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Simulation Analysis in Lateral Torsional Buckling of Channel Section by Using Ansys Software

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ABSTRACT

Design rules for eccentrically loaded beams with open channel cross-sections are not available in Indian code IS 800-2000 general construction in steel-code of practice (third revision). In this study Indian standard medium weight parallel flange ISMCP 175, ISMCP 200, ISMCP 3000 channel beams are used; different span length to section height ratio of the beams is taken. The type of loading and the uniformly distributed load application are limited through the web of the channels. General solutions like Elastic critical moment, Slenderness, Reduction factors ? and the Ultimate loads are determined by using formula given in ANNEX E (CL.8.2.2.1,IS 800:2007) for mono symmetric beams and compared with NEW DESIGN RULE (snijder) and with Finite Element (FE) simulations on the basis of a parameteric study using ANSYS software 14.0. It is was noticed that mono symmetric formula in code is giving elastic critical moment results upto 0.3% difference with ANSYS result for slender beams but showing larger difference for stocky beams. As the size of beam is increasing with constant cross section it is resulting in reduction in design capacity. The design curve for channel beam proposed by snijder seems to be a good choice , taking torsional effect into account, but it dosent claim to be correct for beams with a ratio L/h<15. The results obtained from the IS code formula is matching with ANSYS results for beams having length to depth ratio between range 20 to 40.

KEYWORDS: *Channel Beam, Finite Element Modelling, Symmetric Beam, Lateral Torsional Buckling, Elastic Critical Moment, Slenderness Factor, Reduction Facto*

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INTRODUCTION

Rolled Channel steel beams are regularly used as Purlins to support roofs in truss members, Staging to support bridge decks, etc., As steel beams tend to be slender, lateral displacement and twisting of a member occurs when load is applied on it results to buckling, this phenomena is known as lateral torsional buckling.This failure is usually visible when a load is carried out to an unconstrained rolled steel channel beam in which two flanges performing differently, where upper flange is in compression and the bottom flange is in tension. In this flange under compression first tries to move laterally and then twist causes buckling in compression flange of simply supported beam.

The twist happens in a case for channel sections, when the shear centre does not coincide with the vertical axis of the center of gravity of channel beam. The carried out load will unavoidably cause a torsional moment in the beam, which makes it tough to find elastic critical moment Mcr.

Indian standard code IS 800-2000 General Construction in steel-code of practice (third revision) doesn't provides any formula to calculate theoretical elastic critical moment for channel beams. The formula is given for symmetrical sections which is symmetrical about both the axis and for mono symmetric sections which is symmetrical about only minor axis.

But C channel is a mono-symmetrical section which is symmetric about minor axis. ANSYS Workbench as a modern approach to finite element method is design software is used for advance engineering simulation purpose. The process consists of three stages Preprocessing, Solution and post processing. The disadvantage of this approach is that it is able to be very time eating and consequently now not constantly cost effective

ANSYS, Inc. is a company in the USA that develops computer-aided engineering software (CAE) which gives the user the ability to analyse and simulate different situations concerning electronics, fluid dynamics and structural analysis. The software is centered on an instance called Workbench where the simulation is set up in a treelike manner, where different components are dropped to the canvas and interconnected to other components. In Engineering Data, which is present in each of the analysis components, the material is specified and can also be viewed in Workbench. The below figure shows that static structural is followed by Eigen value buckling for load factor analysis.

ELASTIC CRITICAL MOMENT IN ANSYS 14.0

ANSYS can evaluate the critical load in two ways; by using a linear buckling analysis (Eigen buckling) or by a non-linear buckling analysis. While doing a FEM analysis for a structure, generally an Eigenvalue buckling analysis is performed.

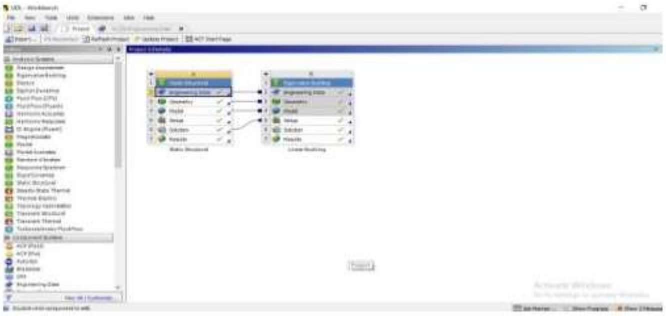


Figure 1.1 shows that static structural is followed by Eigen value buckling for load factor analysis.

EIGENVALUE BUCKLING ANALYSIS

It predicts the theoretical buckling strength for an ideal linear elastic structure. This analysis is corresponds to the textbook approach to elastic buckling analysis: for instance, an eigenvalue buckling analysis of a column will match the classical Euler solution.

PROCEDURE FOR SIMULATION IN ANSYS

In ANSYS, modeling and analysis include three steps as follows:

1. Preprocessing
2. Solution
3. Post processing

➢ **PREPROCESSING**

It is the first step to analyze the physical problem. In this model first the engineering properties were given as shown in figure 1.2 then we go for making geometry

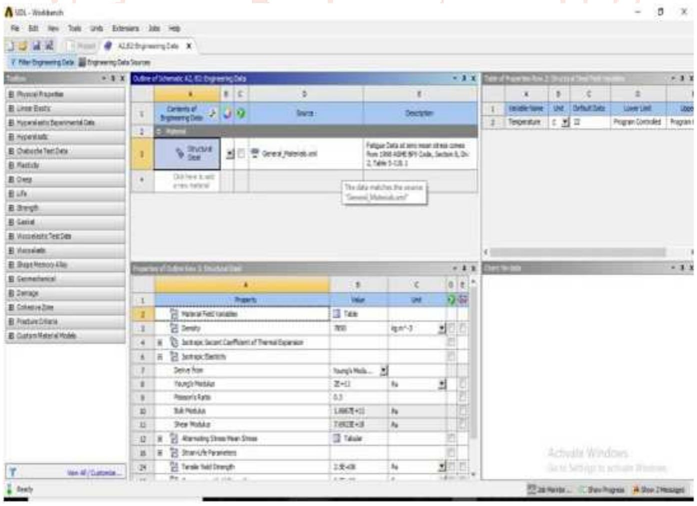


Figure1.2 Engineering library in ANSYS

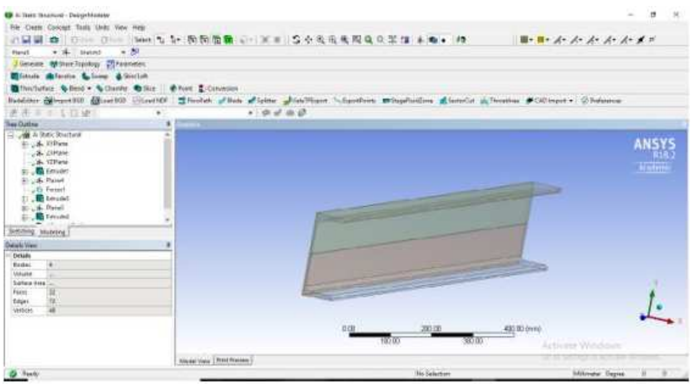


Figure 2.3 Sketching of channel beam model

➢ **SOLUTION:**

In this boundary conditions, meshing, and loading are been applied in static structural multiple system to the model.

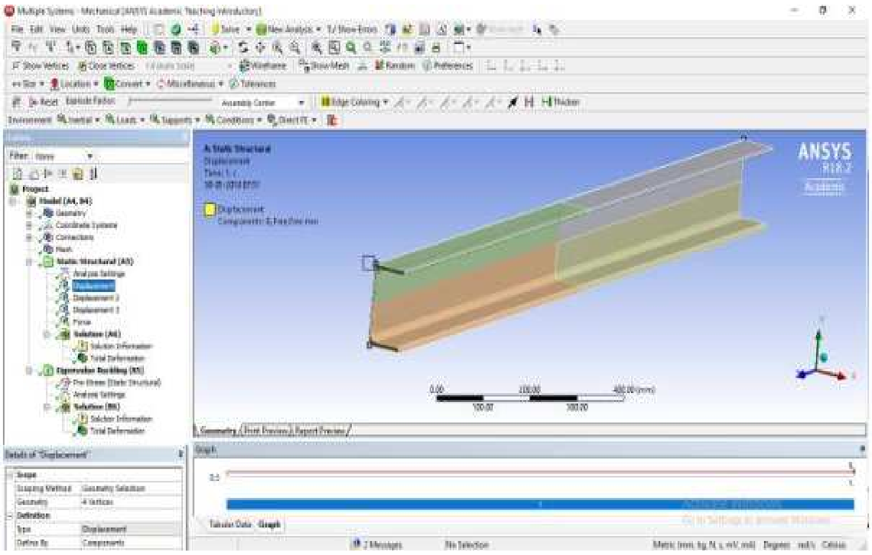


Figure 1.4 shows model with boundary conditions and loading

➢ **POSTPROCESSING:**

The load factor is obtained in Eigen value buckling by linking it with static structural.

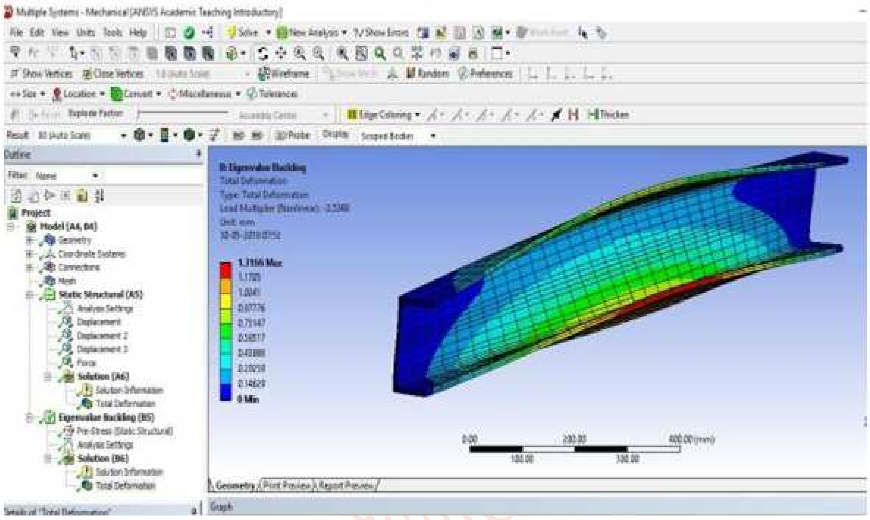


Figure 1.5 Eigen value buckling analysis

PROBLRM IDENTIFICATION & OBJECTIVES

The purpose of the thesis is to analyze the authentication of the theoretical elastic critical moment, acquired from IS code via evaluating it with Finite element Modelling technique. And also to get further knowledge regarding behavior of lateral buckling of steel channel beams concerning the effects of slenderness, factor of load application and cross section size on deformations, stress patterns and load carrying capability.

