I-89 ELASTO-PLASTIC BEHAVIOR OF HIGH STRENGTH STEEL BEAM

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1.INTRODUCTION

The plastic design procedure used to mild steel structural members can not be easily applied to design the high strength structural members. This is primarily due to the difference in stress-strain characteristics. The mild steel subjected to uni-axial stress yields almost at a constant stress level after which a strain hardening is exhibited. Whereas the high strength steel which does not have definite yield point and exhibits strain hardening property until its ultimate strength is reached. Furthermore, in simple tension test, high strength steel is only capable of undergoing less strain increment before break than mild steel is. Therefore, the familiar term in plastic design of mild steel, the fully plastic moment (Mp) needs to be defined to high strength steel to utilize the capacity of it.

In this study, moment-curvature relationship of high strength steel is compared with that of mild steel. A simply supported three-span high strength steel beam is also analyzed.

2.ANALYTICAL METHOD

The uni-axial stress-strain relationship is assumed to be multi-linear for both mild and high strength steel is shown in Fig.1. It is further assumed that the yield stress is a function of endured plastic strain. Because of two different stress-strain curves for tension and compression, iteration is necessary to compute moment-curvature relationship even if the section is symmetrical about its principal axis.

To calculate the moment curvature relationship of an I-section, the cross section is sub-divided into a number of small areas. The strain of each area is considered to be equal to the strain at its centroid. The stress has to be corrected according to the stress-strain relationship.

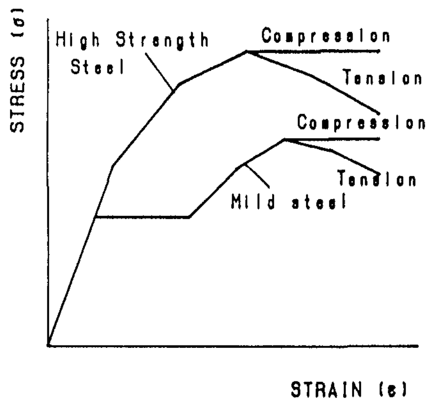

Fig.1 Assumed stress-strain curve

A three-span continuous beam was analyzed employing FEM simple beam element which is subdivided as explained above. The sectional properties of each beam element are obtained by numerical integration. The residual force is dissipated through iterational process. The arc length constraint is applied to limit excessive deformation for a load increment step.

3.ANALYTICAL RESULTS

Experimental stress-strain curves of three mild steel and the same number of high strength steel specimens were considered. For mild steel, stress-strain curves of SM41, SM50, and SM58 are considered. For high strength steel, three experimental uni-axial stress strain curves are used and the specimens are named as HSS1, HSS2 and HSS3. Their tensile strength, yield stress which is equivalent to 0.2% off set stress for high strength steel and yield ratio are given in Table 1.

	SM41	SM50	SM58	HSS1	HSS2	HSS3
Yield Stress (kgf/mm^2)	31.7	41.2	50.8	63.9	78.2	71.4
Tensile Strength (kgf/mm^2)	48.8	55.5	59.3	82.0	86.2	85.8
Yield Ratio	-	-	-	78%	91%	83%

Table 1 : Characteristics of steel specimens

The moment-curvature relationship obtained for mild and high strength steels are plotted in Fig.2 and the I-section shown, was assumed for all six cases. This figure shows that the mild steel is capable of undergoing deformation in the order of more than 80 times the curvature causes initial yielding of extreme fibers and still in strain hardening range, whereas the high strength steel is capable of only around half of it and already in strain softening region. From this figure, it can be said that depending on the allowable curvature, the fully plastic moment of high strength steel can be assumed more than that of mild steel, that is, if the allowable curvature is 10 times the curvature initiates yielding, the plastic moment of mild steel is about 1.14 times the yield moment (My) which is the moment initiates yielding of extreme fibers but that of the high strength steel varies from 1.2 to 1.4 times. This means that if only 1.14 times of My assumed to plastic moment of high strength steel, the capacity is not fully utilized in this case.

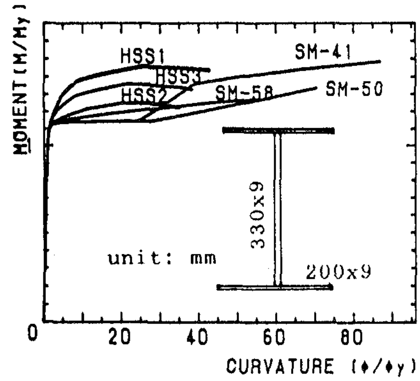

Fig.2 Moment-curvature relation

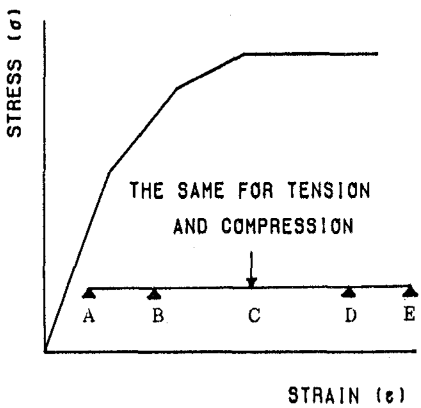

Fig.3 Stress-strain curve and the continuous beam model

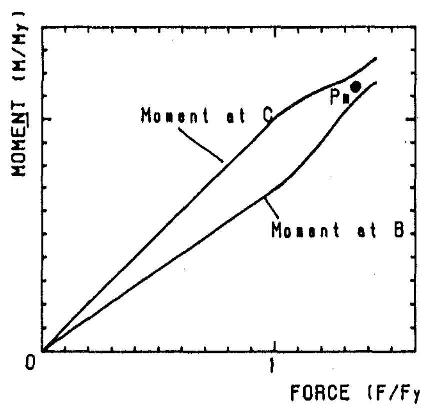

Fig.4 Moment-force relationship

The three-span continuous beam of HSS1 shown in Fig.3 with the stress-strain relationship assumed, is analyzed. The middle span is 12m and the others are 4m and the force is applied at the center of the middle span. The moments at point B and point C are plotted against force in Fig.4. The moments are divided by My and the load is by the load causes yielding of extreme fiber in order to get dimensionless force and moment and to give more information about the plastic moment. This clearly explains that if the load is increased, yielding begins first at point C and then at point B as expected. The simplified plastic design will yield an ultimate force of $8*Mp/L_2$. Where Mp is the fully plastic moment and L_2 is the length of the middle span. If the Mp is calculated as for mild steel, the corresponding point is marked as Pm in Fig.4. This shows that in this case, the simplified plastic design will yield a failure load which is below its capacity. But the difference is not so significant in this case.

4.SUMMARY

To fully utilize the capacity of high strength steels and to have a simplified plastic design procedure for this kind of steel, it is necessary to continue further research and to extend this study to accommodate different cases and to local buckling problems of flange plates as well.

REFERENCE

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