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INVESTIGATION OF THE RELATIONSHIP BETWEEN THE SECTION FORCE AND SECTION DEFORMATION FOR THE BEAM ELEMENT UNDER CYCLIC LOADING

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1. INTRODUCTION

Recently, the study on the destruction of the structure caused by the earthquake has attracted much attention. It becomes more and more important to reveal the behavior of the structures under cyclic loading. One of a good example for the cyclic loading is the two-surface model[1),2)]. However, when such kind of plasticity model on the stress-strain level is used to the analysis of the structures, a large quantity calculation and memory are inevitable. Therefore, a relative simpler model for the structural analysis is necessary. In this paper, the plasticity model for the relationship between the section force and section deformation of beam section is investigated based on the two-surface model.

2. DEVELOPMENT OF THE CYCLIC PLASTICITY CONSTITUTIVE EQUATION FOR THE BEAM SECTION

2.1 The Relationship between the Bending Moment and the Curvature in the Pure Bending[3)]

In the situation of the cyclic pure bending, the relationship between the bending moment and curvature has shown in Ref.3) for the rectangular section and I-section. A good agreement of the comparison between the calculation in meshes and the prediction by the proposed model(a two-surface model on the bending moment-curvature level) has been obtained(as shown in Fig.1(a) and (b)). By using the same method, the calculation of the ring-section is carried out. The result is shown in Fig.1(c). The material for these three kinds of section is the steel JIS SS400.

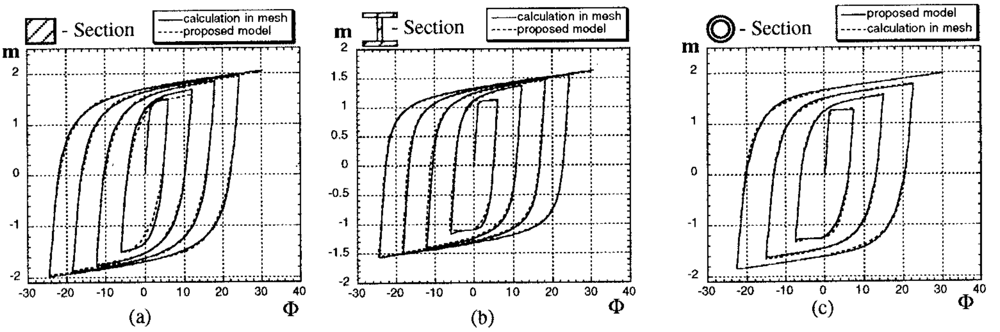

Fig.1 Comparison of the calculation results by using two different methods

2.2 The Relationship between Bending Moment and Curvature with the Constant Axial Force

Similar to the situation of the pure bending, the section is firstly discredited into small meshes. The rectangular section is taken as an example here. Since there exists the axial force, the strain at the center of the section is already nonzero. According to the assumption that the cross section remains as plain after deformation, the strain on the section can be expressed as follows:

$$d\varepsilon = d\varepsilon_{ce} + y\,d\phi \qquad (1)$$

where $d\varepsilon_{ce}$ is the increment of the axial strain at the section center; $d\phi$ is the increment of curvature. From $d\sigma = E^t d\varepsilon$, the axial force and the moment of the section are obtained.

$$dN = \int_A d\sigma dA = \int_A E^t d\varepsilon dA = a_{11} d\varepsilon_{ce} + a_{12} d\phi \qquad (2)$$

$$dM = \int_A y d\sigma dA = \int_A y E^t d\varepsilon dA = a_{21} d\varepsilon_{ce} + a_{22} d\phi \qquad (3)$$

where the coefficients a_{ij} are:

$a_{11} = \int_A E^t dA$; $a_{12} = a_{21} = \int_A y E^t dA$; and $a_{22} = \int_A y^2 E^t dA$;

It is noted that the axial force is always in constant, i.e., $dN = 0$. Therefore, $d\varepsilon_{ce}$ can be calculated from Eq.(2).

$$d\varepsilon_{ce} = -a_{12}/a_{11} d\phi \qquad (4)$$

When the material is in elasto-plastic state, the coefficients a_{ij} should be recalculated by using the new $d\varepsilon_{ce}$. Such calculation should be iterated until dN is converged to zero. Then, the relationship between the bending moment and curvature can be written as:

$$dM = (-a_{12}^2/a_{11} + a_{22}) d\phi \qquad (5)$$

In Fig.2, the results for the rectangular section are shown under monotonic loading and the cyclic loading. In the case of monotonic loading, the yielding moment decreases with the increase in axial force(as shown in Fig.2(a)). From Fig.2(b), it is seen that the length of yield plateau is almost the same for the different axial force when using $\overline{\varepsilon}^p = \phi^p/\phi_y + \varepsilon_{ce}^p/\varepsilon_y$ to replace ϕ^p/ϕ_y. As for the cyclic loading, the moment-curvature curve is is shown in Fig.2(c).

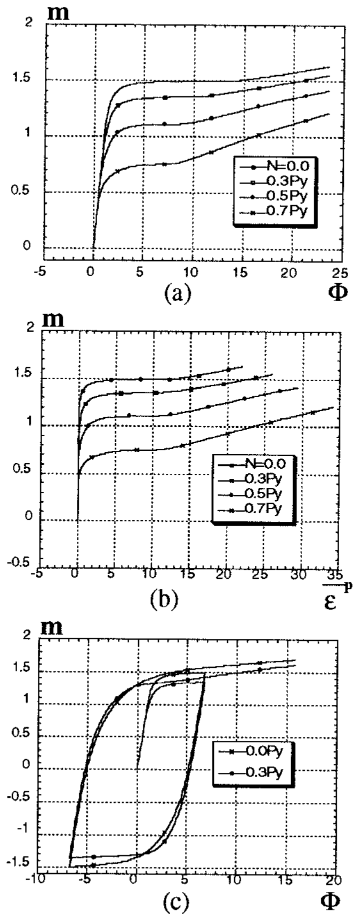

Fig.2 The **m-Φ** Relationship with Constant Axial Force

3. SUMMARY

The present study is aimed at establishing a cyclic elasto-plastic constitutive equation for the beam section on the level of section force and section deformation. For the pure bending, the proposed model has been demonstrated to be accurate enough. However, when there exists the axial force, the problem becomes much complicated. In the present paper, the axial force is limited to a constant. It is expected that the similar model can be obtained by using a suitable definition for the corresponding parameters.

References

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