3D Hysteretic Model for Stiffened Thin-walled Rectangular Steel Piers

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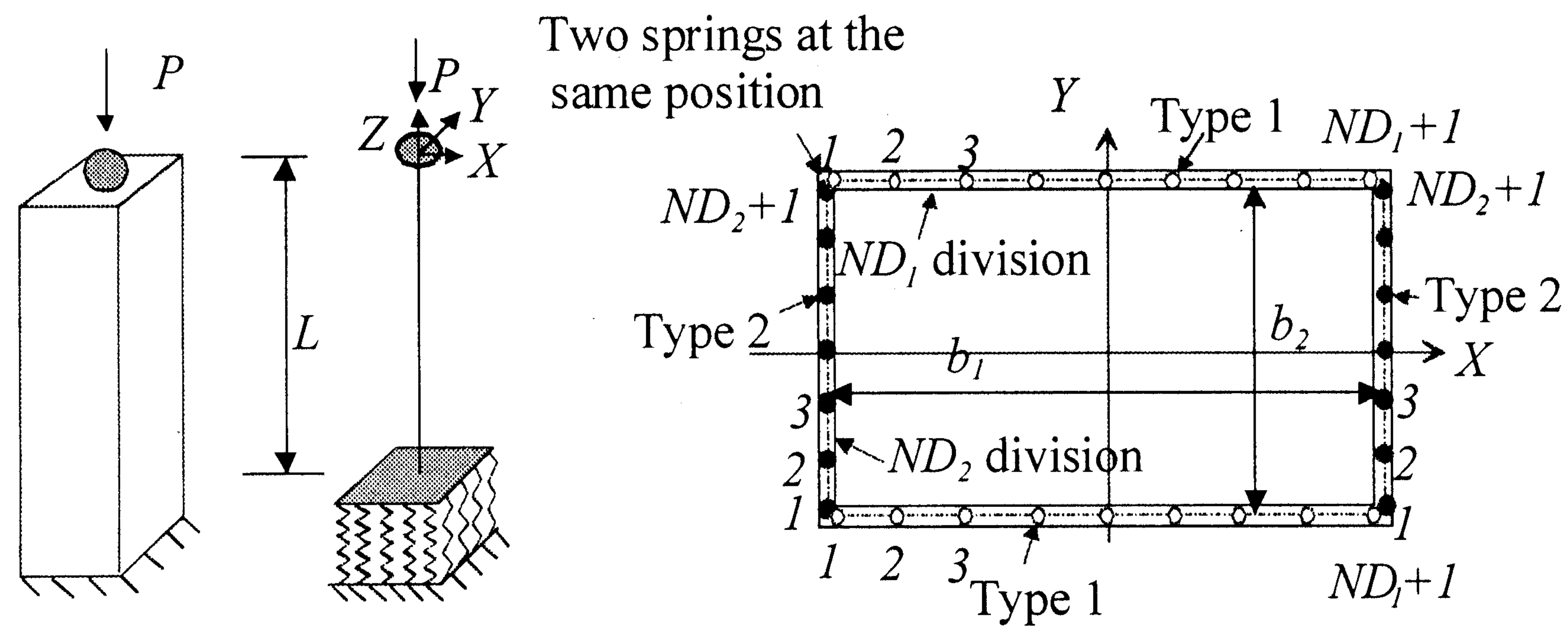
1. Introduction

In the urban area of Japan, thin-walled rectangular steel columns are also often used as elevated highway bridge piers. The effect of local buckling as well as of overall buckling must be carefully considered in the prediction of the strength and ductility of these rectangular steel piers. The 3-D characteristics of earthquake waves affected the damages of the steel piers as observed in the 1995 Kobe Earthquake. Therefore, in order to ensure the safety of steel piers, it is necessary to predict their behaviors under 3-D earthquake excitations. For this purpose, we herein develop a 3-D hysteretic model for the stiffened rectangular steel columns.

