V-222 Response Analysis of Reinforced Concrete Column Subjected to Biaxial Bending Moment

AVILES Nibaldo (*)
MARUYAMA Kyuichi (**)

1. INTRODUCTION

The response analysis of RC structures under dynamic biaxial bending moment has been of interest for many researchers [1) 2)]. However, analytical approaches have not been conducted successful because they involve so many suppositions and because the experimental results are not easy to obtain under the dynamic biaxial bending condition. This paper discusses the application of plastic theory to the response analysis of RC column under biaxial bending. The column modeling is based on the ellipses criterion due to the theory of plasticity applied to the P-Δ relationships and extended to the fracture range.

2. COLUMN MODELING

The modeling is established considering the cantilever column with the mass M located on the top of the column. In order to express the column stiffness in the X-Y plane, the stiffnesses in the two principal directions (xK,yK) are taken and combined with interaction. The damping coefficients(xC,yC) are treated independently. The torsional stiffness is neglected because it becomes very small once cracks initiate. The modeling is illustrated in Fig. 1.

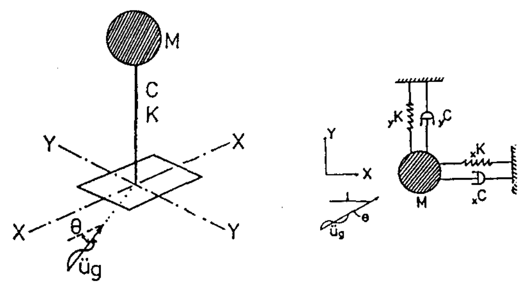

Fig. 1 Model

The restoring force characteristics of the column are expressed in the quadrilinear degrading stiffness system for each principal direction (Fig. 2). The ellipses criterion is, then, introduced to express the different range of column stiffness in the X-Y plane (Fig. 3). The formulation of the column stiffness under the biaxial bending is the important part of this paper. Up to the yield range the Takizawa's approach [1)] is adopted using the P-δ relationship instead of the M-Φ relationship. Namely, the Von Mieses's flow rule is applied for determining the stiffness, and the Ziegler's hardening rule for the expansion of the yield range. In order to extend the stiffness system into the strain softening range(fracture range), the ellipse criterion is assumed even for the deflection space.

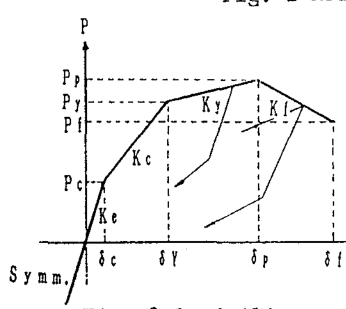

Fig. 2 Quadrilinear degrading stiffness

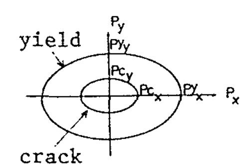

Fig. 3 Ellipses criterion

The equation of the motion is, then, established as a nonlinear system and resolved by the linear acceleration step by step method as follows:

$$[M]\{\Delta\ddot{u}\}+[C]\{\Delta\dot{u}\}+[K]\{\Delta u\}=-[M]\{\Delta\ddot{u}g\} \tag{1}$$

where

$$[M]=\begin{bmatrix} M & 0 \\ 0 & M \end{bmatrix} \quad ; \quad [C]=\begin{bmatrix} xC & 0 \\ 0 & yC \end{bmatrix} \quad ; [K]=\begin{bmatrix} xK_1 & 0 \\ 0 & yK_2 \end{bmatrix};$$

$$\{\Delta\ddot{u}\}=\begin{Bmatrix} \Delta\ddot{u}x \\ \Delta\ddot{u}y \end{Bmatrix} \quad ; \{\Delta\dot{u}\}=\begin{Bmatrix} \Delta\dot{u}x \\ \Delta\dot{u}y \end{Bmatrix} \quad ; \{\Delta u\}=\begin{Bmatrix} \Delta ux \\ \Delta uy \end{Bmatrix} \quad ; \{\Delta\ddot{u}g\}=\Delta\ddot{u}g \begin{Bmatrix} \cos\theta \\ \sin\theta \end{Bmatrix}$$

(*) Graduate student, Nagaoka University of Technology
(**) Associate Professor, Nagaoka University of Technology

The stiffness matrix [K] is formulated according to the range of column stiffness.

