I-622 ON DEFORMATION CAPACITY OF HIGH STRENGTH STEEL SECTION

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1.INTRODUCTION

As far as the ultimate limit state design of structures is concerned, the main objective is to obtain the ultimate load carrying capacity of it. In this study it is assumed that no premature local buckling occurs to cause a drop-off in carrying capacity. For structural mild steel, ductility or deformation capacity is not a common problem which hinders plastic redistribution in the structure. But if the structure contains any high strength steel(HS steel) structural members, one more possible question would be whether the deformation capacity of HS steel is sufficient to consider redistribution of moment. A HS steel I-beam subjected to uniformly distributed load is analyzed employing FEM for two different boundary conditions namely simply supported and fixed ends. The results are discussed with respect to deformation capacity of HS steel section.

2.ANALYTICAL METHOD

FEM beam element with three DOF at each node is utilized. The sectional properties are calculated with reference to an arbitrary axis to allow for plastic portion of the section and for possible change of neutral axis. Further, the element stiffness matrix is constructed assuming a linear variation of tangent modulus along an element if they are different at both edges. This has really improved the convergence characteristics. The modified arc-length solution procedure is adopted for avoiding complex roots to the quadratic constraint equation(Ref.1).

Since it is assumed that no local buckling occurs, the stress-strain relation in compression is taken to have plateau at ultimate strength whereas that in tension is taken to follow the uni-axial tensile test. Therefore, the tensile curve has a strain softening region.

The 0.2% off set stress and the tensile strength of the HS steel specimen are 626N/mm^2 and 804N/mm^2 respectively. The corresponding strain at tensile strength is 7.5% and that at break is 22.5%. The experimental stress-strain curve is approximated to two exponential curves by curve fitting. One for the strain hardening portion and the other for the strain softening part.

3.ANALYTICAL RESULTS

In this study, it is considered that the requirement of deformation capacity of HS steel as structural material and as structural section can be discussed if two extreme cases of simply supported beam and fixed end beam are analyzed. For this purpose 20m length beam is assumed and the section is shown in Fig.1 with the moment curvature relation. The moment and curvature are made into non-dimensional form by dividing moment initiates yielding of outer fibers and curvature at the initiation of yielding respectively. This explains that if the curvature is increased, the moment capacity of a section is increasing to a maximum value and then decreasing. The maximum moment is referred as ultimate moment of the section. The decline occurs due to strain softening part of the stress-strain curve.

In Fig.2, the strain of the outer fiber and corresponding moment of a section are given. The strain is given in percentage of initial length. The ultimate moment is attained for the strain of about 8% at the outer fiber. This value falls in the close vicinity to the strain corresponding to tensile strength which is 7.5%. From this result, it can be said that to attain the ultimate moment carrying capacity, the material does not have to undergo much more strain beyond the value corresponding to tensile strength and this section has necessary deformation capacity.

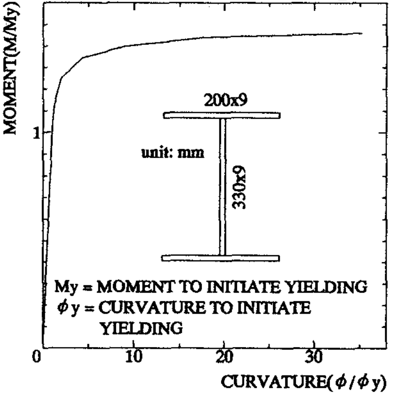

Fig.1 MOMENT-CURVATURE CURVE

Fig.3 shows load carrying capacity against the moment at mid span and at the edges. The load which initiates yielding is calculated for both boundary conditions and called as 'Fy'. The simply supported beam subjected to uniformly distributed load attains the ultimate load carrying capacity when the moment is maximum at the center because the load-moment relation is a straight line. Therefore, this case does not need any substantial deformation capacity of HS steel beyond the strain at tensile strength as the section at mid span should only attain the maximum moment capacity to reach the ultimate load. For this, the material only needs to exhibit a deformation capacity of about 8%.

When both ends are fixed, the deformation capacity comes into question. In this figure, variation of moments at the end and at the mid span is shown for the fixed-end-beam. Even though the moments at the edge and the mid span are hogging and sagging moments respectively, they are taken to be positive. In this case, yielding initiates at the ends and it is followed by yielding at midspan. When the sections at both ends start to yield, the moment at the center increases at a faster rate than in the elastic range to relieve the yielding sections at the ends. The ultimate load carrying capacity is obtained when the moment capacity is on the declining region just after attaining the maximum moment capacity of the section at both ends. This implies that the end section behaves as a softened section and the moment capacity reduces with increasing curvature.

Fig.4 explains the deformation capacity required to achieve the ultimate load carrying capacity. The strain plotted is the maximum of the section concerned. Therefore, it gives the value of required deformation capacity. The simply supported beam needs only a deformation capacity of about 8% and the fixed-end-beam requires only about 9%. These values are only in the vicinity of the strain at tensile strength and are much less than the value at break. The required strain of the outer fiber at center of the beam is about 1% only. The ultimate load of the simply supported beam is about 1.4 times 'Fy' and that of fixed-end-beam is a little more than 1.8 times 'Fy'.

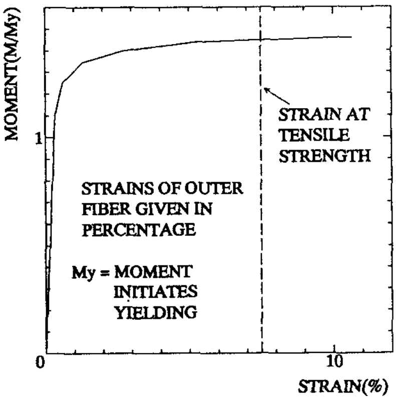

Fig.2 MOMENT-STRAIN CURVE

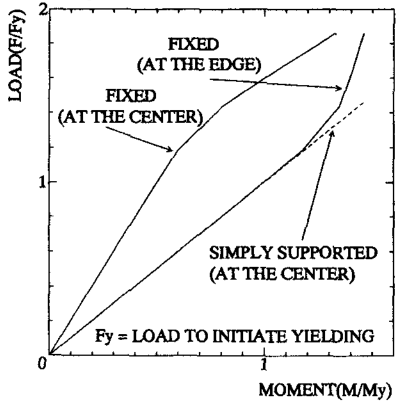

Fig.3 LOAD-MOMENT CURVE

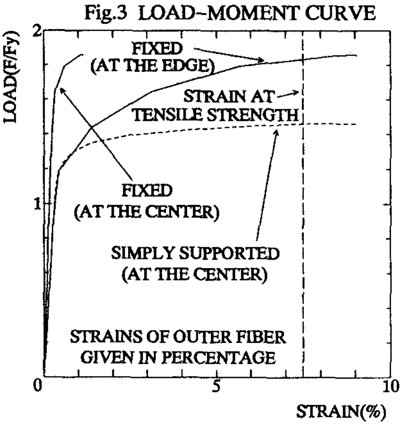

Fig.4 LOAD-STRAIN CURVE

4.SUMMARY

The deformation capacity of HS steel is discussed with respect to structural behavior of HS steel section and beam. This study shows that deformation capacity of somewhat greater than the value at tensile strength would be sufficient to achieve the ultimate strength of the structure considered. Further, the deformation capacity necessary to attain ultimate moment of a section is in the close vicinity of the strain at tensile strength.

REFERENCE

1. Lam, W.F., and Morley, C.T.(1992). "Arc-length method for passing limit points in structural calculation." J. Struct. Div., ASCE, Vol. 118(1),p169-185.