METHODOLOGY

Initially, a literature study on the theory behind various instability phenomena for steel beams was made, including study of formula given in Indian Standard codes IS: 800:2007, ANNEX E and Clause 8.2.2 treats lateral-torsional buckling and establishes the elastic critical moment Mcr.

A parametric observation was conducted in which channel beams with specific dimensions, lengths and load conditions were modelled and analyzed in computer software i.e. ANSYS workbench 14.0.

Three cross sections were chosen ISMCP175, ISMCP200 and ISMCP300 of five different lengths i.e., 1600mm, 2200mm, 3000mm, 4000mm, and 5000mm. A uniformly distributed load of 100 kn/m is applied on each beam at the top, the middle and the bottom of the web respectively.

Theoretical elastic critical moment was calculated from formula for monosymmetric section given in code IS: 800:2007, ANNEX E and Clause 8.2.2 and then validated using ANSYS workbench 14.0 by creating models, giving support conditions and loading.

RESULT & ANALYSIS

THEORETICAL ELASTIC CRITICAL MOMENT CALCULATION:

The example calculation is made for 1600mm long beam with a uniformly distributed load is acting vertically at the top of the web in the centre of the beam. The calculation of the elastic critical bending moment is based on rules for "Elastic Lateral Torsional Buckling "in ANNEX E {IS 800:2007 CLAUSE 8.2.2.1}

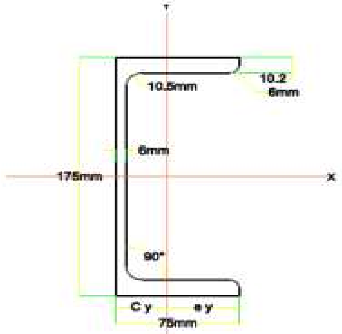


Figure 5.1 ISMCP 175

GEOMETRY:

Chosen profile		= ISMC 175
Height	H =	175mm
Thickness of web	b_w =	6mm
Thickenss of flange	t_f =	10.2mm
Flange width in excel	b_{excel}=	75mm
Height in excel	h_{excel}=	154.6mm
Beam length	L =	1600mm

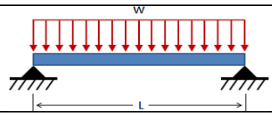
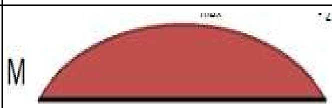
MATERIAL: {IS 800:2007 clause 2.2.4.1}

- Youngs modulus — E=2 x 10^5Mpa
- Poissons ratio — μ=0.3
- Shear modulus — $G = \frac{E}{2*(1+\mu)}$ =76923.077mm^2
- Partial safety factor — F=1.10
- Yield strength — Fy = 350 Mpa {IS 2062, bw<20}

GEOMETRIC PROPERTIES:

- Area cross section — A= 2490 mm^2
- Vertical distance from bottom of the beam to centre of gravity — = 87.5mm
- Horizontal distance from web to cg — = 22.4mm
- Moment of inertia about the major axis — IXX = 12400000 mm^4
- Moment of inertia about the minor axis — IYY = 1380000mm^4
- Torsion moment of inertia — $IT = \frac{2*b*tf^3+2*hexcel*bw^3}{3} = 64191.6mm^4$
- Warping moment of inertia — $I_w = \frac{t_f b^3 h^2}{12}\left(\frac{3bt_f+2h\,t_f}{6bt_f+ht_w}\right) =$ 6677019945□□4
- Vertical distance from the shear centre to bottom of beam — = 87.5mm
- Horizontal distance from shear centre to the centre of the web — = 54.97mm
- Free to bend laterally at end supports — k = 1
- Free to warp at end supports — K w = 1
- Point of load application relative to the shear centre — Yg = 87.5mm
- Degree of mono symmetry — Yj = 0
- Effective length — L_{LT} =X* L= 1600mm {X=1; IS 800-2007, table 15}

TABLE 5.1Is referred from IS 800-2007 from Table no 42 showing constants for loading and support conditions.

Loading and support conditions	Bending moment diagram	Value of K	Constants		
			C_1	C_2	C_3
		1.0 0.5	1.132 0.972	0.459 0.304	0.525 0.980

So for point load with simly supported condition

- C_1 =1.132
- C_2=0.459
- C_3=0.525

THEORETICAL ELASTIC CRITICAL MOMENT CALCULATION USING IS 800:2007 CLAUSE 8.2.2.1

$$M_{cr} = c_1 \frac{\pi^2 EI_{YY}}{L^2_{LT}} \{[(\frac{K}{K_W})^2 (\frac{I_W}{I_{YY}}) + \frac{(L_{LT})^2}{\pi^2 EI_{YY}} + (C_2 y_g - C_3 Y_j)]^{0.5} - (C_2 Y_g - C_3 Y_j)\}$$

ELASTIC CRITICAL MOMENT:

M_{cr} = 77523989N-mm

= 77.52 KN-m

REDUCTION FACTOR for UDL, INDIAN CODE IS 800-2007

- Ultimate design yeild strength $F_d = \frac{F_y}{F}$ = 318.182 Mpa
- Plastic section modulus Zp = 2*(b ∗ tf ∗ x + bw ∗ y ∗ y/2) = 161923.74mm²

$x = \frac{h}{2} - \frac{t_f}{2}$, $y = \frac{h}{2} - t_f$

- Plastic moment resista MPL = $Zp * Fd$ = 51521190.0 N-mm
- Beam slenderness $\lambda_{LT} = \sqrt{\frac{M_{PL}}{M_{CR}}}$ = 0.81
- Imperfection factor buckling curve D α_{LT}=0.76
- Intermediate factor, Φ_{LT} = $0.5*[1+\alpha_{LT}(\lambda_{LT} - 0.2) + \lambda^2_{LT}]$ =1.066
- Reduction factor for lateral torsional buckling

$$\chi_{LT} = \frac{1}{\{\Phi_{LT} + [\Phi^2_{LT} - \lambda^2_{LT}]^{0.5}\}} = 0.57$$

REDUCTION FACTOR for UDL, New design rule (SNIJDER)

- Ultimate design yeild strength $Fd = \frac{F_y}{F}$ = 318.182 Mpa
- Plastic section modulus Zp = 2*(b ∗ tf ∗ x + bw ∗ y ∗ y/2) = 161923.74mm²

$x = \frac{H}{2} - \frac{t_f}{2}$, $y = \frac{H}{2} - t_f$

- Plastic moment resistance MPL = $Zp * Fd$ = 51521190.0 N-mm
- Beam slenderness $\lambda_{LT} = \sqrt{\frac{M_{PL}}{M_{CR}}}$ = 0.82
- Modified relative slenderness $\lambda_{MT} = \lambda_{LT} + \lambda_T$
- TORSION Term **λ_T** depends on the Relative Slenderness

$\lambda_T = 1 - \lambda_{LT}$ IF $0.5 \leq \lambda_{LT} < 0.8$

$\lambda_T = 0.43 - 0.29\lambda_{LT}$ IF $0.8 \leq \lambda_{LT} < 1.5$

$\lambda_T = 0$ IF $\lambda_{LT} \geq 1.5$

$\lambda_T = 1 - 0.82 = 0.1922$

$\lambda_{MT} = \lambda_{LT} + \lambda_T = 1.012$

- Imperfection factor buckling curve " a " $\alpha_{LT} = 0.21$
- Intermediate factor, $\Phi_{MT} = 0.5 * [1 + \alpha_L(\lambda_{MT} - 0.2) + \lambda^2_{MT}] = 1.094$

- Reduction factor for lateral torsional buckling (SNIJDER)

$$= \frac{1}{\{\Phi_{MT} + [\Phi^2_{MT} - \lambda^2_{MT}]^{0.5}\}} = 0.659$$

DESIGN BENDING STRENGTH OF LATERALLY UNSUPPORTED BEAMS M_d

{IS800-2007,clause 8.2.2}

$$M_d = \beta_b Z_P F_{bd}$$

Where,

β_b**= 1** for Plastic and compact Section

$= \frac{Z_E}{Z_P}$ for semi compact section

= plastic section modulus

F_{bd} **=** design bending compressive stress

$$F_{bd} = LT \frac{F_y}{f}$$

= Reduction factor for lateral torsional buckling = 0.57

= Reduction factor for lateral torsional buckling (snijder) = 0.659

F_y= Yield strength = 350 Mpa {IS 2062,b_w<20}

f = Partial safety factor = 1.10 {IS800-2007,TABLE 5} =1

{Section is a plastic section h/ b_w < 9.4 e here e=$(250/f_y)^{0.5}$ IS 800-2007 Table 2}

Z_P= plastic section modulus = 161923.74mm^3

DESIGN BENDING STRENGTH {IS800-2007,clause 8.2.2}

$$M_d = \beta_b Z_P F_{bd} = 29.368 \text{ Kn-m}$$

DESIGN BENDING STRENGTH {SNIJDER}

$$M_d = \beta_b Z_P F_{bd} = 33.953 \text{ Kn-m}$$

ANALYTICAL CALCULATION OF ELASTIC CRITICAL MOMENT USING ANSYS 14.0 SOFTWARE

5.2. UNIFORMLY DISTRIBUTED LOAD ON TOP WEB OF ISMCP 175

- ISMCP 175 channel consists of 175mm channel depth and 75 mm flange width with 10.2mm and 6mm flange and web thickness.
- In this first 3D solid body of ISMC 175 channel beam is created in ANSYS 14.0Workbench software and fork supported boundary condition were given at ends.
- ULD of 100kn/m is applied on top of the beam for different length of 1600mm, 2200mm, 3000mm, 4000mm and 5000mm.
- Mesh has been provided with element size of 50mm in beam.
- First the Static analysis is done then Eigen buckling values i.e., load multiple factors are obtained in workbench by applying point load of **100 KN/m= 100N/mm.**

