SEISMIC DAMAGE ANALYSIS OF RC RIGID-FRAME RAILWAY VIADUCTS USING 3D LATTICE MODEL

Kobe University, JSCE Student Member, ◯Mauro Ricardo Simão
Kobe University, JSCE Regular Member, Tomohiro Miki

1. INTRODUCTION

Whenever a strong earthquake takes place, viaducts are very much exposed to seismic induced damage. The 1995 Kobe Earthquake in Japan was responsible for a big degree of destruction on RC urban elevated viaducts; causing a re-evaluation of seismic performance assessment. On that note, the objective of this study is to use the concept of energy dissipation (Simão and Miki 2014) to perform analysis of damage in a RC rigid-frame railroad viaduct that suffered damage during the Kobe Earthquake.

2. ANALYTICAL MODEL

The analytical system of lattice model divides the concrete in truss members and arch members. For a 2D represented RC column, the concrete is modelled into flexural compression members, horizontal members, diagonal compression members, diagonal tension members, horizontal members and two arch members (Miki et al. 2004) according to Fig. 1. A ratio of the width of the arch part to the cross section *b* is defined as index *t*. Based on the 2D model lattice model, a 3D model, as presented in Fig. 2, is developed where the analytical model is assumed to be equivalent. In the 3D lattice model, the assumption of global stiffness being equivalent to 2D lattice model allows the estimation of the cross sectional area of the arch and truss members.

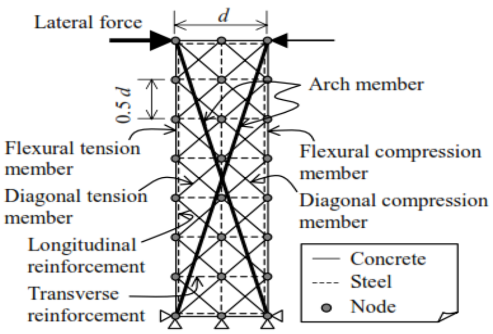

Fig. 1 2D lattice model for columns (Miki et al. 2004)

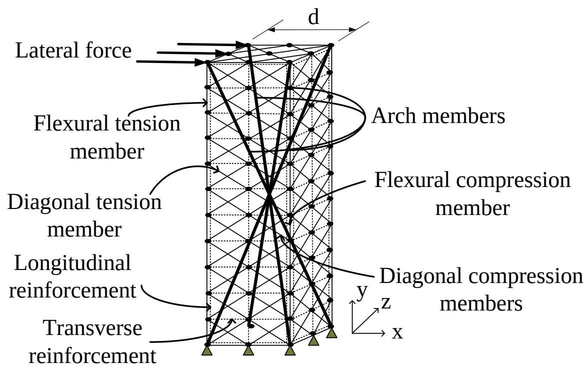

Fig. 2 3D lattice model for columns (Miki et al. 2004)

3. DAMAGE ANALYSIS OF RC VIADUCT

3.1 Outline of target structure modelling and analysis

The seismic performance evaluation is performed for Hansui R5 which is a rigid-frame railroad viaduct. The target is a beam-slab type rigid-frame RC viaduct with three-span. The viaduct was designed according to Structural Design Standards of Japan National Railways enacted in 1970. In the viaduct, the cross section of a column was a square of 900 mm. All reinforcing bars in the columns had a minimum concrete cover of 60 mm. The beams had rectangular cross section with 700 mm width and 1,000 mm depth for the upper portion in transverse direction, while with 700 mm width and 1,100 mm depth for other portions. Heights of columns were 5,000 mm and 4,000 mm in lower and upper portions, respectively as shown in Fig. 3. The compressive strength of concrete was 29.1 MPa, while the tensile strength was 1.27 MPa to a Young's modulus of 18.4 GPa. The longitudinal reinforcement had yield strength of 322 MPa, ultimate strength of 521 MPa and Young's modulus of 203 MPa. While the transverse reinforcement had yield strength of 263 MPa, ultimate strength of 380 MPa and Young's modulus of 183 MPa. The three-span viaduct is treated as a unit of the analytical model.

As seen in Fig. 4, the model consists of beams and columns, while the slab is not included. In the analysis, it is assumed that the masses corresponding to the self-weight of viaducts are uniformly distributed over all nodal points, using the

Keywords: RC Rigid-frame Railroad Viaduct, 3D Lattice Model, Nonlinear Analysis, Seismic Response
Contact address: 1-1 Rokkodai-cho, Nada-ku, Kobe, 657-8501, Japan, Tel: +81- 78 -803 -6094

lumped-mass idealization. It is also assumed that there is a concentrated mass, which is equal to the weight of the superstructure and the slab, acting on the top nodes of columns and beams. In this study, the dynamic lattice model was used for the evaluation of structural response under cyclic loading and has been performed using DYNALLAT 1.1.4, in-house developed software. The damage has been calculated to the full height of the viaduct piers, as well as bottom corresponding to a height of 2100 mm.