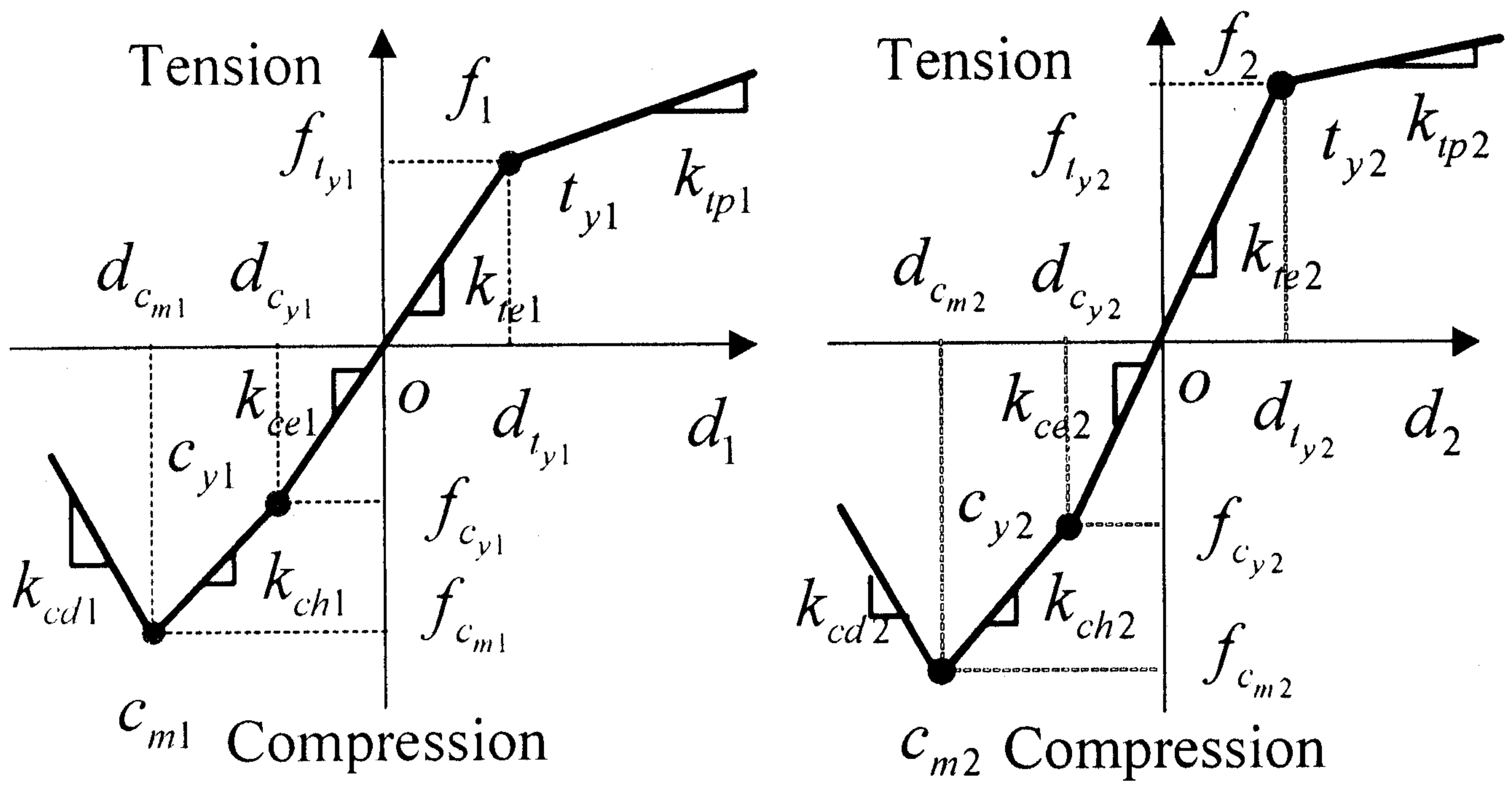
2. Multiple Spring Model

The multiple-spring model consists of a rigid bar and multiple springs located at the base of the rigid bar (Fig. 1). The multiple springs are so arranged that they are located at even intervals on the middle surfaces of the flanges and webs, respectively, of the thin-walled rectangular pier. To consider the non-homogeneous characteristics of rectangular piers, the springs of the model are classified into two types according to whether the springs represent the flanges or webs of the rectangular steel piers. The constitutive relations for the two types of springs are identified by curve-fitting techniques such that the model can best express the in-plain hysteretic behaviors of steel piers in the two principal directions. As the reference of the in-plane behavior of rectangular steel piers in the