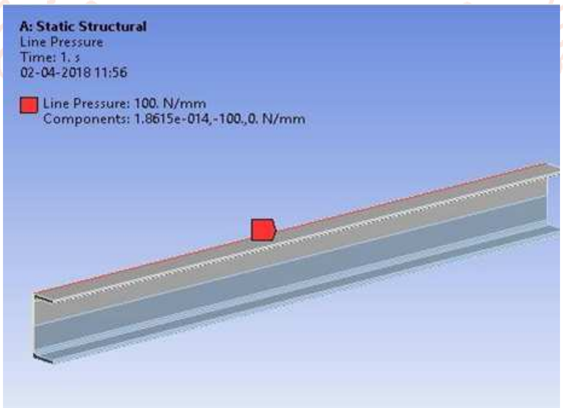


Figure 5.2 Uniformly distributed load on top web of ISMCP 175

A. Load multipier for beam of different lengths ISMCP 175 beams got in ANSYS 14.0 by linear buckling analysis.

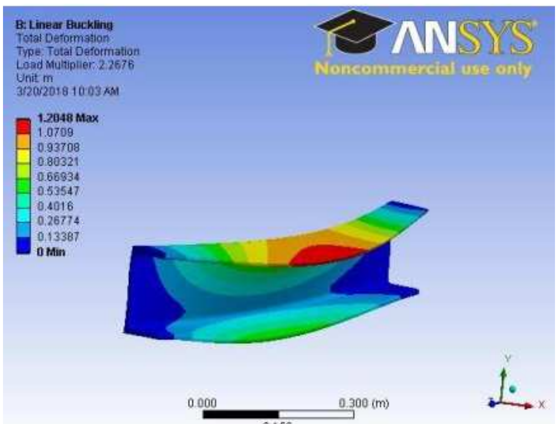


Figure 5.3 Load factor for beam length of 1600 mm

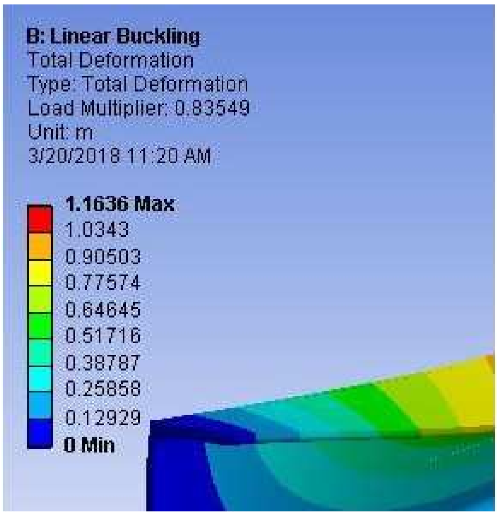


Fig 5.4 Load factor for beam length of 2200 mm

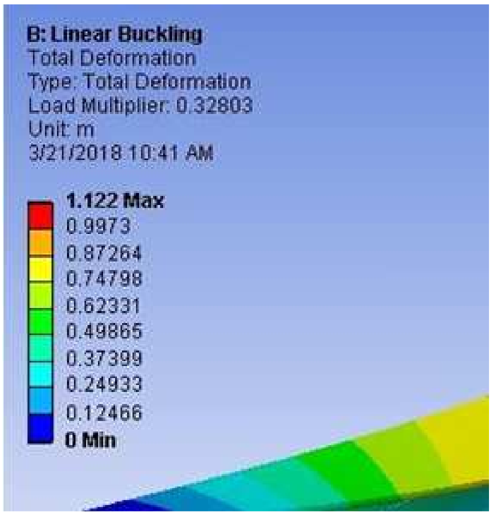


Fig 5.5 Load factor for beam length of 3000 mm

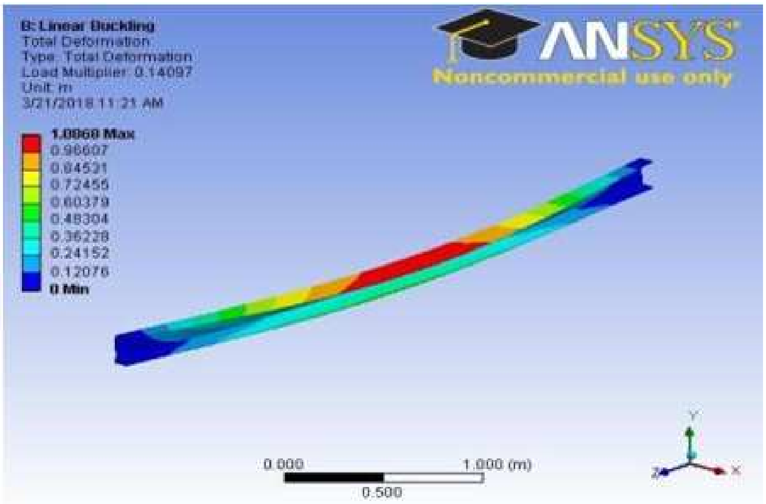


Figure 5.6 Load factor for beam length of 4000 mm

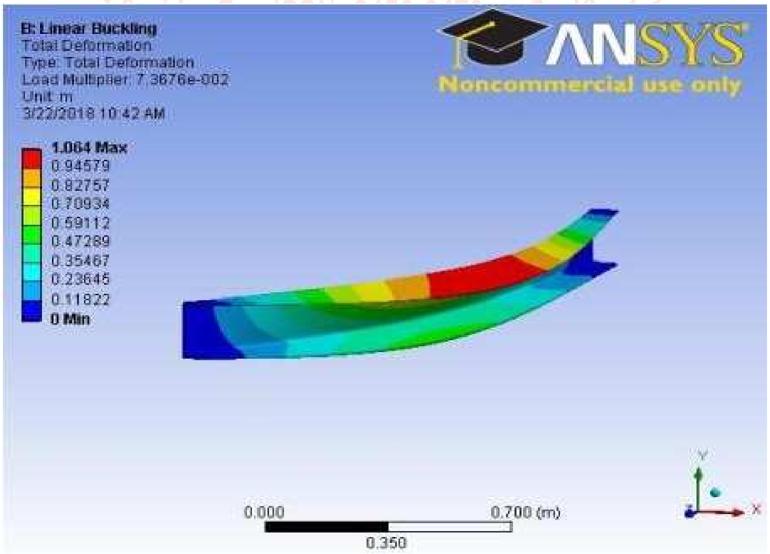


Figure 5.7 Load factor for beam length of 5000 mm

Table 7.2 showing buckling load factors (x) for different channel lengths got in ANSYS for ISMCP 175 on top web.

ISMCP 175 LENGTH mm	BUCKLING LOAD FACTOR (x)
1600	*2.267*
2200	*0.835*
3000	*0.328*
4000	*0.14*
5000	*0.0736*

Graph 5.1 showing buckling load factors (x) for different channel lengths got in ANSYS for ISMCP 175 on top web.

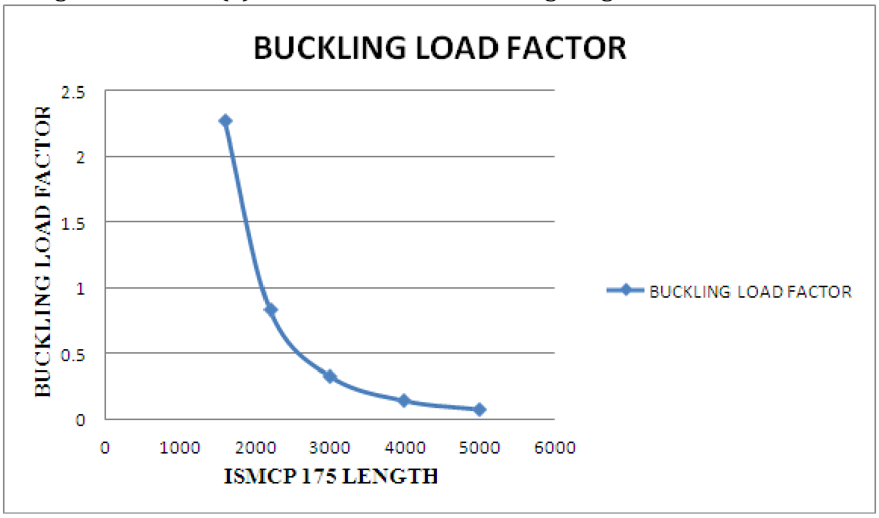
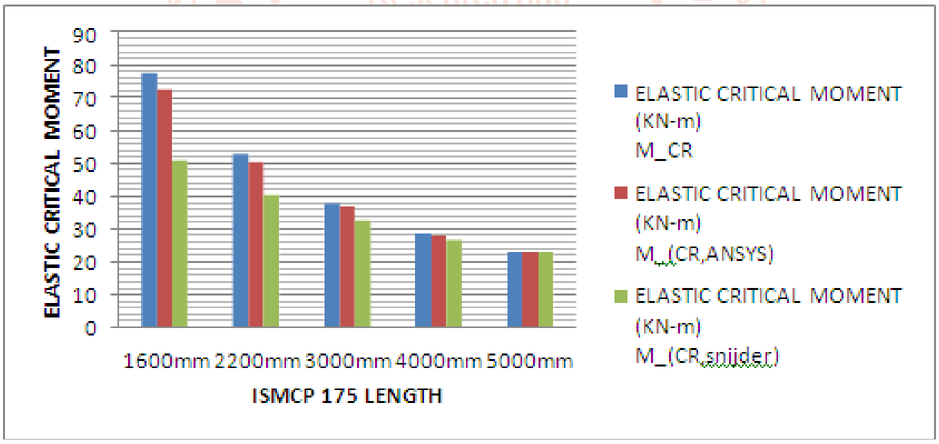


Table 5.3 showing Variation in elastic critical moment calculated theoretically and compared with the values calculated using ANSYS w.r.t different length of beam for ISMCP 175 ontop web.

ISMCP 175 LENGTH	ELASTIC CRITICAL MOMENT (KN-m) M_{CR}	ELASTIC CRITICAL MOMENT (KN-m) $M_{CR,ANSYS}$	ELASTIC CRITICAL MOMENT (KN-m) $M_{CR,snijder}$	%M cr between theoretical and ANSYS
1600mm	77.52	72.544	51.009	7.564
2200mm	52.89	50.5175	40.348	4.72
3000mm	37.75	36.9	32.607	2.741
4000mm	28.46	28	26.897	1.926
5000mm	23.07	23	23.206	0.476

Graph 5.2 showing Variation in elastic critical moment calculated theoretically and compared with the values calculated using ANSYS w.r.t different length of beam for ISMCP 175 ontop web.



