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Research paper

Flexural Behavior of Rolled Steel I Beam with Different Stiffener Position

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Abstract

Economy, ease and speed of construction are the main factors for using steel as a building material. In this paper conventional hot rolled steel I-beam sections are considered as the main flexural member of industrial buildings. The main goal is to increase the load carrying capacity of the beam with inverted w shape stiffener condition at centre. The initiative was to identify the maximum load behaviour and deflection of steel beams with stiffener in the web. The performance of such beams has been considered only for vertical loads. Hot rolled steel beam of ISMB 100 with stiffener were tested to failure experimentally. The beams were simply supported at the ends and subjected to a 2 equal concentrated load applied at one third of span from both ends. The deflection at centre of beam and various failure patterns are studied. All the beams were analyzed by the finite element method by using general finite element analysis software ANSYS and the results were compared with those obtained experimentally. The finite element results for deformation and ultimate strength shows good agreement with the corresponding values observed in the experiments. At last, a comparative study was carried out using finite element method to examine that which type of beam gives best performance during loading. The numerical results indicate that the use of hot rolled I section with stiffener is an economical and advantageous choice.

Keywords*: Horizontal and vertical stiffener, Rolled steel section, Inclined stiffener, Flexural strength, etc..*

1. Introduction

Laterally stable steel beams can fail only by (a) flexure (b) shear (c) bearing, assuming the local buckling of slender components does not occur. These three conditions are the criteria for limit state design of steel beams. Steel beams would also become unserviceable due to excessive deflection and it is classified as a limit state of serviceability.the factored design moment m at any section, in a beam due to external actions shall satisfy

$$M \leq md$$

Where md = design bending strength of the section

Members subjected to predominant bending shall have adequate design strength to resist concentrated force, shear force and bending moment imposed upon and their combinations Further, the members shall satisfy the deflection limitation presented as serviceability criteria. Member subjected to other forces in addition to bending or biaxial bending shall be designed.The effective span of a beam shall be taken as the distance between the centre to centre of supports, except where the point of application of the reaction is taken as eccentric at the support. It shall be permissible

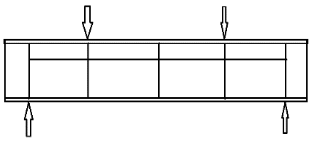
to take the effective span as the length between the assumed lines of the reactions.Lateral-torsional buckling is a limit-state of structural usefulness where the deformation of a beam changes from predominantly in-plane deflection to a combination of lateral deflection and twisting while the load capacity remains first constant, before dropping off due to large deflections. The analytical aspects of determining the lateral-torsional buckling strength are quite complex, and close form solutions exist only for the simplest cases.

2. Objective

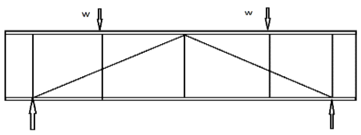
(i)The effect of intermediate and inclined lateral stiffeners on load carrying capacity of simply supported hot rolled steel I-beam under various load combinations.
(ii) Load carrying capacity of beam, maximum deflection, stress-strain behavior, curvature behavior, maximum stresses in beam and stiffener have to be analyzed.
(iii) A series of beams modeled using 3d-finite element software like ansys is used to analyze the behavior of beam.
(iv) A theoretical design results, analytic results along with experimental results have been compared and final results are arrived.

