SEISMIC DAMAGE EVALUATION OF RC STRUCTURAL MEMBERS USING 3D LATTICE MODEL

Kobe University, JSCE Regular Member, Tomohiro Miki

Kobe University, JSCE Student Member, ◯Mauro Ricardo Simão

1. INTRODUCTION

On the scope of the Hyogo-Ken Nanbu Earthquake, a big degree of destruction was registered on RC urban elevated viaducts; causing a re-evaluation of seismic performance assessment. On that note, the objective of this study is to propose a method of the seismic damage assessment of RC structural members. by using 3D lattice model to perform nonlinear static analysis on a RC target structure and propose energy dissipation as a valid measurement for seismic assessment.

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), respectively as shown in Fig. 1. 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 (Miki et al. 2004.).

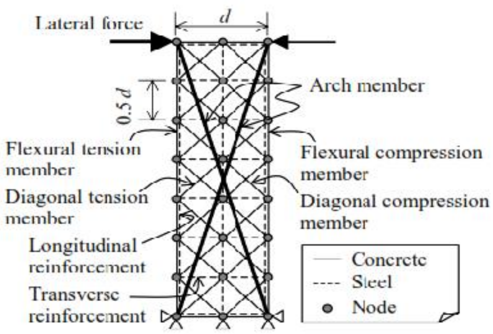

FIG. 1 2D lattice model (Miki et al. 2004)

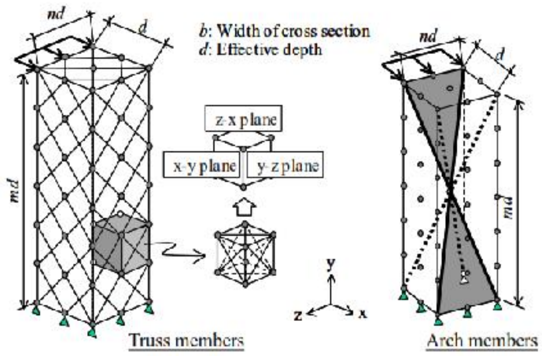

FIG. 2 3D lattice model for an RC column (Miki et al. 2004)

3. NONLINEAR STATIC ANALYSIS FOR RC VIADUCT COLUMN

3.1 Outlines of target structure modelling and analysis

The target structure is a reinforced concrete column (Kawashima et al. 2010).as shown in Fig. 3, with diameter of 2000 mm and 7500 mm tall, where the design concrete strength is 27 MPa and the longitudinal and transverse bars have a nominal strength of 345 MPa (SD 345). The column has been modelled into the 3D static lattice model presented in Fig. 4. The particularity of this modelling is the change in geometry of the target structure, where different from the study presented by Miki et al. (2004), the cross section is circular which introduced a need for readjustments on the analytical model, where an equivalent quadrangular cross section that preserved the value of effective depth d has been used to estimate both mesh size, as well as arch and truss members cross section. Although it proved difficult to accurately estimate the cross section of concrete members from a pure quadrangular equivalence assumption, the analysis was performed in order to reduce the effect of a possible cross disparity in the final result as well as accuracy. The model itself is 7400 mm tall with a mesh size of 925 mm defined as half of the effective depth, which in the case is 1850 mm. Because of its geometry; it has been discretized with six arch members to seek improvement in accuracy. It is difficult to obtain an exact matching model of the target structure, due to differences in discretization based on the mesh size and the actual size of the structure, therefore the main aim is to come as close as possible .In the pre-analysis, the values of t for both width and effective depth are assumed as 0.35 and 0.25 (Miki et al.) for simplification and are based on the principle of minimum total potential energy. The loading point is considered to be at 8 m, and thus the shear span as shown by the experimental program presented by Kawashima et al. (2010).The analysis was performed using STALATT_VER11, in-house developed software for static analysis based on finite elements analysis. The software works by allowing the discretization of nodal points as well as concrete and reinforcement for response simulation.