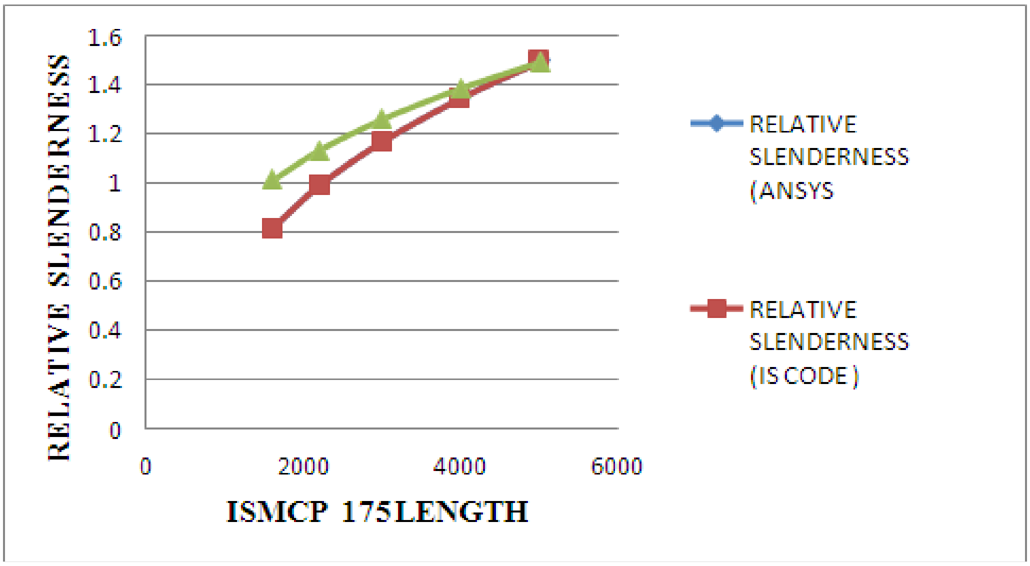
Note:

- $M_{CR,snijder} = \frac{M_{PL}}{\lambda^2}$
- Elastic critical moment (ANSYS)= $(buckling\ load\ factor) * bending\ moment = (x) * wl2$

Table 7.4 showing relative slenderness obtained for different lengths calculated theoretically, analytically using ANSYS and using New design rule (snijder) for ISMCP 175 on top web

ISMCP 175 LENGTH	RELATIVE SLENDERNESS (ANSYS) λ_{ANSYS}	RELATIVE SLENDERNESS (IS CODE) for ISMCP 175 λ_M	RELATIVE SLENDERNESS (NEW DESIGN RULE) λ_{MT}
1600mm	*0.843*	0.815	1.009
2200mm	*1.01*	0.99	1.133
3000mm	*1.182*	1.168	1.259
4000mm	*1.356*	1.345	1.385
5000mm	*1.497*	1.494	1.491

Graph 5.3 representing relative slenderness calculated using different approach with respect to length of beam for ISMCP 175 on top web.



NOTE:

- Modified relative slenderness $\lambda_{MT} = \lambda_{LT} + \lambda_T$
- TORSION Term λ_T depends on the Relative Slenderness

$\lambda_T = 1 - \lambda_{LT}$ IF $0.5 \leq \lambda_{LT} < 0.8$

$\lambda_T = 0.43 - 0.29\lambda_{LT}$ IF $0.8 \leq \lambda_{LT} < 1.5$

$\lambda_T = 0$ IF $\lambda_{LT} \geq 1.5$

Table 5.5 showing reduction factor calculated using is code and new design rule with respect to relative slenderness obtained theoretically and by new design rule (snijder) for ISMCP 175 on top web.

RELATIVE SLENDERNESS (IS CODE) λ_M	RELATIVE SLENDERNESS (NEW DESIGN RULE) λ_{MT}	REDUCTION FACTOR IS CODE χ LT	REDUCTION FACTOR (NEW DESIGN RULE) χ MT
0.815	1.009	0.573	0.659
0.99	1.133	0.474	0.574
1.168	1.259	0.391	0.495
1.345	1.385	0.324	0.426
1.494	1.491	0.278	0.377

Graph 5.4 showing variation between theoretically calculated relative slenderness and reduction factor for ISMCP 175 on top web

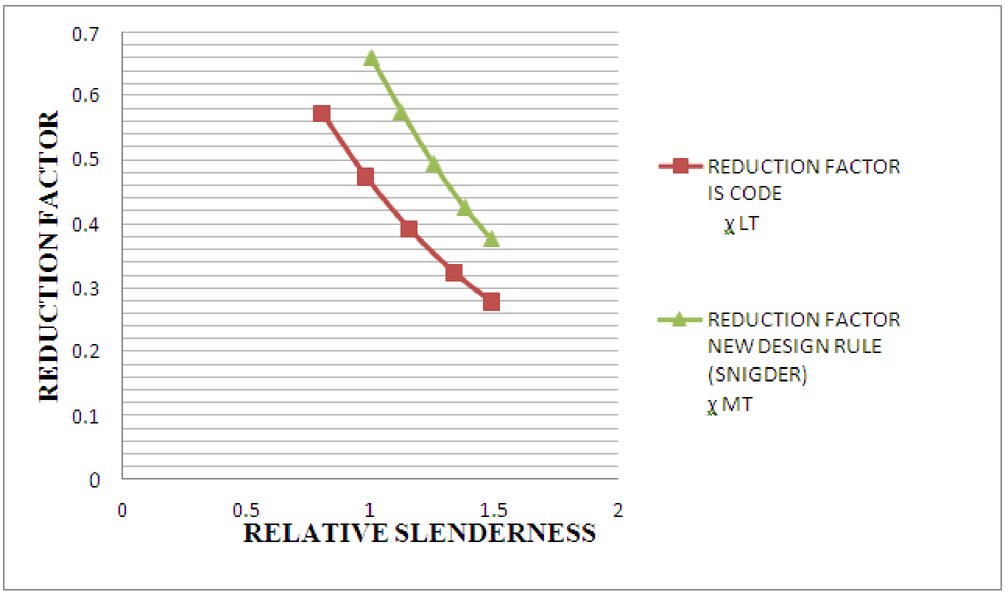


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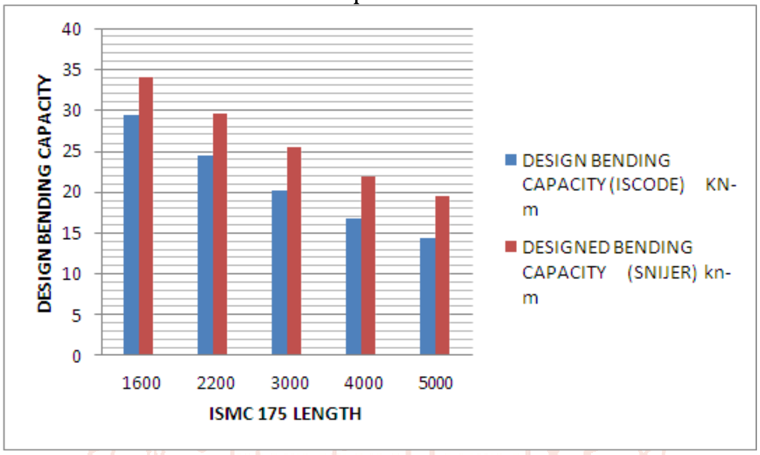
Table5.6 showing comparison between theoretically calculated design beam capacity using IS code and New design rule (snijder) w.r.t different beam lengths for ISMCP 175 on top web.

ISMCP 175 LENGTH	DESIGN BENDING CAPACITY (ISCODE)KN-m $M_{d,IS\ code}$	DESIGNED BENDING CAPACITY (SNIJER) kn-m $M_{d,snijder}$	% DIFFERENCE IN BENDING CAPACITY
1600	29.522	34.108	15.534
2200	24.422	29.677	21.517
3000	20.145	25.504	26.602
4000	16.693	21.949	31.486
5000	14.323	19.424	35.614

Graph 5.5 representing design beam capacity calculated w.r.t IS code and new design rule (Snijder) for ISMCP 175 on top web



Note: Design bending capacity $M_d = \beta_b Z_P{}^F bd = \beta_b Z_P * \chi_{LT} * F_y f$

5.3. UNIFORMLY DISTRIBUTED LOAD ON MID WEB OF ISMCP175

- ISMCP 175 channel consists of 175mm channel depth and 75 mm flange width with 10.2mm and 6mm flange and web thickness.
- In this first 3D solid body of ISMCP 175 channel beam is created in ANSYS 14.0Workbench software and fork supported boundary condition were given at ends.
- ULD of 100kn/m is applied on middle of the beam for different length of 1600mm, 2200mm, 3000mm, 4000mm and 5000mm.
- Mesh has been provided with element size of 50mm in beam.
- First the Static analysis is done then Eigen buckling values i.e., load multiple factors are obtained in workbech by applying point load of **100KN/m= 100N/mm**

