# Seismic Performance Evaluation of a Curved Rigid-frame Bridge Using Three-dimensional Dynamic Analysis

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## Summary

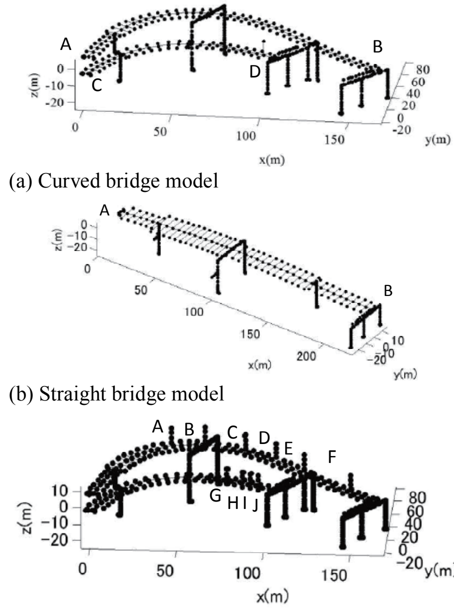
Curved rigid-frame bridges used in interchanges and junctions play important roles in urban highway networks. Seismic safety of curved bridges is important as these networks are often used for transportation of relief materials and evacuation after earthquakes. The objective bridge of this study is the Ohashi Junction connection viaducts, which is a two layer rigid frame curved bridge which has large curvature. A three dimensional nonlinear frame model is constructed based on the design and calibrated with traffic vibration measurement. Dynamic analysis of the model is then conducted to clarify the response dependency on input direction, effect of pounding, and safety of non-structural components.

**Keywords:** curved bridge; dynamic analysis; input direction pounding; non-structural components.

## 1. Introduction

Curved rigid-frame bridges which are often used at interchanges and junctions play important roles in urban highway networks. If these networks are damaged, huge economic loss is expected. Therefore, evaluation of seismic safety of curved bridge is needed. In the Japanese design code, dynamic analysis is required for curved bridges. Usually, input direction of ground motion is changed multiple times and the maximum response is estimated. However, the number of input directions is often limited. Thus maximum response can be underestimated and response which is not considered in design, for example, pounding between neighbor girders, may happen.

Also, trouble of traffic function is occurred in railway viaduct because of collapse of non-structural components on the superstructure. So, not only seismic safety of main structure but also that of non-structural components is required.




(a) Curved bridge model

(b) Straight bridge model

(c) Bridge-attachment integrated model

*Figure 1: Analysis model*

In this study, the dependency of input direction is clarified by nonlinear dynamic analysis changing input direction. Also effect of pounding is clarified by dynamic analysis which can consider pounding. Also evaluate seismic safety of non-structural components.

## 2. Analysis model and dynamic analysis

The objective bridge of this study is the Ohashi Junction connection viaducts, which is a two layer rigid frame bridge with large curvature. A three-dimensional nonlinear frame model(Figure 1) is constructed based on the design and calibrated with traffic vibration measurement. The first and second modal parameters of the model show a good agreement with the measurement.

Dynamic analysis of the model is then conducted to clarify the response dependency on input directions, effect of pounding, and safety of non-structural components. For this analysis, dynamic analysis program with pounding analysis cpability is developed. To investigate the response characteristics unique to curved bridges, the dynamic analysis of the curved bridge is compared with that of a straight bridge.

## 3. Seismic response analysis result

Seismic response analysis is conducted by changing the input direction from $0^\circ$ to $360^\circ$ (In design, input range is from $0^\circ$ to $135^\circ$), and compare the response characteristics between curved bridge and straight bridge. Interval of input direction is $11.25^\circ$ (1/4 of design), and total input case is 32.

As a result, the maximum displacement was found to be possibly underestimated. The maximum responses at ends of the girder depend on input directions (Figure 2); analysis with coarse interval on input ground excitation direction can easily miss maximum responses. Even reversing input direction results in large difference in maximum responses. Furthermore, pounding analysis revealed that the maximum lateral response of the curved bridge is large because the pounding force applies from multiple direction. On the other hand, lateral response of straight bridge isn't large because pounding occured only in the longitudinal direction(Figure 3). In addition, as a result of seismic response analysis using bridge model including non-structural components, difference of local response characteristics affects the damage condition of attachments on superstructure (Figure 4).

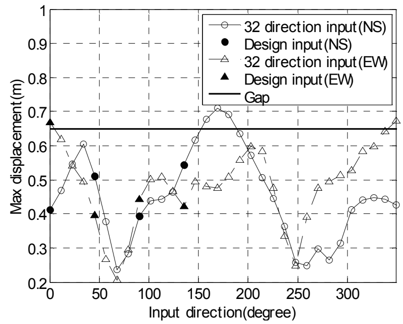
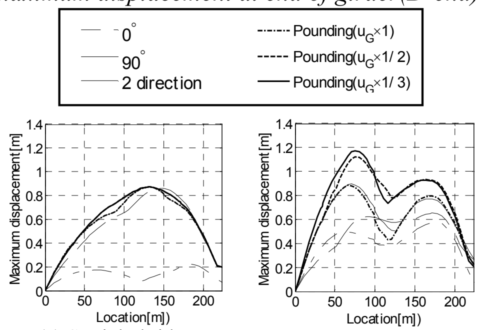



*Figure 2: Input direction dependency of maximum displacement at end of girder(D-end)*




(a) Straight bridge (b) Curved bridge

*Figure 3: Max lateral displacement of each case*

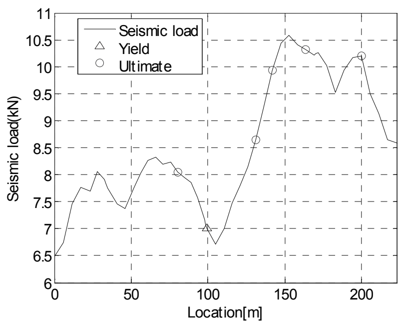



*Figure 4: Damage location of anchor bolt and seismic load. (B1 bridge)*