A Study on Yield Surface and Principal Elastic Axes of RC Structures

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Summary

Some methods calculating displacement of buildings postulate its elastic axes are orthogonal to its yield surface, however, it is considered there are actually some cases contradicting the postulation. In order to learn general knowledge of three-directional nonlinear behaviour of reinforced concrete structures, pushover analyses were conducted on a 6 story RC building with L-shaped floor plan. It was confirmed the principal elastic axes were not always perpendicular to its yield surface as well as it was found out to be adequate to apply flow rule to a frame composed of columns and beams.

Keywords: nonlinear analysis; frame analysis; three-dimension; fiber model; yield surface

1 Introduction

In some methods calculating displacement of buildings, the effect of multidimensional interaction is ignored although in a plastic stage considering it is necessary for achieving a correct response. That is because nonlinear numerical analyses are difficult to be conducted and takes time.

As for this problem, Takiguchi et al. [1] introduced plastic theory for simplifying analyses. They reported general earthquake response of one mass model subjected to three dimensional forces could be obtained with their method.

In practice, structures are multilayer and torsional response can be produced. In order to create general plastic model, referring to the result of numerical analysis is considered to be necessary. As a preparation of that, the interest of this study is to discuss relations of its displacement and yield surface in terms of plastic theory as well as relations of principal elastic axes and yield surface.

2 Outline of analysis

A RC structure analysed is presented in Fig. 1. Figure 2 shows its floor plan. All bottom ends of columns were modelled fixed-ended and every floor was modelled with rigid floor. The principal axes were 35.1° and 125.1° measured from the positive half of x-axis. They are given with broken lines in Fig. 2.

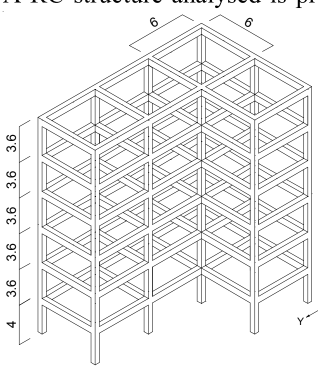

Fig. 1 Structural model

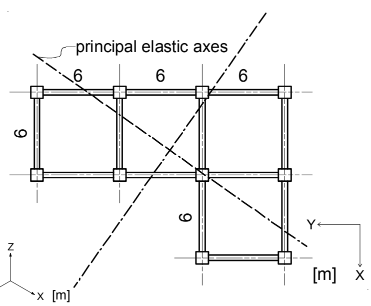

Fig. 2 Floor plan

As to material nonlinearity, bottom ends of columns connecting to the ground were modelled with fiber model and rigid-plastic spring was used at the both ends of beams.

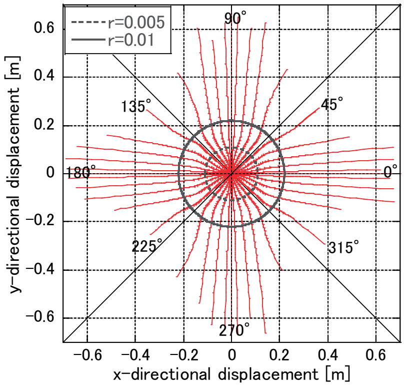

Fig. 3 Horizontal displacement

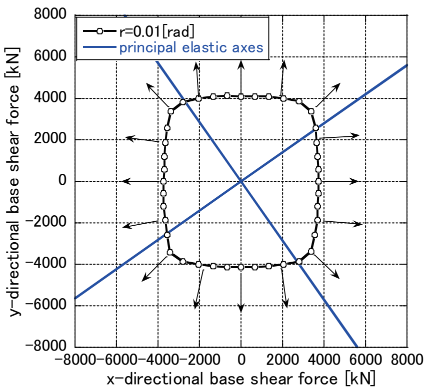

Fig. 4 Yield surface

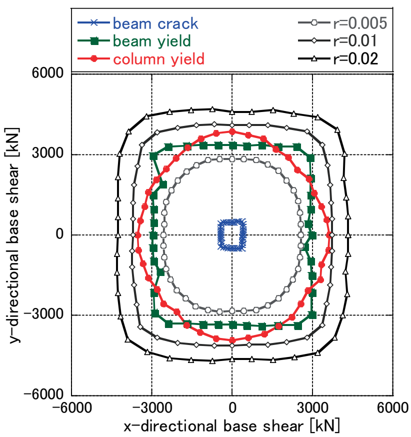

Fig. 5 Horizontal base shear force

3 Result and Discussion

Pushover analyses were performed in 40 separate input directions. Figure 3 shows horizontal displacement at the top level and deformation point according to *r*, where *r* is displacement at the top level divided by the height of the structure. It is verified that displacement did not always appear in the input direction. This is considered the influence of plastic deformation of the larger direction.

Figure 4 shows horizontal base shear force at the point of *r*=0.01[rad]. In this paper, the surface in Fig. 4 is considered as yield surface. The arrows represents the normal direction of the surface. The principal elastic axes represented with two orthogonal lines in Fig. 4 shows they are not orthogonal to its yielding surface. Although it is known that provided horizontal orthogonal two axes are dynamically independent from each other, the shape of the yield surface is a rectangle, the yield surface obtained from this analyses was slightly rounded. It is considered the effect of bidirectional interaction. Comparing Figs. 3 and 4, it is confirmed that the direction of displacement after *r*=0.01[rad] circle was almost identical to the normal direction of the yield surface.

Horizontal base shear force at the point of cracking of beams, yield of beams, yield of columns and point of *r* is presented in Fig. 5. It is found out that in orthogonal coordinate axes directions, the yield of beams began prior to that of columns, while in diagonal directions, the yield of columns was prior to that of beams. The shape of crack and yield surface of the beams was almost a rectangle. This indicates that there is little influence of bidirectional interaction with regard to beams. On the other hand, the shape of surface of column yield was closer to a circle. This means that the effect of bidirectional interaction is significant as to columns. It can be seen that the difference between *r*=0.01[rad] and *r*=0.02[rad] was relatively small with respect to base shear force. So the state of force after *r*=0.01[rad] can be considered to be in plastic stage.

4 Conclusions

Based on the results of this analysis, the following conclusions were recognized; 1) It is considered to be adequate to apply the flow rule to frame models with columns and beams. 2) Principal elastic axes are not always perpendicular to its yield surface in the case of asymmetry floor plan. 3) Displacement does not always appear in the input direction especially in plastic stage.

5 Reference

[1] TAKIGUCHI K., HORIE A., NISHIMURA K., and NAKAHARA K., “Three-Dimensional Non-Linear Earthquake Response Analyses with Macro Model for RC Structure.”, *Summaries of Technical Papers of Annual Meeting of Architectural Institute of Japan*, September, 2003.