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Comparative Study of Cold Formed Steel Sections with Hot Rolled Steel Sections

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Abstract
Structural steel has become the best alternative for concrete in present construction industry. Hot Rolled steel Sections (HRS) available in market have standard shapes and sizes where as Cold Formed steel Sections (CFS) are produced in various shapes and sizes as per the needs of customer. A comparative study of cold formed sections and hot rolled section with respect to its axial load carrying capacity as a column is attempted. Hot rolled I-Sections and I-Sections formed by assembly of two cold formed channel sections are undertaken for the study. Columns with two end conditions i.e., both ends fixed, one end fixed and other end hinged of unsupported length 3 and 4 m are considered in the analysis. The safety index 'β' by reliability analysis is evaluated for cold formed sections.

Keywords: *Hot rolled steel sections, cold formed steel sections, reliability index*

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INTRODUCTION

In steel construction, there are two main families of structural members. One is the familiar group of hot-rolled shapes and members built up of plates. The other, less familiar but of growing importance, are cold formed sections formed from steel sheet, strip, plates, or flat bars by roll-forming or press braking operation of certain shapes.

The thickness of steel sheets or strip generally used in cold-formed steel structural members ranges from 0.4 to 6.4 mm [1]. The major structural advantage of cold formed steel members lies with the 'thinness' of the material, which can be used, leading to an extremely light-weight construction. Hence, buckling is a predominant failure mode in cold formed sections [2].

Cold forming has the effect of increasing the yield strength of steel, the increase being the consequence of cold working well into the strain-hardening range. These increases are predominant in zones where the metal is bent by folding. The effect of cold working is thus to enhance the mean yield stress by 15–30%. For purposes of design, the yield stress may be regarded as having been enhanced by a minimum of 15% [3].Thus the advantages which can be gained by the use of cold forming are bought at the expense of the requirement to use increased sophistication in the design analysis.

METHODOLOGY OF THE WORK

Selection of Section

Steel sections are selected as per Indian Standard codes and Handbook. Hot rolled I-Section profiles are chosen from SP: 6(1)-1964 (Reaffirmed 1998). I-Section profiles include a series of Indian Standard Junior Beam (ISJB), Indian Standard Lightweight Beam (ISLB), Indian Standard Medium weight Beam (ISMB) Indian Standard Wideflange Beam (ISWB).

Though, an infinite number of profiles are available in CFS, only those sections mentioned in IS: 811-1987 (Reaffirmed 1995) are chosen for the analysis. Cold formed sections include rectangular channels with lips (edge stiffeners) and without lips. I-sections formed by the assembly of two cold formed channel sections which are undertaken for study. The sections of depth up to 250 mm are considered in both HRS and CFS.

Evaluation of axial load carrying capacity of column

The axial load for the column is evaluated as per provision given in IS: 800-2007 for HRS and IS: 801-1975 (Reaffirmed 1995) for CFS.

In the present analysis, axial load carrying capacity of the column is evaluated with only two end conditions i.e., i) both ends fixed, ii) one end fixed and other end hinged. The unsupported length of the column having 3m and 4m are considered in the analysis. The grade of steel considered for CFS is St.42 which has yield strength of 235 MPa and for HRS is St.42 which has minimum yield strength of 250 MPa. The design compressive load for cold formed section is given by,

$$P = Af_a \quad (1)$$

Where,

A = area of the section

f_a = allowable average compressive stress (IS: 801-1975, clause 6.6.1.1)

$$P = \frac{12}{23} Q.f_y - \frac{3(Q.f_y)^2}{23.\pi^2.E}\left(\frac{KL}{r}\right)^2$$

$$for\ \frac{KL}{r} < \frac{C_c}{\sqrt{Q}} = \frac{12\pi^2 E}{23(KL/r)^2}$$

$$for\ \frac{KL}{r} \geq \frac{C_c}{\sqrt{Q}}$$

Where,

$$C_c = \sqrt{2\pi^2 E / f_y}$$

P = total load

A = full unreduced cross-sectional area of the member

f_a = allowable average compressive stress

E = modulus of elasticity

K = effective length factor

L = unsupported length of the member

r = radius of gyration

f_y = yield point of steel

Q = a factor (≤1) determined as follows

$= \frac{F_c}{f}\frac{A_e}{A}$ (since the members composed of both stiffened and unstiffened members)

where, $\frac{F_c}{f} = Q_s$, is the stress factor

$\frac{A_e}{A} = Q_a$, is the area factor

A_e = effective area of cross-section (depends on effective width, b)

f = basic design stress

$= 0.6 f_y$

F_c = allowable compression stress on unstiffened element.

Comparative Analysis of HRS and CFS

Comparative analysis of HRS and CFS is made with reference to axial load carrying capacities. The comparison is made separately for stiffened and unstiffened sections in CFS. The least self-weight of the hot rolled I-Section profiles is considered in each of the series, ISJB, ISLB, ISMB and ISWB.

The sections ISJB150, ISLB75, ISMB100 and ISWB150 are found to have least self-weights and thus these sections are considered as benchmark for comparison. The cold formed sections comprising the self-weights lower than that of the benchmark hot rolled series are considered. It is found that many alternatives of CFS are found in both stiffened and unstiffened sections, which have higher axial load carrying capacity than that of HRS.

Tables 1 and 2 show the load carrying capacities of HRS and alternate CFS (Unstiffened and Stiffened). The average percentage savings in weight over HRS is found to be 9.05% for unstiffened CFS and 14.67% for stiffened CFS [4–7].