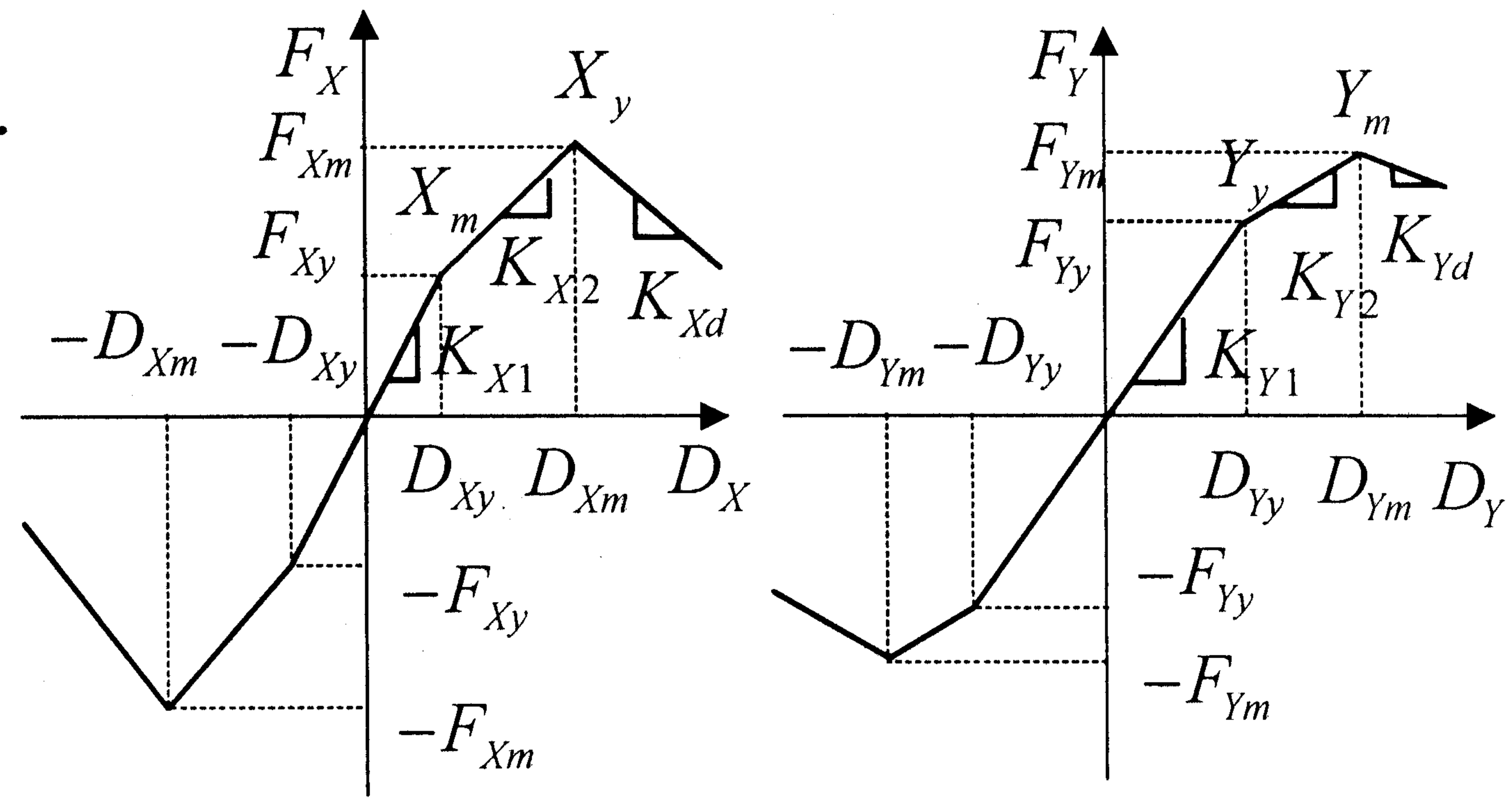
(a) Pier (b) Model

Figure 1 Multiple Spring Model



(a) Type 1 (b) Type 2

Figure 2 Two types of skeleton curves of spring



(a) X direction (b) Y direction

Figure 3 Skeleton curve of 2-parameter model

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principal directions, the 2-parameter model presented by Suzuki *et al.* (1997) is used. The idea of the above curve-fitting process is similar to that presented by the authors for thin-called circular piers(Jiang et al, 2002). After the constitutive relations are determined for the two types of springs, the results of the multiple-spring model is compared with those of the 3-D earthquake response analysis by FEM shell model.