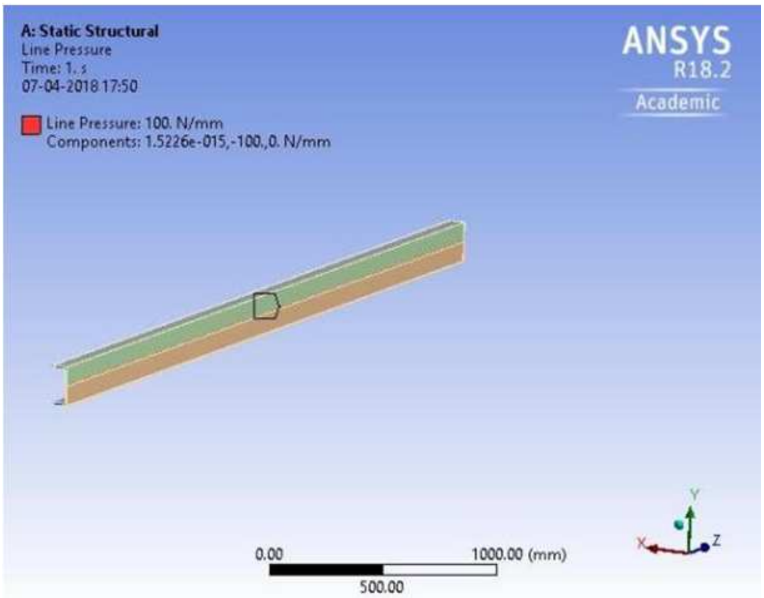
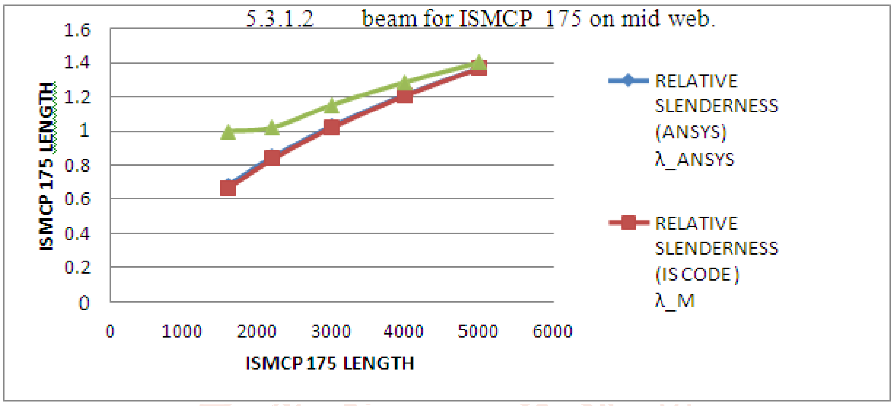


Figure 5.8 uniformly distributed load on middle web of ISMCP 175

Table 5.7 showing relative slenderness obtained for different lengths calculated theoretically, Analytically using ANSYS and using New design rule (snijder) for ISMCP 175 on mid web relative slenderness obtained for different lengths calculated theoretically, Analytically using ANSYS and using New design rule (snijder) for ISMCP 175 on mid web.

ISMCP 175 LENGTH	RELATIVE SLENDERNESS (ANSYS) λ_{ANSYS}	RELATIVE SLENDERNESS (IS CODE) λ_M	RELATIVE SLENDERNESS (NEW DESIGN RULE) λ_{MT}
1600mm	0.685	0.666	1
2200mm	0.848	0.835	1.023
3000mm	1.028	1.019	1.153
4000mm	1.212	1.207	1.287
5000mm	1.368	1.367	1.401

Graph 7.6 representing relative slenderness calculated using different approach with respect to length of beam for ISMCP 175 on mid web.



NOTE:
- Modified relative slenderness $\lambda_{MT} = \lambda_{LT} + \lambda_T$
- TORSION Term λ_T depends on the Relative Slenderness

$\lambda_T = 1 - \lambda_{LT}$ IF $0.5 \leq \lambda_{LT} < 0.8$

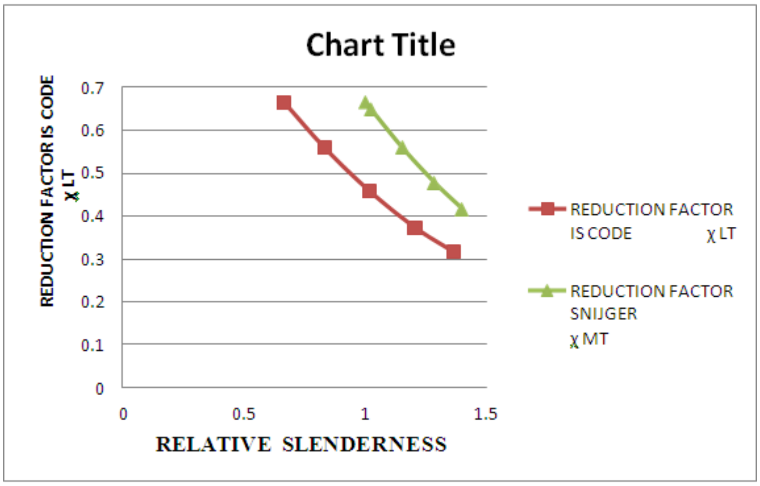
$\lambda_T = 0.43 - 0.29\lambda_{LT}$ IF $0.8 \leq \lambda_{LT} < 1.5\ \lambda$

$_T = 0$ IF $\lambda_{LT} \geq 1.5$

Table 5.8 showing reduction factor calculated using is code and new design rule with respect to relative slenderness obtained theoretically and by new design rule (snijder) for ISMCP 175 on mid web.

RELATIVE SLENDERNESS (IS CODE) λ_M	RELATIVE SLENDERNESS (NEW DESIGN RULE) λ_{MT}	REDUCTION FACTOR IS CODE χ LT	REDUCTION FACTOR (NEW DESIGN RULE) χ MT
0.666	1	0.665	0.666
0.835	1.023	0.558	0.650
1.019	1.153	0.458	0.560
1.207	1.287	0.373	0.478
1.367	1.401	0.316	0.417

Graph 5.7 showing variation between theoretically calculated relative slenderness and reduction factor for ISMCP 175 on mid web



5.3.2. UNIFORMLY DISTRIBUTED LOAD ON BOTTOM WEB OF ISMCP 175

- ISMCP 175 channel consists of 175mm channel depth and 75 mm flange width with 10.2mm and 6mm flange and web thickness.
- In this first 3D solid body of ISMCP 175 channel beam is created in ANSYS 14.0Workbench software and fork supported boundary condition were given at ends.
- ULD of 100kn/m is applied on bottom of the beam for different length of 1600mm, 2200mm, 3000mm, 4000mm and 5000mm.
- Mesh has been provided with element size of 50mm in beam.
- First the Static analysis is done then Eigen buckling values i.e., load multiple factors are obtained in workbech by applying point load of **100KN/m= 100N/mm**

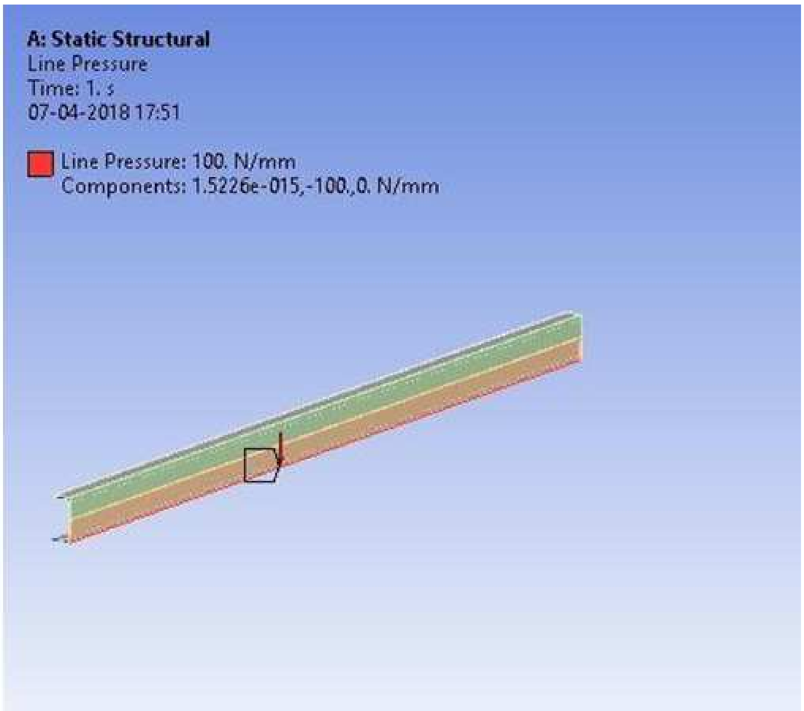
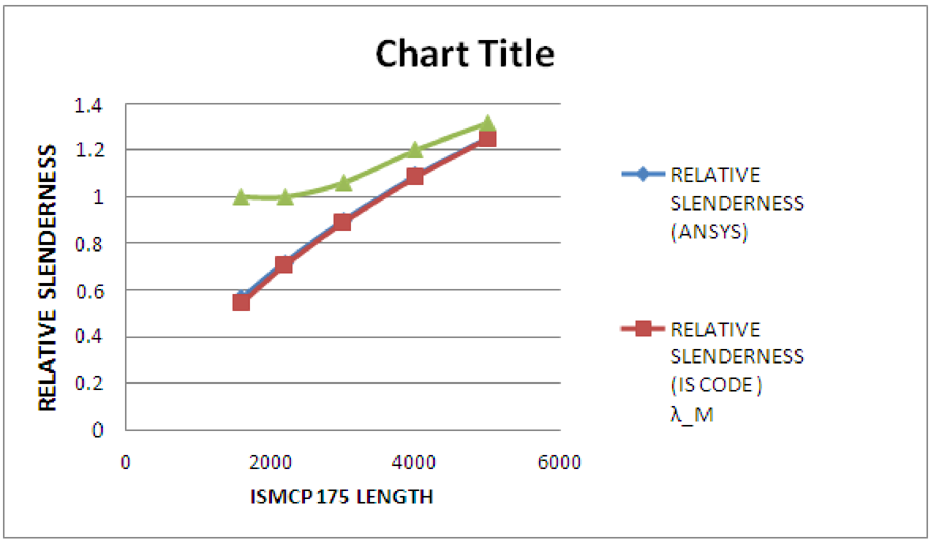


Figure 5.9 Uniformly distributed load on bottom web of ISMCP 200

Table 5.9 showing relative slenderness obtained for different lengths calculated theoretically, Analytically using ANSYS and using New design rule (snijder) for ISMCP 175 on bottom web

ISMCP 175 LENGTH	RELATIVE SLENDERNESS (ANSYS)λ_{ANSYS}	RELATIVE SLENDERNESS (IS CODE) λ_M	RELATIVE SLENDERNESS (NEW DESIGN RULE) λ_{MT}
1600mm	*0.566*	0.544	1
2200mm	*0.719*	0.705	1
3000mm	*0.897*	0.888	1.06
4000mm	*1.09*	1.083	1.199
5000mm	*1.253*	1.25	1.318

Graph 5.8 representing relative slenderness calculated using different approach with respect to length of beam. for ISMCP 175 on bottom web



NOTE:

- Modified relative slenderness $\lambda_{MT} = \lambda_{LT} + \lambda_T$
- TORSION Term λ_T depends on the Relative Slenderness

$\lambda_T = 1 - \lambda_{LT}$ IF $0.5 \leq \lambda_{LT} < 0.8$

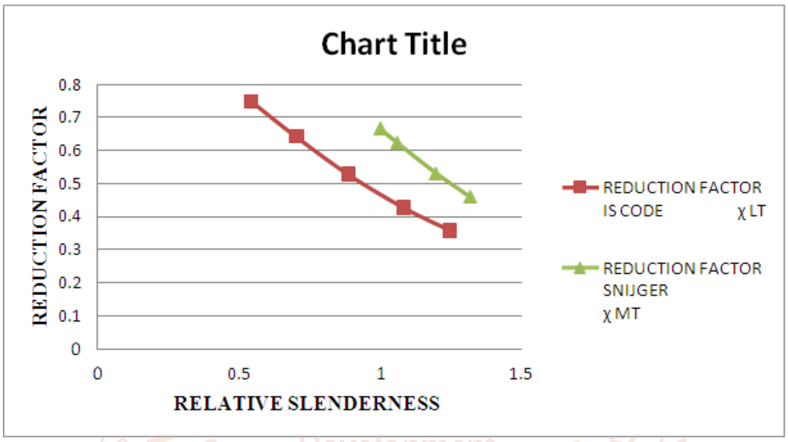
$\lambda_T = 0.43 - 0.29\lambda_{LT}$ IF $0.8 \leq \lambda_{LT} < 1.5$

$\lambda_T = 0$ IF $\lambda_{LT} \geq 1.5$

Table 5.10 showing reduction factor calculated using is code and new design rule with respect to relative slenderness obtained theoretically and by new design rule (snijder) for ISMCP 175 on bottom web.