Keywords: Reinforced Concrete Column, Lattice Model, Nonlinear Analysis, Seismic Response

Contact address: 1-1 Rokkodai-cho, Nada-ku, Kobe, 657-8501, Japan, Tel: +81- 78 -803 -6094

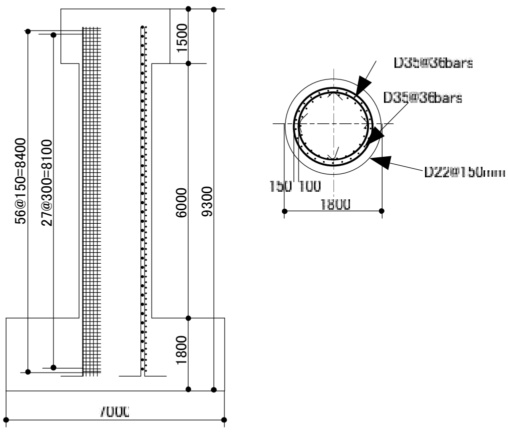

FIG. 3 Target structure details Kawashima et al. (2010)

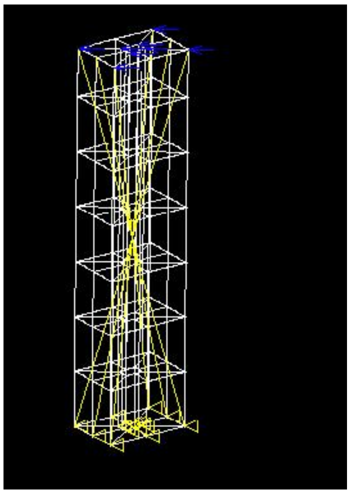

FIG 4. Column discretization model

3.2 Energy dissipation on RC column

To evaluate the amount of energy dissipated, the energy inside the pier is addressed in terms of the elemental energy where it's assumed that the average stress-strain relationships govern each element. That being said, stress-strain relationships are used for the estimation of strain energy for each element. For the target structure three steps are taken; the first one is the estimation of the most damaged column region, which for the case was assumed as being the height equivalent to depth of 1850 mm corresponding to two lattice layers from the bottom of the column. Furthermore strain energy is calculated using Eq. (1), from the stress-strain relationships for each element.

$$\text{STRAIN ENERGY} = \frac{1}{2}(\sigma_i + \sigma_{i-1})(\varepsilon_i - \varepsilon_{i-1}) \tag{1}$$

The next step is the calculation of the volume of each element that belongs to the identified bigger impact region. The volume of the element is calculated by multiplying the cross sectional area of each element that has been previously determined during the pre-analysis by and its respective length, which for the case of the longitudinal elements is equal to the 925 mm that also defines mesh size, and for diagonal members is calculated from simple mathematical formulations. To finally calculate the energy dissipation, Eq. (2) is used, where dissipation energy will be the total sum of the product between strain energy and volume for each element on the sensitivity analysis region, and for the case in hand the maximum dissipation energy is estimated as being equal to 6103 KN-m.

$$\text{DISSIPATION ENERGY} = \sum_{i=1}^{n}(strain\ energy_i \times V_i) \tag{2}$$

4. CONCLUSIONS

The study presented 3D static lattice model analysis of RC column, in order to grasp seismic behaviour. A model based on the dissipation of energy is presented, where based on stress-strain relationship and volume of each element is possible to quantitatively predict the damage zone on a RC column during an earthquake. It is possible to conclude from the analysis, regarding the lattice model itself, that the arch members have little influence on the resisting mechanism, due to the shape of the of the column and loading conditions, thus most of the resisting mechanism lies within the truss members. Furthermore, the results of stress-strain relationships for the target elements prove to have a bigger degree of accuracy despite the difficulty determining cross sectional areas. Overall, the prediction of dissipation energy in most damaged portions of RC members offer a simple and fast way of quantitatively evaluate the degree of seismic induced damage in order to further improve design considerations as well as seismic retrofitting for future situations.

5. REFERENCES

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