ANALYSIS OF EARTHQUAKE RESPONSE BEHAVIOR OF TOTAL BRIDGE SYSTEM

Tomohiro NAKANO, Graduate School of Engineering, Nagoya University
Tada-aki TANABE, Graduate School of Engineering, Nagoya University

1. INTRODUCTION

In order to estimate the bridge behavior during the earthquake, it is necessary to consider soil, piers and superstructures as a total system. However, because of too many degree-of-freedom, it is difficult to calculate dynamic response of the bridge as a total system. For that reason, we suggest the tri-section method as dynamic analysis for the total system. The purpose of the present study is the formulation of tri-section method and the examination of its applicability of this method based in the comparison of analysis with the record of observation.

2. OUTLINE OF TRI-SECTION METHOD

In tri-section method, firstly, we divide a bridge into three equal parts as shown in Fig.1 and center block B is taken for the analysis. Secondly, we calculate mass matrix, stiffness and damping matrix of block B. thirdly, and we input ground seismic motions into structures and estimate the response performance. In these calculations, the effects from the left block A and right block C are replaced by the equivalent boundary spring. We can calculate the total bridge system behavior by block B done by these boundary springs (Fig.2).

3. ANALYSIS OF TOTAL BRIDGE SYSTEM BY TRI-SECTION METHOD

The mass matrix of the total system is denoted by M, the damping matrix C, the stiffness matrix K, and the displacement denoted by X(/x). According to Ref. [1], the equation of motion including the boundary springs is

$$\begin{bmatrix} M_{22} & & \\ & M_{BB} & \\ & & M_{33} \end{bmatrix} \begin{Bmatrix} \ddot{x}_2 \\ \ddot{X}_B \\ \ddot{x}_3 \end{Bmatrix} + \begin{bmatrix} & & \\ & C & \\ & & \end{bmatrix} \begin{Bmatrix} \dot{x}_2 \\ \dot{X}_B \\ \dot{x}_3 \end{Bmatrix} + \begin{bmatrix} K_{22} - K_{2A} \cdot K_{AA}^{-1}(\alpha K_{A1} + K_{A2}) & K_{2B} & \\ K_{B2} & K_{BB} & K_{B3} \\ & K_{3B} & K_{33} - K_{3C} \cdot K_{CC}^{-1}(K_{C3} + \beta K_{C4}) \end{bmatrix} \begin{Bmatrix} x_2 \\ X_B \\ x_3 \end{Bmatrix} = \begin{Bmatrix} f_2 \\ F_B \\ f_3 \end{Bmatrix} \quad (1)$$

where subscripts A, B, C mean block A, B, C and subscripts 1,2,3,4 mean boundary node 1,2,3,4. α and β are the boundary spring constants.

