I －12 ULTIMATE STRENGTH OF STEEL STRUCTURES UNDER THE INFLUENCE OF MATERIAL SOFTENING

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1. INTRODUCTION

The stress-strain curve obtained by the tensile test shows that the tensile strength is followed by a strain softening portion. In compression, the softening portion may not be observed because the primary cause of this softening is supposed to be necking in the specimen. But when subjected to compression, the structural element may buckle depending on its slenderness ratio. It is suggested that by modifying the stress-strain relation, the influence of buckling of an element can be estimated. Therefore, the ultimate strength of plate girders including local buckling effects can be obtained analytically by adopting a modified stress-strain relation with a strain softening portion in compression. In this study, assuming certain degree of material softening in tension and compression depending on the case, the ultimate strength of steel structures under the influence of material softening is discussed.

2. ANALYTICAL METHOD

The stress-strain relation in tension is the same as obtained by the uni-axial tensile test except the softening portion which is taken to be linear. But in compression, three different relations are assumed to compare the behaviors influenced by this material softening introduced by the modification of the stress-strain relation. The relations are shown in **Fig.1** and named as cases 1 through 3. Case 1 assumes no strain softening portion and there is a plateau beyond the corresponding point of tensile strength in compression. In Case 2, it is assumed to comply with elastic-perfectly plastic relation and the yield plateau is at the yield stress. Case 3 exhibits a strain softening portion when the strain is greater than the yield strain and the slope is assumed to be equal to the tangent modulus of the softening portion in tension. The moment-curvature relation is obtained numerically by dividing the section into number of small layers and the stress is assumed to vary linearly in each layer. The flanges are divided into 4 layers each and the web is into 32 layers. The different stress-strain relations in tension and compression necessitate iteration to compute this relation. A beam with fixed ends loaded with uniformly distributed load is analyzed by employing the displacement control method to trace the load displacement relation. Due to symmetry, only a half of the beam is considered in the analysis with 32 elements.

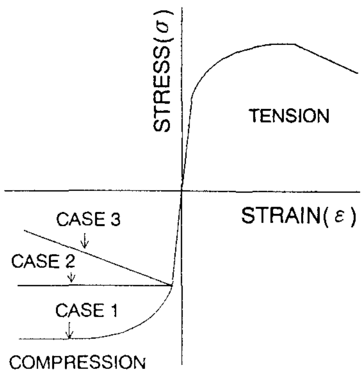

Fig. 1 $\sigma - \epsilon$ Relation

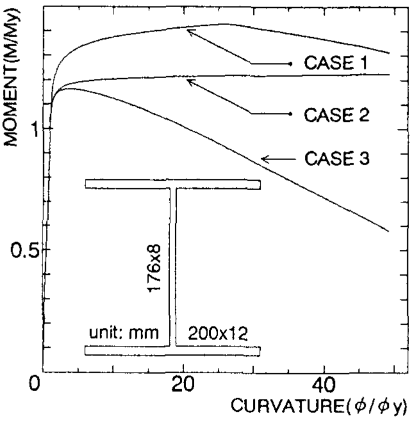

Fig. 2 $M - \phi$ Relation

3. DISCUSSION OF RESULTS

The moment curvature relation obtained is shown in **Fig.2** with the section and its dimensions. The moment and curvature are made into non-dimensional form using the values initiate yielding of extreme fibers. These values are marked with suffix y. Case 1 gives the maximum moment capacity which is just above 1.4 times the yield moment(My). The moment capacity reduces when the curvature increases beyond 25 times the yield value (ϕ_y). In case 2, the moment capacity is almost constant at 1.2My for the range shown in the figure. The influence of the softening portion of the stress-strain relation is quite explicit in case 3. As expected, the moment capacity starts to decline even before $5\phi_y$ is endured. These M-ϕ curves resemble the $\sigma - \epsilon$ relations of the weaker one for the same strain value. For case 1, it is the tensile one but for others, it is the compressive one.

Fig.3 explains the load-displacement curves for 10m long beam of the same section under uniformly distributed load. In case 1, the ultimate strength is reached when the displacement at mid-span is about 10 times U_y. Case 2 produces almost a constant load resistance and case 3 exhibits a declining load carrying capacity even though the tensile $\sigma - \epsilon$ relation is in the strain hardening range. It can be said that the ultimate strength is for the most part governed by the weaker material property assumed.

In **Fig.4**, the curvature variations of sections at the edge and the center are drawn. In all three cases, the curvature at the center increases in a faster rate when F is exceeded about $1.1 * F_y$. In cases 1 and 2, the curvatures at the center increase in a faster rate but the load resistance of the structure in that state is not improving in any significant manner and the structure has almost attained the ultimate strength with the properties of case 2. But in case 1, before undergoing considerable increment in curvature at the center, ultimate strength is achieved and the load resistance is being exhausted due to softening behavior.

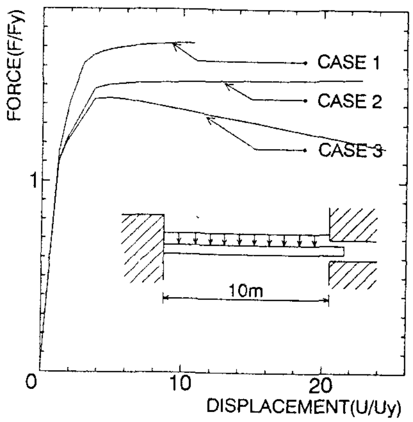

Fig. 3 Force Displacement Curve

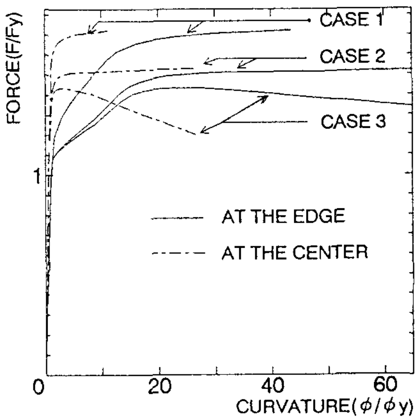

Fig. 4 Force Curvature Curve

4. SUMMARY

The influence of the strain softening portion of $\sigma - \epsilon$ curve on the M-ϕ relation and on the behavior of a fixed end beam subjected to bending stresses is discussed with the help of three different relations in compression. The ultimate strength is very much decided by the weaker $\sigma - \epsilon$ relation either in tension or in compression.

5. REFERENCE

1. Owen, D.R.J. and Hinton, E. :*Finite Elements in Plasticity: Theory and Practice.* Pineridge Press Limited, 1980.