3. Stiffener Outline

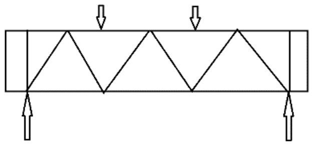
(I) Type 1 Stiffener



(Ii) Type 2 Stiffeners



(iii) Type 3 stiffeners



4. Theoretical Report

Designation	Values
code	Is800:2007
Section type	Girder beam
Loading type	Udl
Span	20m
Dead load	20KN/m
Live load	250KN/m
Self weight	18KN/m
Ultimate load	432KN/m
Maximum BM	21.6E9Nmm
Maximum SF	4320KN
Overall depth	2500mm
Depth of web	2400mm
Thickness of web	12mm
Thickness of flange	50mm
Breadth of flange	500mm
Outstand of flange	244mm
B/t_f	4.88
Classification	Plastic
Plastic section modulus	78.53E6 cu.mm
Designation	**Values**
Elastic section modulus	70.4E6 cu.mm
Moment of inertia(elastic)	88E9 mm^4
Plastic moment capacity	27.85E9 nmm
d/t_w	206
Spacing of stiffener	3000mm
C/d	1.25
K_v	11.6
Poisson ration	0.3
Young modulus	2E5 MPa
Elastic critical shear stress	52.42MPa
Non dimensional slenderness ratio	1.65
Shear stress(nominal)	53.01MPa
Critical force	1526KN
Margin of unsafety	2794KN
Designation	Values
Limited moment of resistance	4.09E9 Nmm
Moment in tension field	991.6E6 Nmm
Force in tension field	4.156E6 N
Additional force due to moment in tension field	330KN
Total design force	4650KN
Longitudinal shear	2100KN
Design load on EBS(end bearing stiffener)	4650KN
Breadth of stiffener	200mm
Thickness of stiffener	25mm
Area of stiffener	10000 sq mm
Web crippling	340KN
Load distribution	1V:2.5H
Total bearing strength	4960KN
Outstand condition	Within permissible limits
Buckling area of EBS	22880 sq mm
MOI of axis level	291.42E6 mm4
Radius of gyration	112.85mm
Slenderness ratio	14.8
Designation	**Values**
Buckling class	C
Direct compression	225.5 MPa
Compression load	5159 KN
Design load on its	3024KN
Minimum MOI	3.98E6 mm4
Stiffener force due to external load	2540KN
Direct compression	224.5MPa
Compression load	3538KN
Minimum MOI	20.76E6 mm4
Stiffener requirements	Satisfied limit conditions as per code
Connection (EBS and web)	Provide 40mm weld @150mm c/c
Connection (HS and web)	Provide 40mm weld @300mm c/c
Deflection	78.23mm

5. Experimental Report (1:20)

(I) Steel Beam without Stiffener

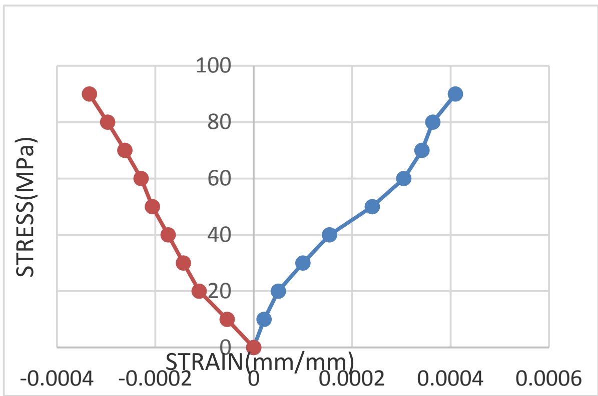


Fig 2 stress strain diagram of unstiffened beam

(Ii) Stiffener Beam 1

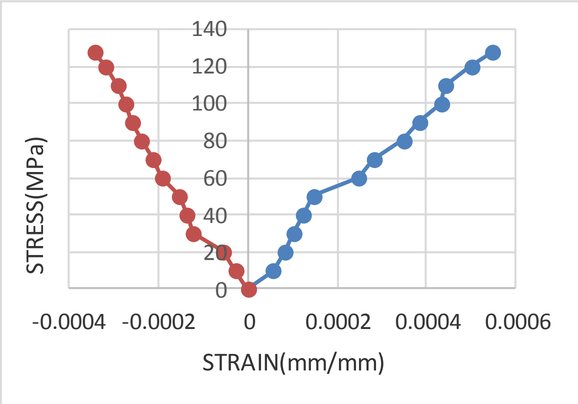


Fig 3 stress strain diagram for stiffened beam 1

(Iii) Stiffened Beam 2

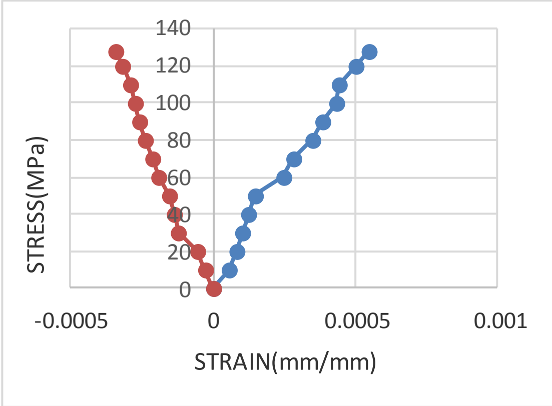
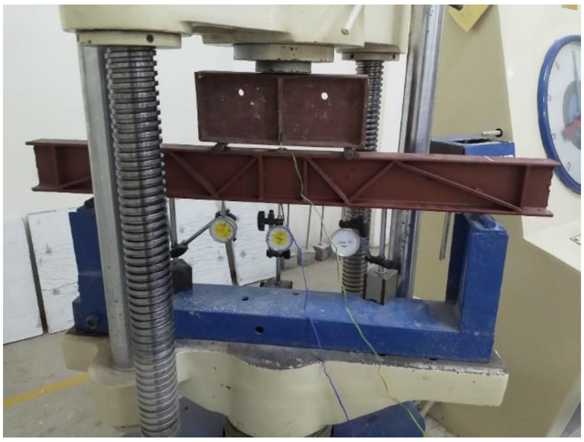