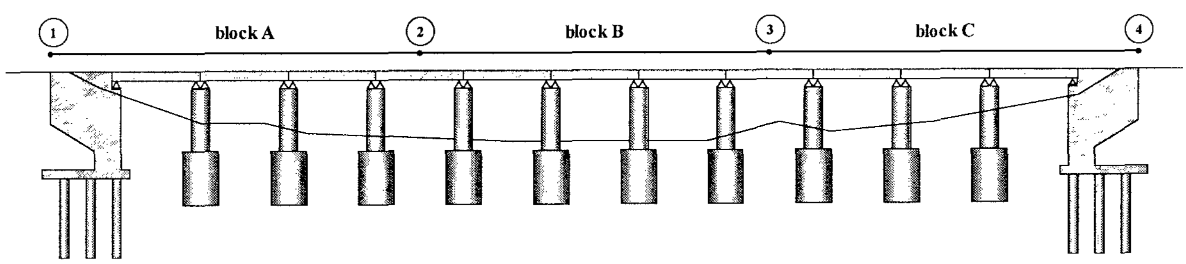

Fig.1 Concept of tri-section method

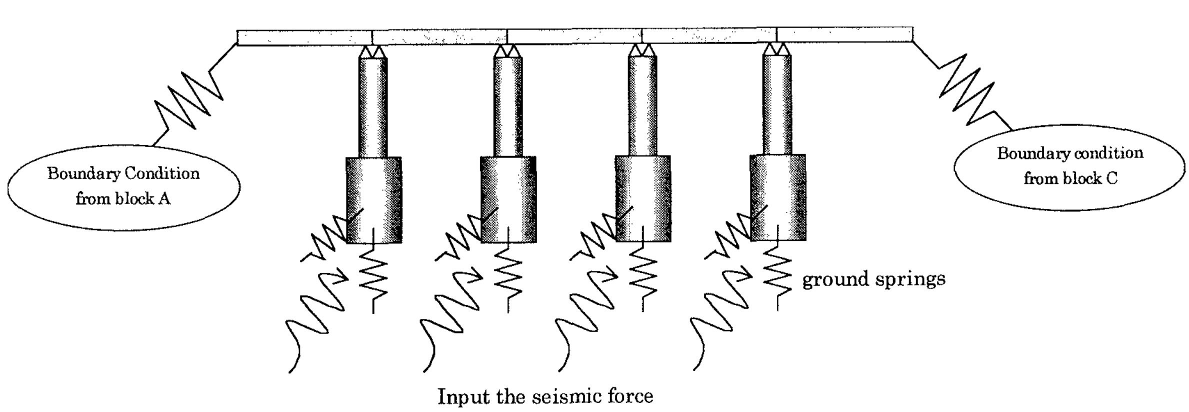

Fig.2 Analysis of total system by tri-section method

4. ANALYZED MODEL AND INPUT DATA

Fig.3 shows the analyzed model, which has 16 nodes and 48 degrees of freedom. In this model, boundary springs exist at the edges.

In this model, Raileigh damping is adopted as damping matrix. And the node under ground is supported by ground spring calculated by Ref.[2]

This analysis was calculated using the record of the observation on the 222nd pier in the Oodaka line in the Nagoya expressway on August 21st, 1999 as shown in Fig.4.

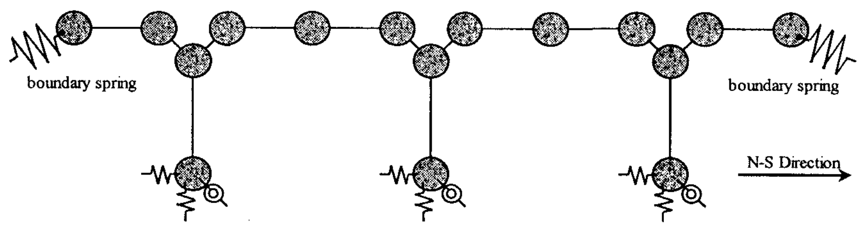

Fig.3 Analyzed Model

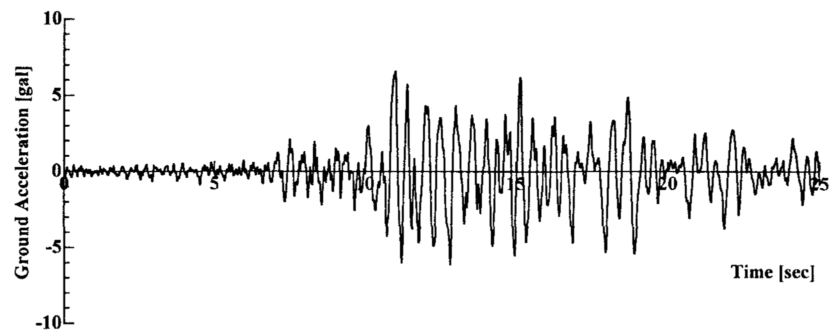

Fig.4 Ground Acceleration [N-S direction]

5. ANALYSIS RESULT

Analysis result is shown by the solid line in Fig.5 in comparison with the records of the observation.

The envelope curves of these two waves are very similar and their eigenperiods are almost same. Only difference between analysis results and records of observation is the time of the maximum acceleration.

(analysis: 22.8[gal] at 14.54[sec] / observation: 24.6[gal] at 11.51[sec]) However, the acceleration between 11[sec] to 15[sec] is approximately 23[gal]. Therefore, this difference is insignificant.

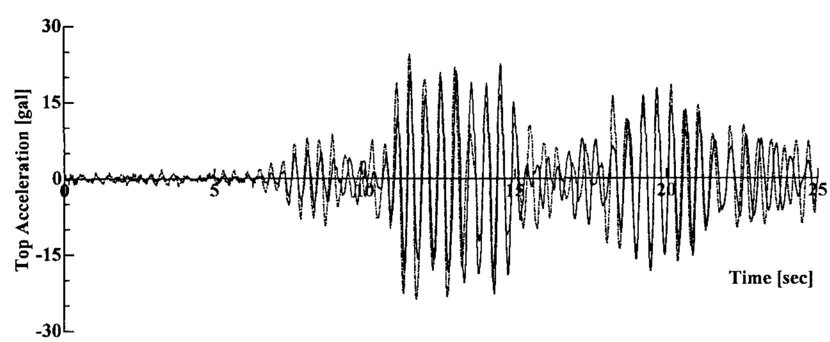

Fig.5 Top Acceleration [N-S direction]
(dotted line: observation / solid-line: analysis)

6. CONCLUSIONS

Based on the above consideration, the following conclusions can be extracted.

1) Using tri-section method, it is possible to represent the behavior of the bridge to a certain extent. This method can estimate the total bridge system behavior exactly.
2) The observation results gives the information of tri-section parameter α and β. Once we get these parameters, we will be able to estimate the seismic behavior of total system.

ACKNOWLEDGEMENT

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REFERENCES

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2. Japan Road Association, "Specifications for Highway Bridges Part III", Japan Road Association, 1997 (in Japanese)