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LOAD-SHORTENING BEHAVIOR OF SQUARE PLATE

Nippon Eng. Consultant Co., Ltd. member ○Mohamed Anzar.M.A.C.
Kanto Gakuin Univ. member Shigeru KURANISHI
Tohoku Univ. member Masatoshi NAKAZAWA

1. INTRODUCTION

Plates under uniform compression are studied to understand the behavior when the strain hardening property as seen in high strength steel is taken into consideration. The typical strain hardening portion is assumed in a form convenient to introduce material properties even though it is somewhat complicated to manipulate in the analysis. The results obtained for mild steel(with yield plateau) and high strength steel are compared for the case where residual stress is included. The generalized width-thickness ratio or the slenderness ratio is used to present the results since it is not very much susceptible to changes in the yield stress.

2. METHOD OF ANALYSIS

The plastic analysis is based on the kinematic hardening model and deflection control method is employed in the present FEM analysis. The strain hardening portion is assumed to be defined by

$$\left(\frac{(\sigma-\sigma_o)}{A(\sigma_u-\sigma_y)}\right)^n+\left(\frac{(\epsilon_o-\epsilon)}{B(\epsilon_u-\epsilon_y)}\right)^n=1 \qquad \epsilon_y\leq\epsilon\leq\epsilon_u$$

where $\sigma_o, \sigma_u, \sigma_y, n, \epsilon_o, \epsilon_u, A, B$ are constants for a material. σ_y and ϵ_y are the yield values. σ_u and ϵ_u are the ultimate strength and the strain level at the same point, respectively. The unknown constants should be solved for the material in question and some assumptions are made to represent the typical experimental curve of high strength steel. In the analysis, n is taken to be 2 which means the curve is a part of an ellipse. This relation requires iterations to obtain the tangent modulus to evaluate incremental stress and plastic strains. The yield stress is taken to be 600MPa for both steel types to compare the results and the yield ratio is 0.8 for high strength steel. The strain level at the tensile strength is changed to 10, 20 and 30 times the yield strain to discuss the influence of its variation. The initial out-of-plane deflections of $b/150$ and $b/1000$ are considered where b is the width of the plate.

3. ANALYTICAL RESULTS

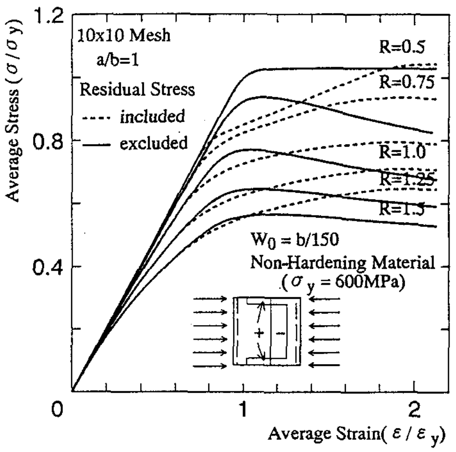

Fig.1 Influence of Residual Stress (Non-hardening Case)

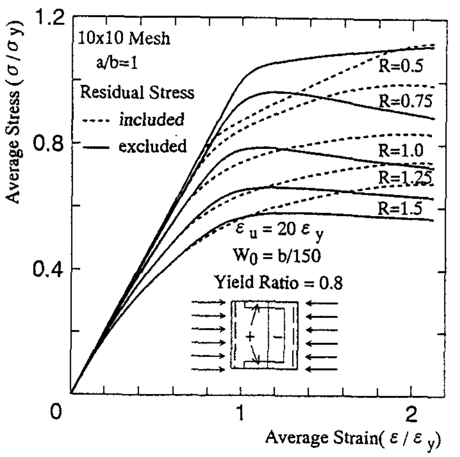

Fig.2 Influence of Residual Stress (Hardening Case)

Fig.1 shows the load-shortening behavior of a plate when the strain hardening property is neglected. The residual stress pattern assumed in the analysis is inscribed in the figure. The tensile residual stress is assumed to be $0.9\sigma_y$ in one tenth of the width whereas the compressive one is $0.225\sigma_y$ which is assigned so that the equilibrium condition is satisfied. These values are comparable with the values reported in **Ref.1** for SM58 and they are $0.9\sigma_y$ and $0.2\sigma_y$ in tension and compression respectively.