3. Results and Summary

Three rectangular pier models with different governing parameters are used as numerical examples to examine the accuracy of the proposed model. Here the result of one pier is illustrated representing all the analysis results. In Fig.4, the multiple-spring model is compared with the 2-parameter model . In the 3-D dynamic response analyses, the accuracy of the multiple-spring model is examined in comparison with the 3-D FEM dynamic analysis using shell element where the local buckling behavior is precisely considered. As the constitutive model to express the cyclic plasticity of steel, the three-surface model (Goto. *et al.* (1998)) is implemented in ABAQUS by using the user defined subroutine feature. Fig.5 show the sway displacement trajectories at the top of the piers. As observed from Fig.6, the pier exhibits local buckling phenomena at the base location in the response analysis. The results confirmed that the multiple spring model can be an acceptable alternative to the costly FEM shell analysis as long as the localized deformation is moderate and not extremely large. It should be noted that the computing time of the multiple-spring model in the 3-D dynamic response analysis is drastically shortened to 1/4000~1/6000 of those of the FEM shell model.

Reference

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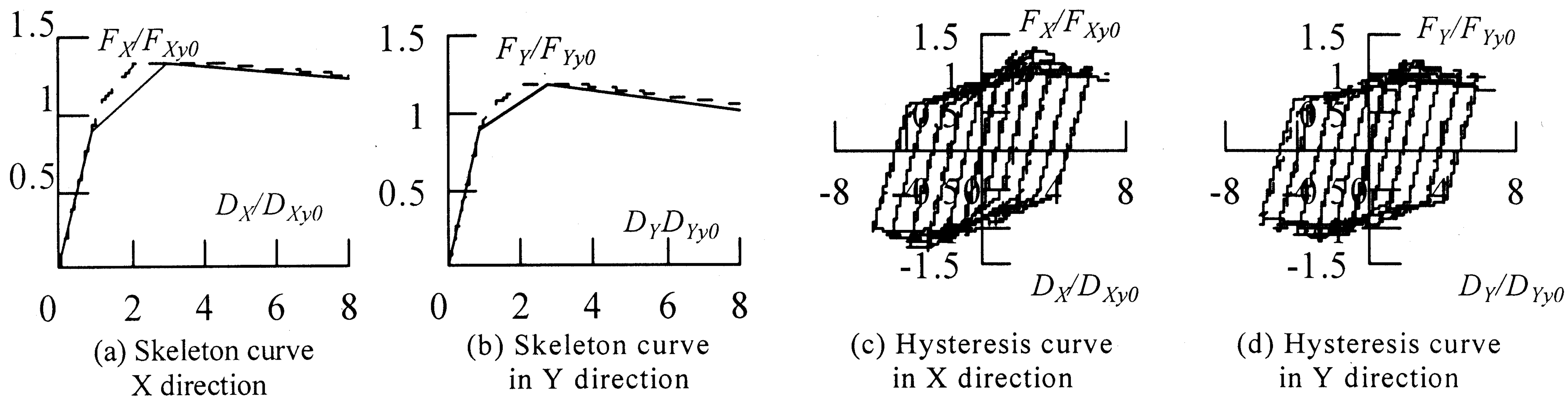

(a) Skeleton curve X direction (b) Skeleton curve in Y direction (c) Hysteresis curve in X direction (d) Hysteresis curve in Y direction

(- - -Multiple-spring model ——2-parameter model)