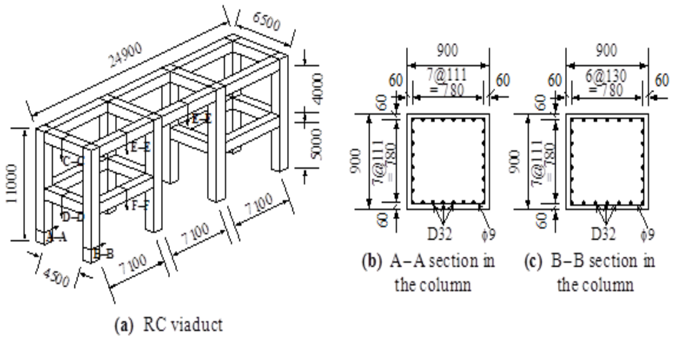

Fig. 3 Target structure details

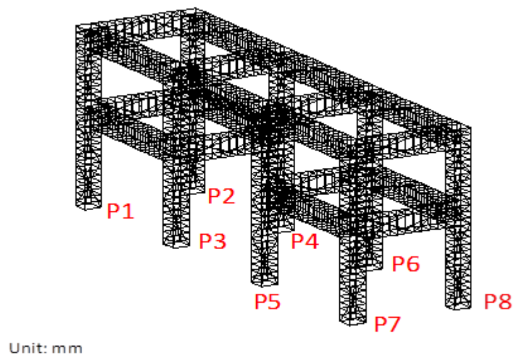

Fig 4. Viaduct model

3.2 Energy dissipation on RC column

The results from dynamic analysis are used to propose the amount of energy dissipated under seismic loading as a measurement of damage range. To do that, the energy inside the pier is addressed in terms of the local energy dissipation where it's assumed that the average stress-strain relationships govern each element after cracking occurs and used for estimation of strain energy as presented in Eq. (1). The total energy dissipation presented in Eq. (2) is used, where it will be the sum of the product between strain energy and volume for each element. The energy dissipation has been calculated for eight target columns for total size and bottom part of the columns corresponding to2100 mm.

$$\mathrm{E_{Strain}} = \frac{1}{2}(\sigma_i + \sigma_{i-1})(\varepsilon_i - \varepsilon_{i-1}) \quad (1)$$

$$\mathrm{E_{dissip}} = \sum_{i=1}^{n} (E_{strain-i} \times V_i) \quad (2)$$

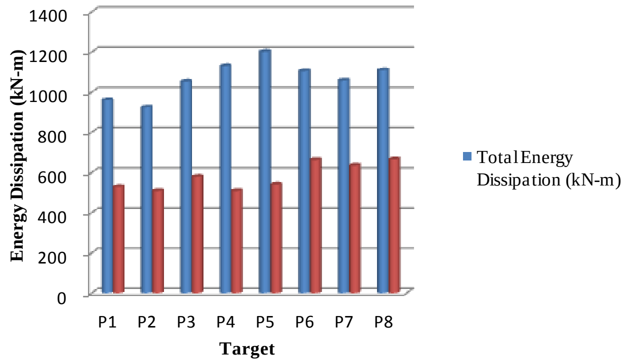

Fig. 5 Energy dissipation in Hansui R5 viaduct columns

4. CONCLUSIONS

The study presented 3D lattice model analysis for RC rigid-frame railway viaduct that suffered damage during the Kobe Earthquake. The calculations of damage range of the columns suggest that about 40% to 60% of the total damage was located at the bottom. Comparison between the analysis and the actual damage conditions of the Hansui R5 viaduct after the earthquake shows that the biggest range of damage or damage concentration effect is at the bottom of the piers. The damage range analysis based on energy dissipation numerically proposes to quantify the damage condition. The level of response and damage was predicted by the 3D Dynamic Lattice Model, especially the damage range evaluation considering the nonlinearities, by using the stress-strain relationships.

REFERENCES

Miki, T., and Niwa, J.: Nonlinear Analysis of RC Structural Members using 3D Lattice Model, Journal of Advanced Concrete Technology, Vol.2, No. 3, pp.345-358, 2004

Simão, M.R. and Miki, T.: Seismic Damage Range Evaluation of RC Columns with Circular Cross Section by Energy Dissipation Using 3D Lattice Model, Proc. 2014 JSCE International Summer symposium, 2014