Fig 4 stress strain diagram for stiffened beam 2

(Iv)Stiffener Beam 3



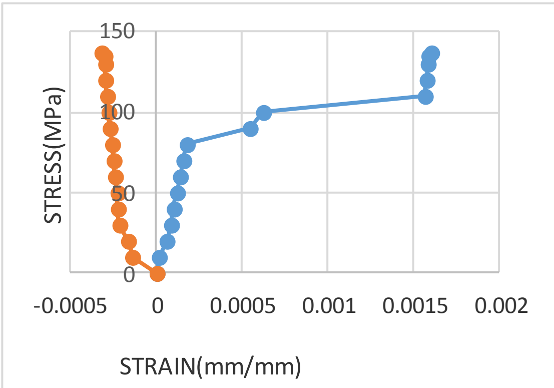
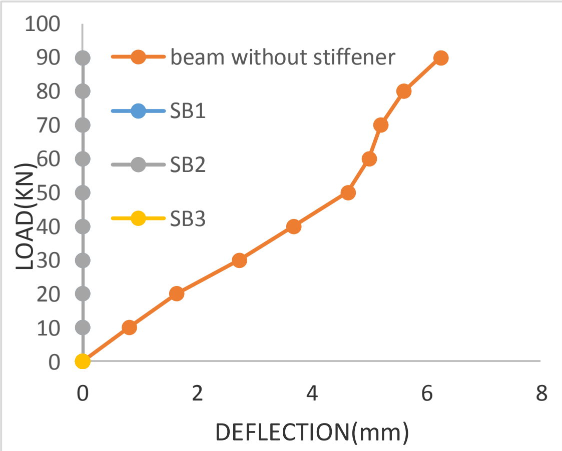


Fig 5 stress strain diagram for stiffened beam 3

(V) Deflection Comparison



6. Analytical Report

(i) Unstiffened Beam (Using STADDPRO)

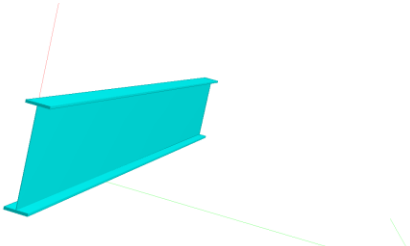
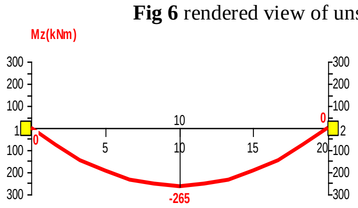


Fig 6 rendered view of unstiffened beam



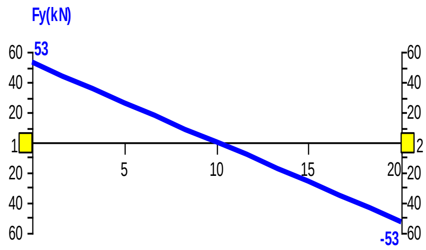
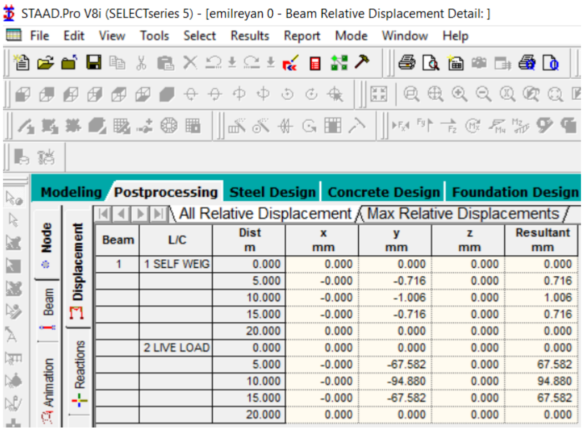


Fig 6: BM and SF diagram of unstiffened beam



Beam	L/C	Dist m	x mm	y mm	z mm	Resultant mm
1	1 SELF WEIG	0.000	0.000	0.000	0.000	0.000
		5.000	-0.000	-0.716	0.000	0.716
		10.000	-0.000	-1.006	0.000	1.006
		15.000	-0.000	-0.716	0.000	0.716
		20.000	0.000	0.000	0.000	0.000
	2 LIVE LOAD	0.000	0.000	0.000	0.000	0.000
		5.000	-0.000	-67.582	0.000	67.582
		10.000	-0.000	-94.880	0.000	94.880
		15.000	-0.000	-67.582	0.000	67.582
		20.000	0.000	0.000	0.000	0.000