Figure 4 Comparison between multiple-spring model and 2-parameter model

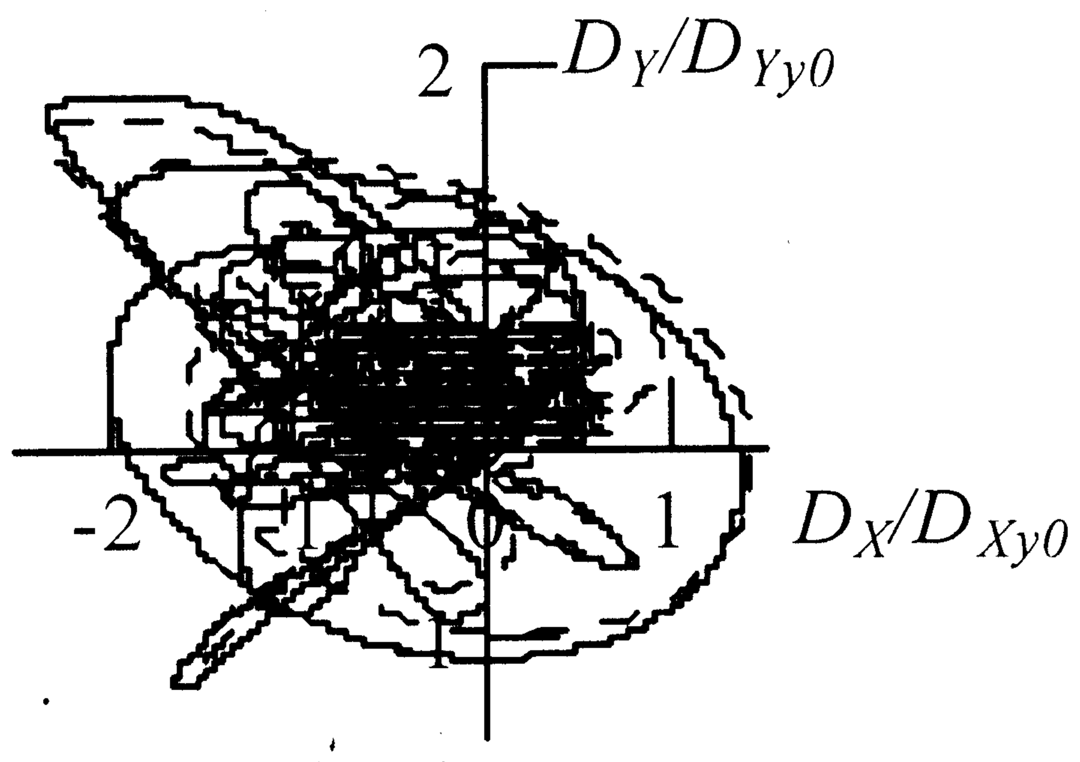

Figure 5 Trajectory of response sway displacement on X-Y plane under JMA wave

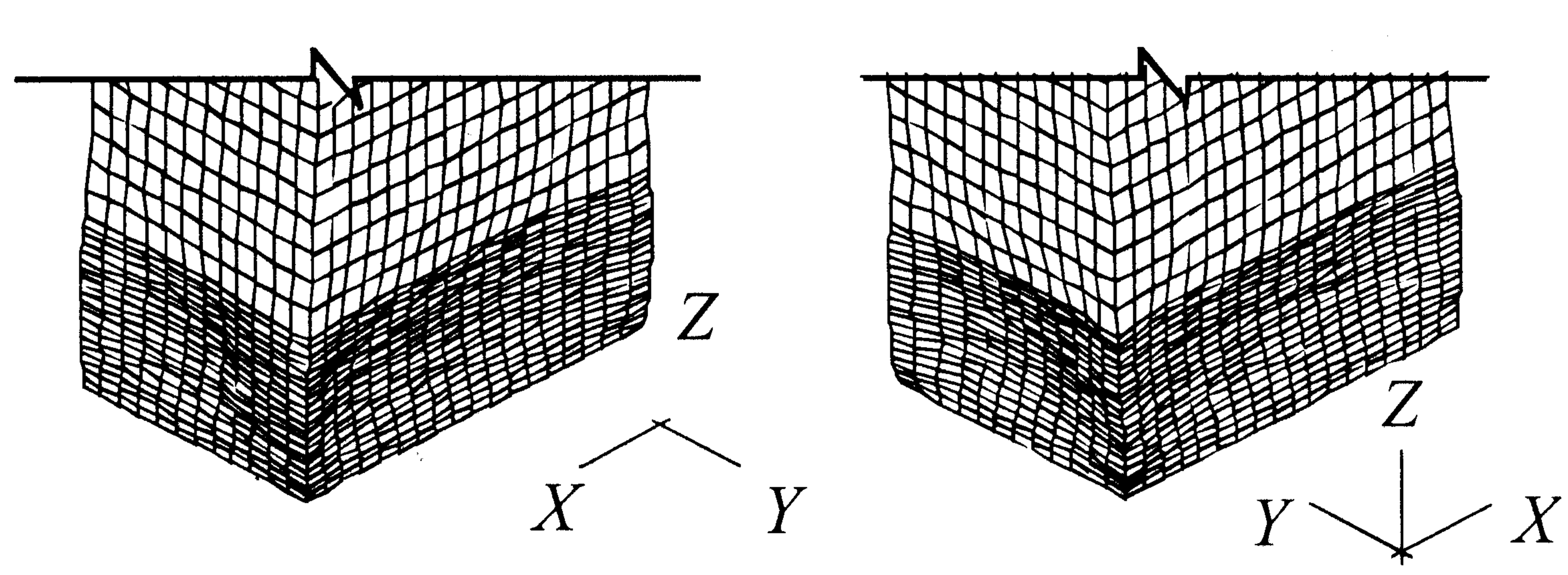

Figure 6 Deformation patterns at the pier bottom obtained by FEM shell model(displacement magnification factor=8)