For the elastic range

$$[K]=[Ke]=\begin{bmatrix} xKe & 0 \\ 0 & yKe \end{bmatrix} \quad \text{(No interaction for biaxial bending)}$$

For the crack range

$$[K]^{-1}=[Ke]^{-1}+\frac{\{Nc\}\ \{Nc\}^{T}}{\{Nc\}^{T}([Kc]^{-1}-[Ke]^{-1})^{-1}\{Nc\}}$$

For the yield range

$$[K]^{-1}=[Ke]^{-1}+\frac{\{Nc\}\ \{Nc\}^{T}}{\{Nc\}^{T}([Kc]^{-1}-[Ke]^{-1})^{-1}\{Nc\}}+\frac{\{Ny\}\ \{Ny\}^{T}}{\{Ny\}^{T}([Ky]^{-1}-[Kc]^{-1})^{-1}\{Ny\}}$$

For the fracture range

$$[K] = [\text{Yield range stiffness}] - \frac{\{G\}\ \{G\}^{T}}{\{G\}^{T}\ (\ [Ky] + [Kf]\ )^{-1}\ \{G\}}$$

in which {Nc} = Normal vector to the crack ellipse ;{Ny} = Normal vector to the yield ellipse and {G} = Normal vector to the displacement ellipse.

3. COMPARISON OF ANALYTICAL RESULTS WITH EXPERIMENTAL RESULTS

One of the previous experimental results 3) 4) is picked up for examining the proposed model. The dimension of the column specimen is 4 cm x 6 cm x 30 cm with four D2 bars. The quadrilinear degrading stiffness for each principal direction is obtained by the static loading test of the specimen. Fig. 4 shows both the experimental and the analytical results of the force-deflection relationship of the column at the mass point in the both X and Y direction, where the ground excitation is applied at the 30 degree from the X direction.

4. CONCLUSIONS

From the results the followings are concluded.

1) The response model of RC columns is extended into the biaxial bending with the strain softening effects.

2) The comparison with experimental results may not be satisfactory, because the experimental technique is not adequate enough to examine the analytical results.

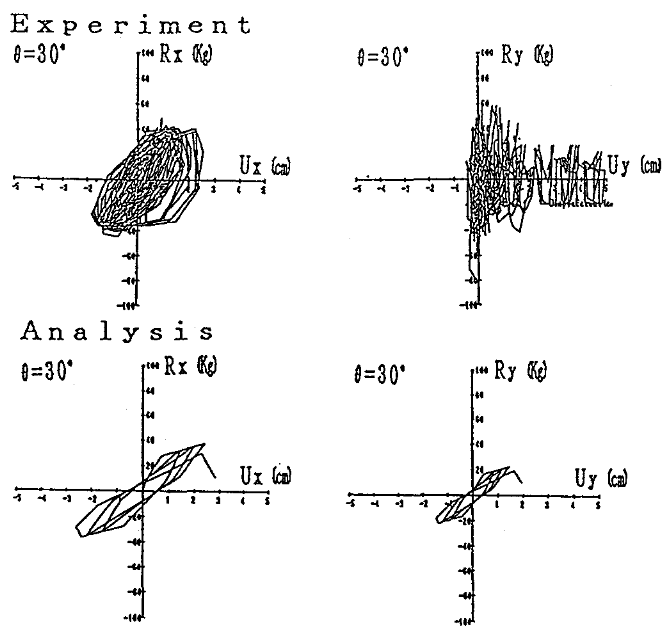

Fig. 4 Comparison

REFERENCES

(1) Takizawa,H. and Aoyama, H.,"Biaxial Effects in Modelling Earthquake Response of R/C Structures", Journal of Earthquake Engineering and Structural Dynamics, Vol. 4 ,1976, pp.523-552.

(2) 市之瀬敏勝、滝口克己、古井正行、" 耐力の低下を考慮した鉄筋コンクリート断面の二軸曲げモデル、" コンクリート工学年次講演会論文集、1984, Vol.6,pp.581-584.

(3) 高橋秀明、" ＲＣ柱の２軸曲げ振動実験における変位計測システムの開発に関する研究" 長岡技術科学大学修士論文、1988.

(4) Nibaldo Aviles. " 鉄筋コンクリート柱部材の２軸曲げ振動特性に及ぼす外力角度の影響" 土木学会第４３回年次学術講演会、1988,vol.5,pp.608-609.