RELATIVE SLENDERNESS (IS CODE) λ_M	RELATIVE SLENDERNESS (NEW DESIGN RULE) λ_{MT}	REDUCTION FACTOR IS CODE χ LT	REDUCTION FACTOR (NEW DESIGN RULE) χ MT
0.544	1	0.748	0.666
0.705	1	0.64	0.666
0.888	1.06	0.527	0.624
1.083	1.199	0.427	0.531
1.25	1.318	0.357	0.46

Graph 5.9 showing variation between theoretically calculated relative slenderness and reduction factor for ISMCP 175 on bottom web



5.3.3. UNIFORMLY DISTRIBUTED LOAD ON TOP WEB OF ISMCP 200

- ISMCP 200 channel consists of 200mm channel depth and 75 mm flange width with 11.4mm and 6mm flange and web thickness.
- In this first 3D solid body of ISMC 175 channel beam is created in ANSYS 14.0Workbench software and fork supported boundary condition were given at ends.
- ULD of 100kn/m is applied on top of the beam for different length of 1600mm, 2200mm, 3000mm, 4000mm and 5000mm.
- Mesh has been provided with element size of 50mm in beam.
- First the Static analysis is done then Eigen buckling values i.e., load multiple factors are obtained in workbench by applying point load of **100 KN/m= 100N/mm.**

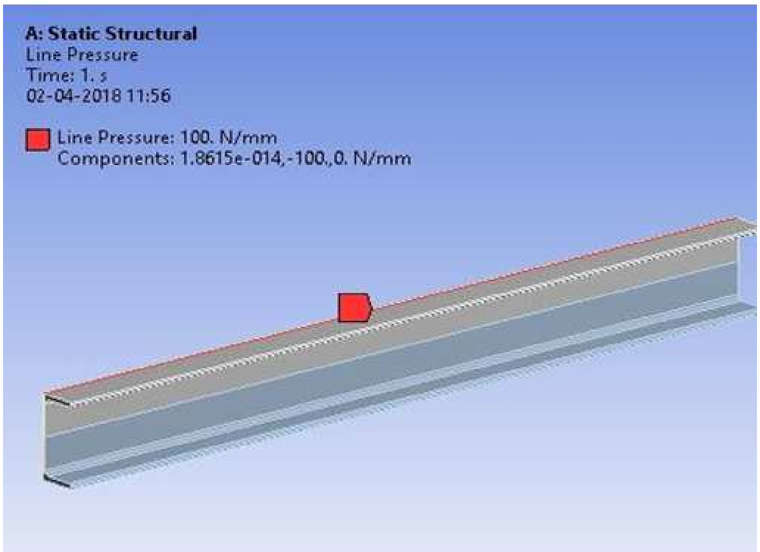
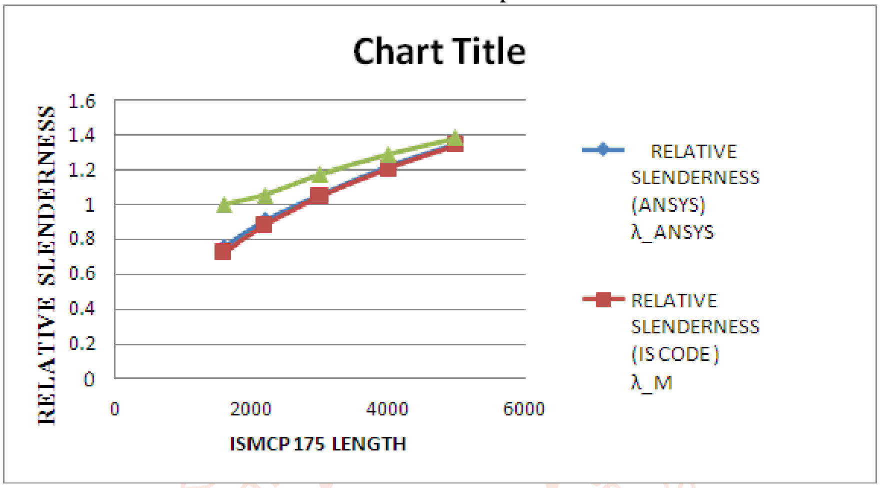


Figure 5.10 Uniformly distributed load on top web of ISMCP 200

Table 5.11 showing relative slenderness obtained for different lengths calculated theoretically, Analytically using ANSYS and using New design rule (snijder) for ISMCP 200 on top web

ISMCP 200 LENGTH mm	RELATIVE SLENDERNESS (ANSYS) λ_{ANSYS}	RELATIVE SLENDERNESS (IS CODE) λ_M	RELATIVE SLENDERNESS (NEW DESIGN RULE) λ_{MT}
1600mm	0.757	0.725	1
2200mm	0.908	0.883	1.057
3000mm	1.053	1.045	1.172
4000mm	1.217	1.206	1.286
5000mm	1.347	1.34	1.381

Graph 5.10 representing relative slenderness calculated using different approach with respect to length of beam. for ISMCP 200 on top web



NOTE:

➢ Modified relative slenderness $\lambda_{MT} = \lambda_{LT} + \lambda_T$

TORSION Term λ_T depends on the Relative Slenderness

$\lambda_T = 1 - \lambda_{LT}$ IF $0.5 \leq \lambda_{LT} < 0.8$

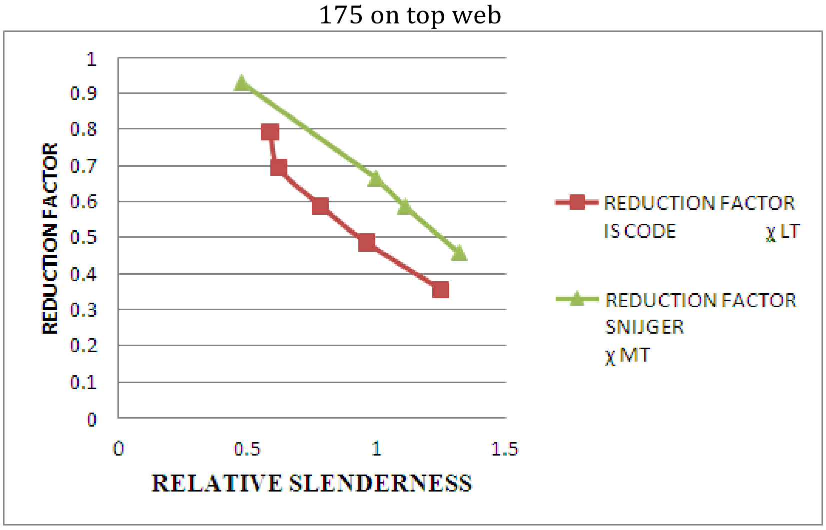
$\lambda_T = 0.43 - 0.29\lambda_{LT}$ IF $0.8 \leq \lambda_{LT} < 1.5$

$\lambda_T = 0$ IF $\lambda_{LT} \geq 1.5$

Table 5.12 showing reduction factor calculated using is code and new design rule with respect to relative slenderness obtained theoretically and by new design rule (snijder). for ISMCP 200 on top web

RELATIVE SLENDERNESS (IS CODE)λ_M	RELATIVE SLENDERNESS (NEW DESIGN RULE) λ_{MT}	REDUCTION FACTOR IS CODE χ LT	REDUCTION FACTOR (NEW DESIGN RULE) χ MT
0.725	1	0.627	0.666
0.883	1.057	0.531	0.626
1.045	1.172	0.445	0.548
1.206	1.286	0.374	0.478
1.34	1.381	0.325	0.427

Graph 5.11 showing variation between theoretically calculated relative slenderness and reduction factor for ISMCP 175 on top web



5.3.4. UNIFORMLY DISTRIBUTED LOAD ON MID WEB OF ISMCP200

- ISMCP 200 channel consists of 200mm channel depth and 75 mm flange width with 11.4mm and 6mm flange and web thickness.
- In this first 3D solid body of ISMCP 200 channel beam is created in ANSYS 14.0Workbench software and fork supported boundary condition were given at ends.
- ULD of 100kn/m is applied on middle of the beam for different length of 1600mm, 2200mm, 3000mm, 4000mm and 5000mm.
- Mesh has been provided with element size of 50mm in beam.