Reliability Analysis

The Reliability index, 'β' which indicates the safety factor is evaluated by assuming the random variables to be normally distributed. First order second moment method is adopted in the reliability analysis.

The resistance variable (R) is the design capacity of CFS which includes the uncertainties in yield strength of the steel, modulus of elasticity of steel, geometry of the structure. The load variable (S) is the design capacity of HRS which includes the uncertainties in loading.

The Reliability index, 'β' which is evaluated for CFS undertaken for study is given by,

$$\beta = \frac{\mu_R - \mu_S}{\sqrt{\sigma_R{}^2 - \sigma_S{}^2}} \quad (2)$$

Where
μ_R = mean value of resistance variable
σ_R= standard deviation of resistance variable
μ_S = mean value of load variable
σ_S = standard deviation of load variable

The value of 'β' for all the cold formed sections evaluated is greater than 3.09, which is a value normally considered for civil engineering structures.

1) Some CFS having lesser self-weight possess higher load capacity than the conventional HRS. Hence CFS provides an alternative choice to HRS in steel construction.
2) CFS which serves as an alternative to HRS have the reliability index, β greater than 3.09 indicates the probability of failure of one in thousand.
3) Considerable savings in weight is achieved for CFS over conventional HRS.

RESULTS AND CONCLUSIONS

Table 1: *Load Carrying Capacities of HRS and Alternate CFS (Both the End of Column Fixed).*

Unsupported length (m)	HRS	Load (kN)	Alternate Unstiffened CFS		Alternate Stiffened CFS	
			CFS (h x b x t)	Load (kN)	CFS (h X b X c X t)	Load (kN)
3	ISJB150@ 7.1 kg/m	36.97	100 x 40 x 2.00	45.96	100 x 40 x 10 x 1.60	40.49
			100 x 50 x 2.00	69.62	100 x 40 x 15 x 2.00	61.84
			100 x 60 x 2.00	47.29	100 x 50 x 15 x 2.00	78.00
	ISLB75@ 6.1 kg/m	39.27	100 x 40 x 2.00	45.96	100 x 40 x 10 x 1.60	40.49
			100 x 50 x 2.00	69.62	100 x 40 x 15 x 2.00	61.84
4	ISJB150 @7.1 kg/m	21.74	100 x 40 x 2.00	26.08	100 x 40 x 10 x 1.60	30.25
			100 x 50 x 2.00	50.72	100 x 40 x 15 x 2.00	45.45
			100 x 60 x 2.00	43.98	100 x 50 x 15 x 2.00	66.56
	ISLB75@ 6.1 kg/m	23.31	100 x 40 x 2.00	26.08	100 x 40 x 10 x 1.60	30.25
			100 x 50 x 2.00	50.72	100 x 40 x 15 x 2.00	45.45
	ISMB100@ 11.5 kg/m	87.62	100 x 50 x 4.00	100.51	100 x 40 x 25 x 3.15	90.54
			100 x 60 x 3.15	113.47	100 x 50 x 20 x 3.15	116.06
	ISWB150@ 17 kg/m	187.98	-	-	100 x 60 x 25 x 4.00	188.00
					120 x 60 x 25 x 4.00	199.51

Table 2: *Load Carrying Capacities of HRS and Alternate CFS (One End of the Column Fixed and Other end Hinged).*

Unsupported length (m)	HRS	Load (kN)	Alternate Unstiffened CFS		Alternate Stiffened CFS	
			CFS (h x b x t)	Load (kN)	CFS (h X b X c X t)	Load (kN)
3	ISJB150@7.1 kg/m	25.25	100 x 40 x 2.00	30.60	100 x 40 x 10 x 1.60	33.71
			100 x 50 x 2.00	57.11	100 x 40 x 15 x 2.00	50.99
			100 x 60 x 2.00	45.10	100 x 50 x 15 x 2.00	70.43
	ISLB75@ 6.1 kg/m	27.02	100 x 40 x 2.00	30.60	100 x 40 x 10 x 1.60	33.71
			100 x 50 x 2.00	57.11	100 x 40 x 15 x 2.00	50.99
	ISMB100@ 11.5 kg/m	100.35	100 x 50 x 4.00	112.16	100 x 50 x 20 x 3.15	123.33
			100 x 60 x 3.15	120.26	-	-
4	ISJB150@7.1 kg/m	14.68	100 x 40 x 2.00	17.21	100 x 40 x 10 x 1.60	20.29
			100 x 50 x 2.00	33.70	100 x 40 x 15 x 2.00	30.28
			100 x 60 x 2.00	40.10	100 x 50 x 15 x 2.00	53.08
	ISLB75@ 6.1 kg/m	15.81	100 x 40 x 2.00	17.21	100 x 40 x 10 x 1.60	20.29
			100 x 50 x 2.00	33.70	100 x 40 x 15 x 2.00	30.28
	ISMB100@ 11.5 kg/m	60.72	100 x 50 x 4.00	67.35	100 x 40 x 25 x 3.15	61.25
			100 x 60 x 3.15	89.83	100 x 50 x 20 x 3.15	91.10
			-	-	100 x 60 x 15 x 2.00	72.66
	ISWB150@ 17 kg/m	133.83	100 x 60 x 5.00	141.77	100 x 60 x 25 x 4.00	165.86
			-	-	120 x 60 x 25 x 4.00	173.46

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