(Ii) Stiffened Beams (ANSYS)

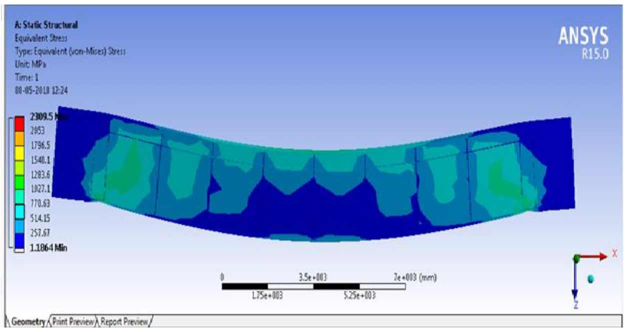


Fig 7 stress variation in stiffened beam

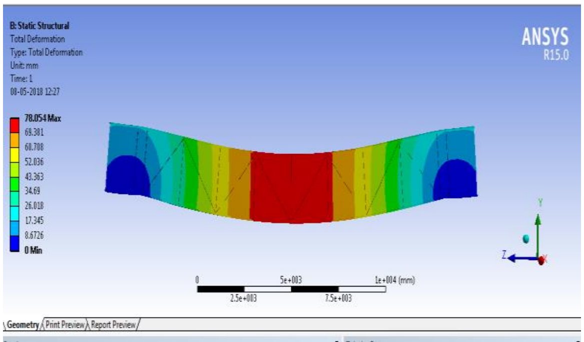


Fig 8 deflection in stiffened beam

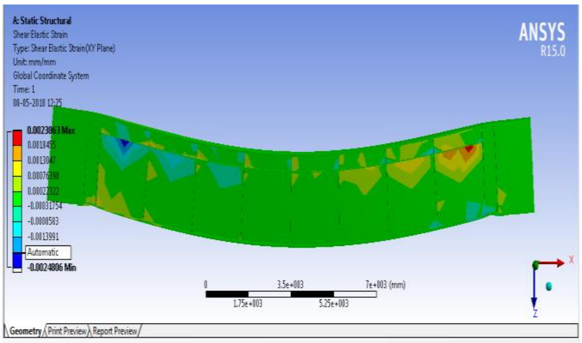


Fig 9 strain variation in stiffened beam

7. Result and Discussion

(i) Load carrying capacity of beam

- (a) Without stiffener =90 KN
- (b) Type 1 stiffener =102KN
- (c) Type 2 stiffener =128KN
- (d) Type 3 stiffener =137KN

(ii) Comparative results

Stiffener position	AD (mm)	AS	ED (mm)	ES
Without stiffener	94.88	0.00186	125	0.00041
Type 1 stiffener	91.66	0.00191	85.66	0.00085
Type 2 stiffener	85.26	0.00193	81.23	0.0012
Type 3 stiffener	78.66	0.00203	76.25	0.0019

Note:
Ad=analytic deflection
As=analytic strain
Ed=experimental deflection(1:20)
Es=experimental strain(1:20)
(iii) Estimation of material cost(as per field application)

(a) Beam with no stiffener

Volume of beam =1.576 cubic metre
Unit weight of steel =7850kg/cub m
Weight of beam = 12371.6 kg
Cost of steel per kg =rs.60
Total cost = 7.42 lakhs

(b) Beam with type 1 stiffener

Volume of beam =1.824 cubic metre
Unit weight of steel =7850 kg/cub m
Weight of beam =14318.4 kg
Cost of steel per kg =rs.60
Total cost =8.6 lakh

(c) Beam with type 2 stiffener

Volume of beam =1.856 cubic metre
Unit weight of steel =7850 kg/cub m
Weight of beam =14569.6 kg
Cost of steel per kg =rs.60
Total cost =8.74 lakh

(d) Beam with type 3 stiffener

Volume of beam =1.923cubic metre
Unit weight of steel =7850kg/ cub m
Weight of beam =15095.5 kg
Cost of steel per kg =rs.60
Total cost =9.5 lakh

8. Conclusion

(i) The load carrying behaviour of type 3 stiffener beam is 20% higher than type 1 stiffener, 10% higher than type 2 stiffener and 41% higher than beam with no stiffener.
(ii) The deflection behaviour of type 3 stiffener beam is5% higher than type 2 stiffener and 10% higher than type 1 stiffener and 15% higher than beam with no stiffener.
(iii) For higher strength purpose, type 3 stiffener beam is preferable but for both economical and strength purpose , type 2 stiffener beam is preferable.
(iv) The above results should be completely compared and concluded theoretically, analytically and experimentally (1:20).

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