First the Static analysis is done then Eigen buckling values i.e., load multiple factors are obtained in workbech by applying point load of **100KN/m= 100N/mm**

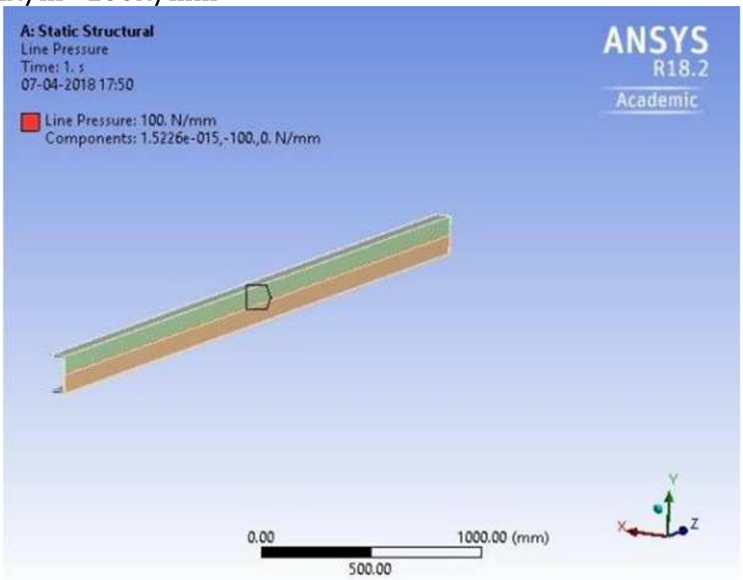
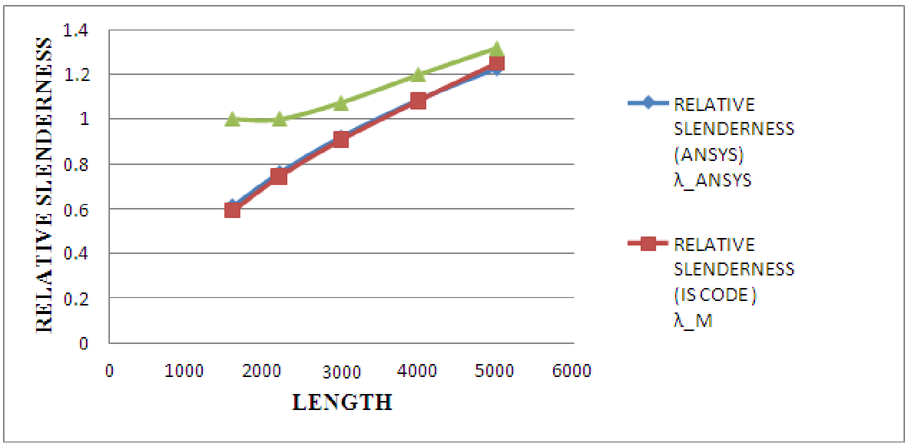


Figure 5.11 Uniformly distributed load on middle web of ISMCP 200

Table 5.13 showing relative slenderness obtained for different lengths calculated theoretically, Analytically using ANSYS and using New design rule (snijder) for ISMCP 200 on mid web

ISMCP200 LENGTH mm	RELATIVE SLENDERNESS (ANSYS) λ_{ANSYS}	RELATIVE SLENDERNESS (IS CODE) λ_M	RELATIVE SLENDERNESS (NEW DESIGN RULE) λ_{MT}
1600mm	0.611	0.59	1
2200mm	0.759	0.743	1
3000mm	0.921	0.908	1.075
4000mm	1.087	1.083	1.199
5000mm	1.227	1.25	1.318

Graph 5.12 representing relative slenderness calculated using different approach with respect to length of beam. for ISMCP 200 on mid web



NOTE:

- Modified relative slenderness $\lambda_{MT} = \lambda_{LT} + \lambda_T$
- TORSION Term **λ_T** depends on the Relative Slenderness

$\lambda_T = 1 - \lambda_{LT}$ IF $0.5 \leq \lambda_{LT} < 0.8$

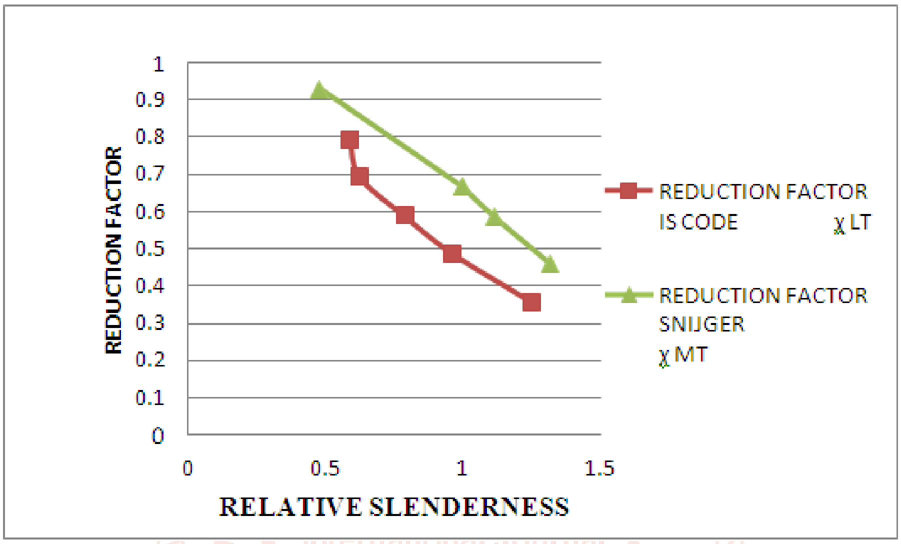
$\lambda_T = 0.43 - 0.29\lambda_{LT}$ IF $0.8 \leq \lambda_{LT} < 1.5$

$\lambda_T = 0$ IF $\lambda_{LT} \geq 1.5$

Table 5.14 showing reduction factor calculated using is code and new design rule with respect to relative slenderness obtained theoretically and by new design rule (snijder). for ISMCP 200 on mid web

RELATIVE SLENDERNESS (IS CODE) λ_M	RELATIVE SLENDERNESS (NEW DESIGN RULE) λ_{MT}	REDUCTION FACTOR IS CODE χ LT	REDUCTION FACTOR (NEW DESIGN RULE) χ MT
0.59	1	0.717	0.666
0.743	1	0.616	0.666
0.908	1.075	0.516	0.613
1.083	1.199	0.427	0.531
1.25	1.318	0.357	0.46

Graph 5.13showing variation between theoretically calculated relative slenderness and reduction factor for ISMCP 200 on mid web.



5.3.5. UNIFORMLY DISTRIBUTED LOAD ON BOTTOM WEB OF ISMCP 200

- ISMCP 200 channel consists of 200mm channel depth and 75 mm flange width with 11.4mm and 6mm flange and web thickness.
- In this first 3D solid body of ISMCP 200 channel beam is created in ANSYS 14.0Workbench software and fork supported boundary condition were given at ends.
- ULD of 100kn/m is applied on bottom of the beam for different length of 1600mm, 2200mm, 3000mm, 4000mm and 5000mm.
- Mesh has been provided with element size of 50mm in beam.
- First the Static analysis is done then Eigen buckling values i.e., load multiple factors are obtained in workbench by applying point load of **100 KN/m=100N/mm**

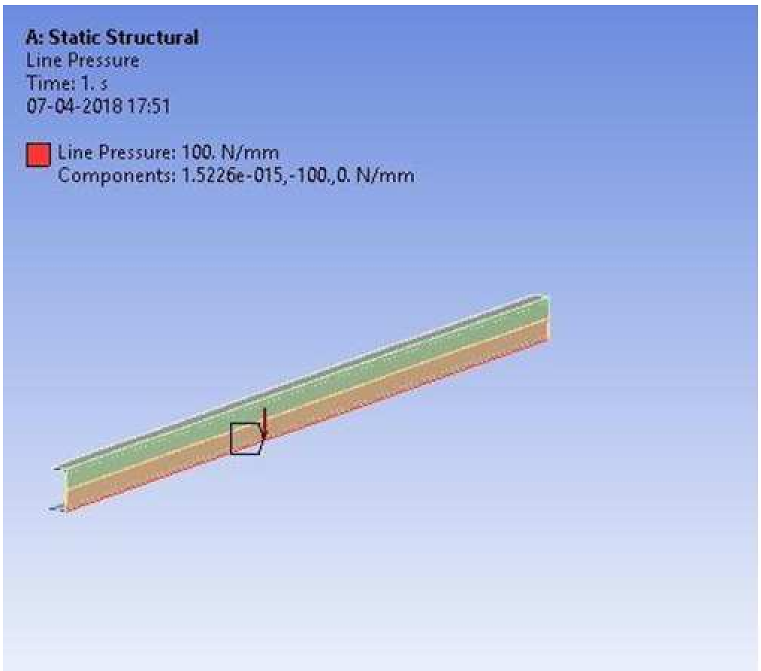
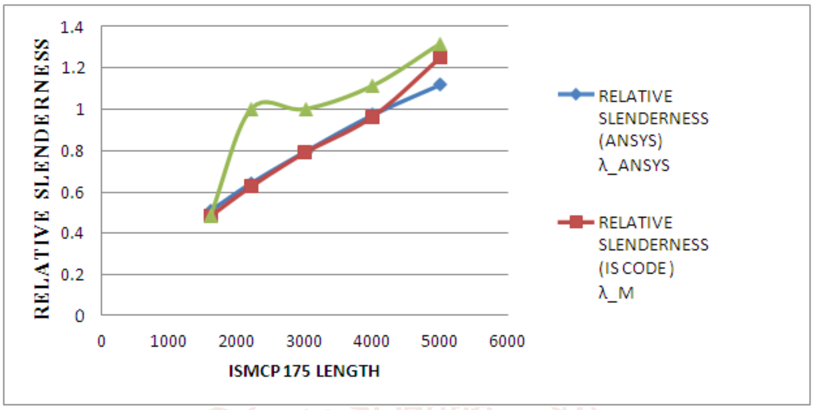


Figure 5.14 Uniformly distributed load on bottom web of ISMCP 200

Table 5.15 showing relative slenderness obtained for different lengths calculated theoretically, Analytically using ANSYS and using New design rule (snijder) for ISMCP 200 on bottom web.

ISMCP200 LENGTH mm	RELATIVE SLENDERNESS (ANSYS) λ_{ANSYS}	RELATIVE SLENDERNESS (IS CODE) λ_M	RELATIVE SLENDERNESS (NEW DESIGN RULE) λ_{MT}
1600mm	0.507	0.481	-
2200mm	0.640	0.624	1
3000mm	0.793	0.789	1
4000mm	0.971	0.964	1.114
5000mm	1.118	1.25	1.318

A. Graph 5.14 representing relative slenderness calculated using different approach with respect to length of beam. for ISMCP 200 on bottom web.