The stress pattern assumed actually results in an increase in the ultimate load specially when the generalized width-thickness ratio(R) is greater than 1.0. This is really the influence of tensile residual stress block assumed in the analysis. Whether the residual stress is included or not, the ultimate strength is almost the same when R is less than 1.0. But the required average strain to attain the ultimate strength is almost doubled in the former case. Furthermore, when R is equal to 0.5 in the non-hardening case, the ultimate strength is about 3% greater than the yield stress. It appears that this is the result of converting the average two dimensional behavior into one dimensional case and partly due to the mesh size used in the numerical analysis.

The tendency observed in the non-hardening case is repeated in **Fig.2**. But the ultimate strength is higher because of the strain hardening behavior. When R becomes smaller and smaller, the load-shortening curve gets closer and closer to the uniaxial stress-strain relation adopted in the analysis.

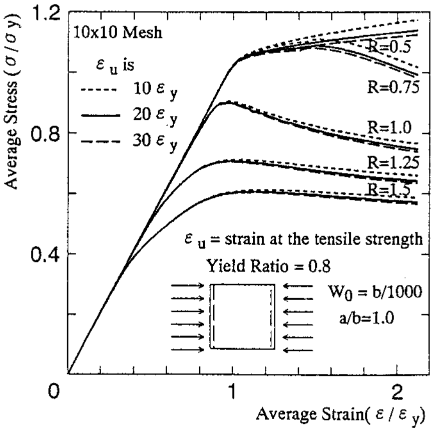

Fig.3 Load-Shortening Curve ($W_0 = b/1000$)

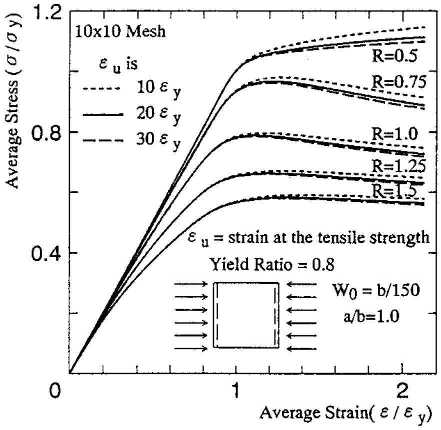

Fig.4 Load-Shortening Curve ($W_0 = b/150$)

Fig.3 explains the influence of changing the strain level at the tensile strength for a material which exhibits strain hardening behavior. The initial out-of-plane deflection(W_0) is b/1000 since this particular value is adopted by several researchers to obtain load-shortening curves which are used as modified stress-strain relations in compression to include the local buckling effects in simplified computations. The yield ratio is kept constant while the strain level required to attain the tensile strength is changed. When strain level at the tensile strength is increased, it practically brings down the tangent modulus in a range that follows yielding. It is evident that increasing ϵ_u as high as three times does not influence the result considerably when R is greater than or equal to 1.0. But for less values of R, the difference is a little higher. It appears that ϵ_u does not influence the tendency very much but with decreasing R, the difference in ultimate strength is expanding.

In **Fig.4**, the initial out-of-plane deflection is taken as b/150 which is the allowable limit for plate bending mode in Japan(JSHB1980). The increase in W_0 lowers the ultimate strength but the difference is remarkable for the intermediate values of R, for example, between 0.75 and 1.25. The influence of different ϵ_u is similar even if the initial deflection is changed.

4. SUMMARY

Load-shortening curves are obtained for plates considering the strain hardening portion that follows just after yielding as a part of an ellipse. For the residual stress case, the tendency is very similar whether strain hardening is considered or not. But for larger values of R, higher ultimate strength is attained when residual stress is included. Changing the initial deflection does not alter the influence of varying the strain level at the tensile strength.

REF.1 Komatsu,S. et al., An experimental $\cdots$, Proc. JSCE, No.265,pp.25-35,1977(in Japanese)