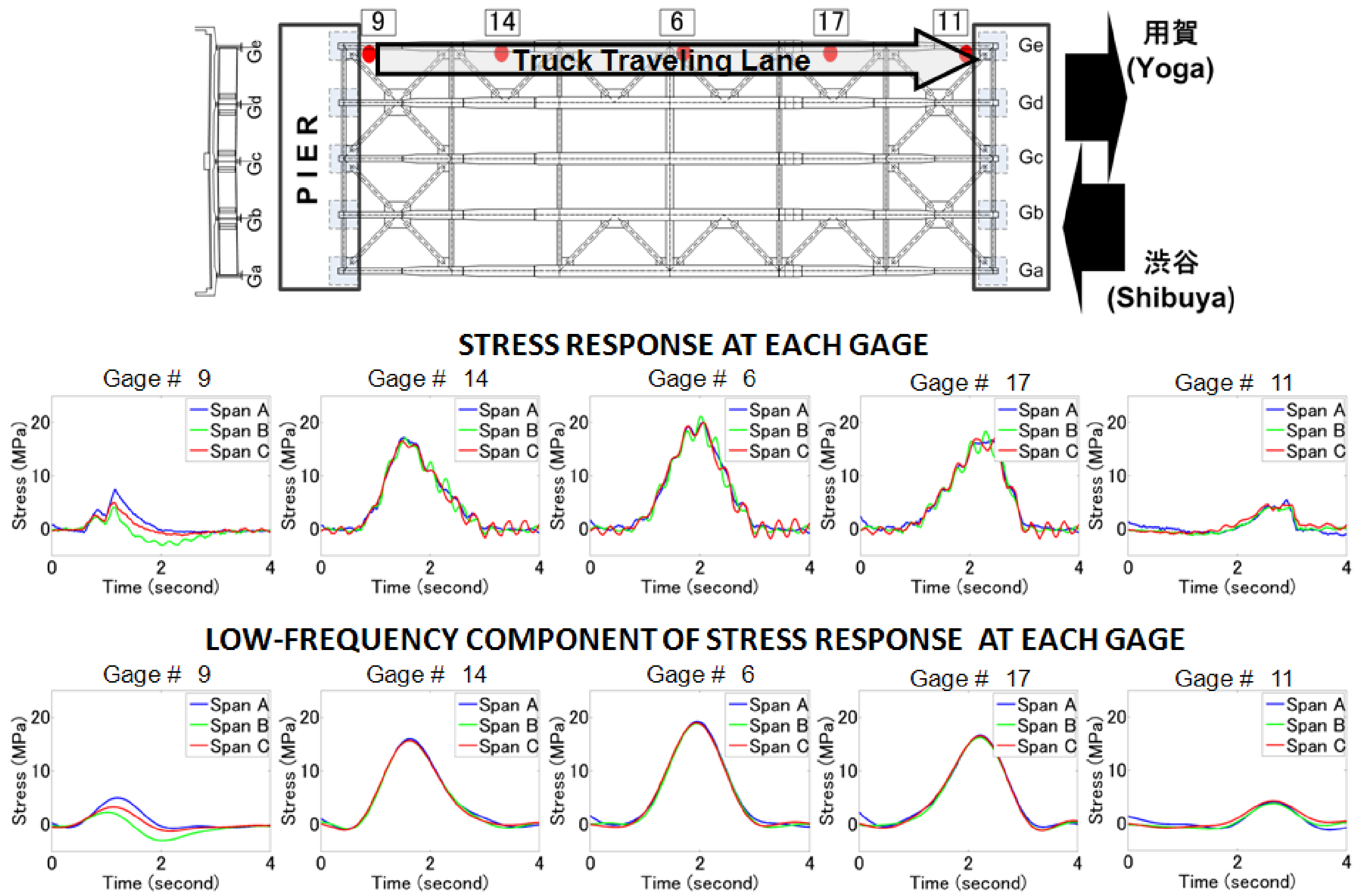

Fig.4 – Stress responses of main girder Ge (truck ran at Yoga-bound, outer/slow lane, with speed = 60 km/h)

4. Measurement results and discussion

Due to space limitation, only the strain responses of the same-designed bridge (spans A, B, and C) during the passage of 25-ton test truck will be discussed. Consider that the same test truck crossed each span at the same traveling lane (Yoga-bound, outer/slow lane) and at the same speed (about 60 km/h). The upper part of Fig. 4 shows the stress response of main girder **Ge** in different span (span A, B, or C) during the track passing. Each line color in Fig. 4 indicates different span. The truck was on each span, approximately from time t=0.8 sec to time t=2.7 sec. The stress at selected points (Gauges no. 9, 14, 6, 17, and 11) was calculated from the strain measurement, assuming that the stress of steel is linearly proportional to its strain during the truck passing (steel elastic modulus E=206 GPa).

As shown in the upper part of Fig. 4, the stresses of all tested spans at the same location (Gauges no. 14, 6, 17, and 11) are comparable to each other. However, the stresses of all spans at Gauge no. 9 (near left-bearing zone) seemed to be varied. Only span B experienced negative stresses from time t=1.3 sec, until the test truck left the corresponding span. This indicates the presence of additional axial stiffness or restraint in near bearing area of span B. This stiffness may be activated only when the transverse displacement of span B at the near bearing zone reaches certain amount.

The stress response of all spans was found to be much dominated by its low-frequency component. Applying low-pass filter to the stress responses with cutoff frequency of 0.85 Hz, one can obtain the low-frequency component of the stress responses as shown in the lower part of Fig. 4. For the same location, this low-frequency stress component of all spans is close to each other, expect that of Gauge #9. This similarity confirms that all the tested spans have the same design configuration.

5. Conclusion

This study confirms that despite the same design configuration, the variability may exist among the local dynamic responses of expressway bridges.

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