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ULTIMATE STRENGTH OF HIGH STRENGTH STEEL BEAM

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1.INTRODUCTION

In the plastic design procedure applied to mild steel beam, the ultimate load for a structure is obtained using plastic hinge assumptions in which moment capacity of a hinge is taken to be equal to full plastic moment(Mp). And the uni-axial stress-strain curve of mild steel is assumed to be elastic-perfectly plastic. But in this study, experimental stress-strain curves idealized to multi-linear relationship are used to estimate the ultimate strength of mild and high strength steel beams. For comparison, the same I-section is adopted for both cases. The results of simplified plastic design procedure are also indicated.

2.ANALYTICAL METHOD

In the analysis, FEM simple beam element is employed. Each element is subdivided into a number of small areas to account for the plastic zone of a section. The strain of each area is considered to be equal to the strain at its centroid. This means the centroid of each small area is taken as its representative point. Sectional properties of each beam element are computed by numerical integration. The stress is corrected according to the stress-strain relationship.

Further, different stress-strain curves are assumed in tension and compression. The tensile curve is taken to be the same as the experimental one and this has a strain softening range just after achieving tensile strength but the idealized compressive one does not exhibit strain softening instead yields at constant stress equal to the compressive strength which is numerically equal to the tensile strength. In both tension and compression, the material is assumed to break when the strain reaches the value at break in the experiment.

A three span continuous beam is analyzed to compare the behavior of mild steel and high strength steel beams. In the analysis, arc length constraint is employed with modified Newton-Raphson method to limit excessive deformation for a load increment step.

The characteristics of mild and high strength steel (referred as HS steel hereafter) specimens are shown in Table.1. The yield stress of HS steel is equivalent to 0.2% off set stress. Yield stress and tensile strength are given in N/mm^2 and others are in percentage (%).

Sample	Yield stress	Tensile strength	Yield ratio	Yielding range	Strain at tensile strength	Strain at Break
Mild steel	310	478	65%	0.15 - 1.7%	18.0%	34.0%
HS steel	626	804	78%	-	7.5%	22.5%

Table 1 : Characteristics of both steel specimens

3.ANALYTICAL RESULTS

The three span continuous beam shown in Fig.1 is analyzed and the moment curvature relation is given in the same figure at the loading point 'C'. The moment and the curvature are made into non-dimensional form by dividing them by corresponding full plastic moment and curvature which initiates yielding in the outer fibers, respectively. Fig.1 indicates that the normalized moment capacity of HS steel is higher than that of mild steel in a range after the full plastic moment is exceeded. But if the strain hardening part of mild steel is taken into account moment capacity of mild steel will surpass that of HS steel because the yield ratio is higher for HS steel specimen. If the HS steel is considered, the moment capacity reaches more than 1.2 times of Mp which is developed for a

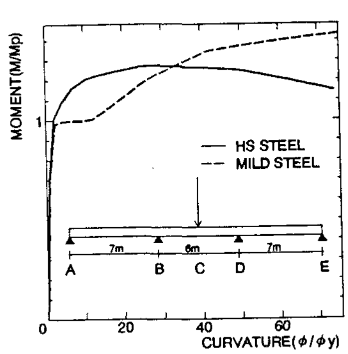

Fig.1 Moment curvature relation

non-dimensional curvature of around 28.

Force-deflection curve is shown in Fig.2. This gives the deflection at point 'C' in times of corresponding deflection at the beginning of yielding of the outer fibers. The non-dimensional form of deflection is less for HS steel for a particular F/Fu until after the ultimate strength of HS steel beam is attained. The load carrying capacity of more than Fu (ie F/Fu>1) is achieved in mild steel due to strain hardening effect.

In Fig.3, the absolute values of curvature at points 'B', and 'C' are normalized by dividing them by curvature of mild steel when yielding initiates at the outer fibers. This is done in order to compare the absolute curvatures for both type of steel. At point 'C', the absolute curvature for mild steel is less than that for HS steel for almost all values of F/Fu. This means that for the same F/Fu, the deflection of HS steel beam is higher. But it is necessary to note that if the absolute value of load F is considered for any deflection, the HS steel yields more carrying capacity from the onset of yielding in mild steel beam.

Fig.4 explains the force-moment relation at points 'B' and 'C'. Moments at these points are marked as 'MB' and 'MC' respectively. In this plot, hogging moment is taken to be negative and sagging moment is positive. Mp is the full plastic moment estimated with simplified stress block for both steel sections. 'Fu' is the calculated ultimate load adopting simplified plastic design. From the figure, it is clear the HS steel specimen exhibits about 25% more than the ultimate load obtained by simplified plastic design procedure. Therefore, it seems that higher Mp should have to be assumed to estimate the ultimate load of HS steel correctly.

Fig.4 also shows that the ultimate load is not achieved for the maximum moment capacity of the section at 'C' but the moment at 'C' is already on the decline. The decline in the moment capacity after reaching the maximum value is caused by the strain softening part of the stress strain curve. As a result, the reduction in load carrying capacity occurs after reaching the ultimate load. The moment at 'C' clearly shows the formation of plastic hinge at the load of about 0.7 times of Fu and continues to increase due to strain hardening region when F passes Fu.

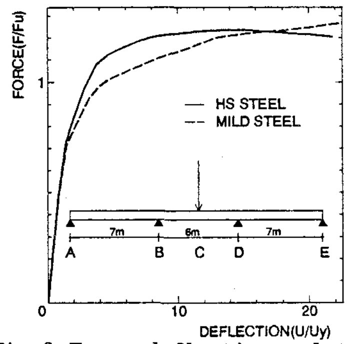

Fig.2 Force deflection relation

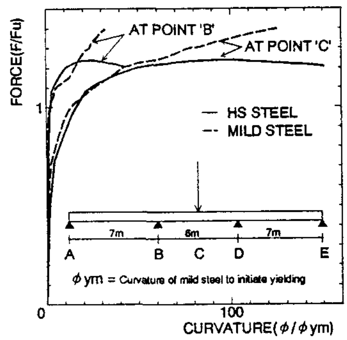

Fig.3 Force curvature relation

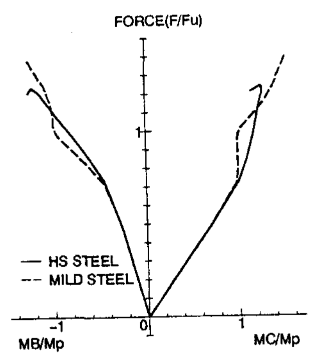

Fig.4 Force moment relation

4.SUMMARY

By assuming the uni-axial stress-strain relation as multi-linear, the ultimate strength of HS steel beam is studied employing FEM and compared with that of mild steel beam and with the result of simplified plastic design.

The ultimate load of the HS steel beam having plastic section (class 1) is about 25% higher than the value obtained by the simplified plastic design for this case.

REFERENCE

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