NOTE:

- Modified relative slenderness $\lambda_{MT} = \lambda_{LT} + \lambda_T$
- TORSION Term λ_T depends on the Relative Slenderness

$\lambda_T = 1 - \lambda_{LT}$ IF $0.5 \leq \lambda_{LT} < 0.8$

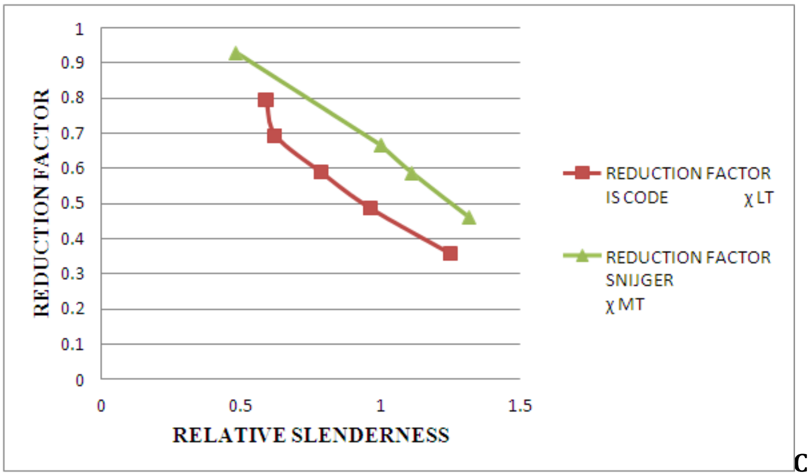
$\lambda_T = 0.43 - 0.29\lambda_{LT}$ IF $0.8 \leq \lambda_{LT} < 1.5$

$\lambda_T = 0$ IF $\lambda_{LT} \geq 1.5$

Table 5.16 showing reduction factor calculated using is code and new design rule with respect to relative slenderness obtained theoretically and by new design rule (snijder). for ISMCP 200 on bottom web.

RELATIVE SLENDERNESS (IS CODE) λ_M	RELATIVE SLENDERNESS (NEW DESIGN RULE) λ_{MT}	REDUCTION FACTOR IS CODE χ LT	REDUCTION FACTOR (NEW DESIGN RULE)χ MT
0.481	-	0.793	-
0.624	1	0.693	0.666
0.789	1	0.587	0.666
0.964	1.114	0.486	0.586
1.25	1.318	0.357	0.46

Graph 5.15 showing variation between theoretically calculated relative slenderness and reduction factor for ISMCP 200 on bottom web



C

5.3.6. UNIFORMLY DISTRIBUTED LOAD ON TOP WEB OF ISMCP 300

- ISMCP 300 channel consists of 300mm channel depth and 90 mm flange width with 13.6mm and 7.8mm flange and web thickness.

- In this first 3D solid body of ISMC 300 channel beam is created in ANSYS 14.0Workbench software and fork supported boundary condition were given at ends.
- ULD of 100kn/m is applied on top of the beam for different length of 1600mm, 2200mm, 3000mm, 4000mm and 5000mm.
- Mesh has been provided with element size of 50mm in beam.
- First the Static analysis is done then Eigen buckling values i.e., load multiple factors are obtained in workbench by applying point load of **100 KN/m= 100N/mm**.

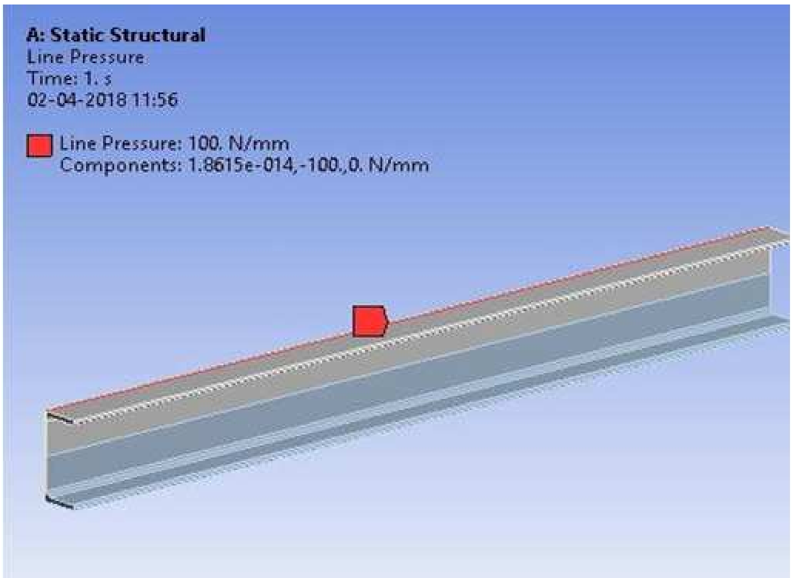
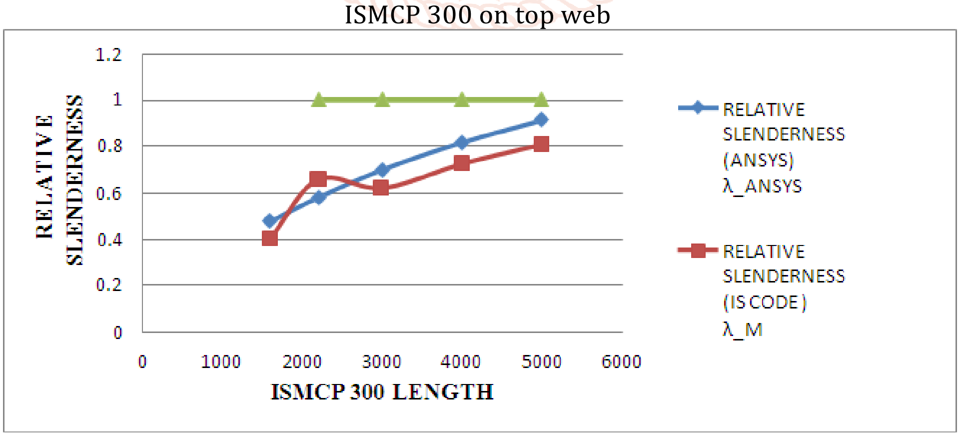


Figure 5.13 Uniformly distributed load on top web of ISMCP 300

Table 5.17 showing relative slenderness obtained for different lengths calculated theoretically, Analytically using ANSYS and using New design rule (snijder) for ISMCP 300 on top web.

ISMCP300 LENGTH mm	RELATIVE SLENDERNESS (ANSYS) λ_{ANSYS}	RELATIVE SLENDERNESS (IS CODE) λ_M	RELATIVE SLENDERNESS (NEW DESIGN RULE) λ_{MT}
1600mm	*0.476*	0.402	-
2200mm	*0.579*	0.658	1
3000mm	*0.699*	0.62	1
4000mm	*0.817*	0.725	1
5000mm	*0.912*	0.809	1.004

Graph 7.16 representing relative slenderness calculated using different approach with respect to length of beam. for ISMCP 300 on top web



NOTE:

- Modified relative slenderness $\lambda_{MT} = \lambda_{LT} + \lambda_T$
- TORSION Term λ T depends on the Relative Slenderness

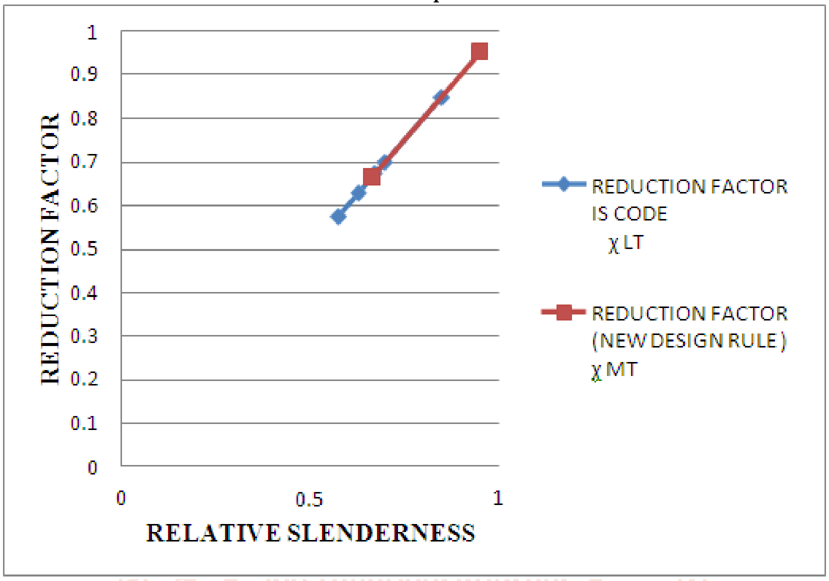
$$\lambda_T = 1 - \lambda_{LT} \quad \text{IF } 0.5 \leq \lambda_{LT} < 0.8$$
$$\lambda_T = 0.43 - 0.29\lambda_{LT} \quad \text{IF } 0.8 \leq \lambda_{LT} < 1.5$$
$$\lambda_T = 0 \quad \text{IF } \lambda_{LT} \geq 1.5$$

- Here λm is less than 0.5, since new design rule is valid for slenderness value greater than 0.5

Table 5.18 showing reduction factor calculated using is code and new design rule with respect to relative slenderness obtained theoretically and by new design rule (snijder) for ISMCP 300 on top web.

RELATIVE SLENDERNESS (IS CODE) λ_M	RELATIVE SLENDERNESS (NEW DESIGN RULE)λ_{MT}	REDUCTION FACTOR IS CODEχ LT	REDUCTION FACTOR (NEW DESIGN RULE) χ MT
0.402	-	0.848	-
0.658	1	0.67	0.666
0.62	1	0.696	0.666
0.725	1	0.627	0.666
0.809	1.004	0.574	0.666

Graph 5.17 showing variation between theoretically calculated relative slenderness and reduction factor for ISMCP 300 on top web



5.3.7. UNIFORMLY DISTRIBUTED LOAD ON MID WEB OF ISMCP300

- ISMCP 300 channel consists of 300mm channel depth and 90 mm flange width with 13.6mm and 7.8mm flange and web thickness.
- In this first 3D solid body of ISMCP 300 channel beam is created in ANSYS 14.0Workbench software and fork supported boundary condition were given at ends.
- ULD of 100kn/m is applied on middle of the beam for different length of 1600mm, 2200mm, 3000mm, 4000mm and 5000mm.
- Mesh has been provided with element size of 50mm in beam.
- First the Static analysis is done then Eigen buckling values i.e., load multiple factors are obtained in workbench by applying point load of **100 KN/m=100N/mm**

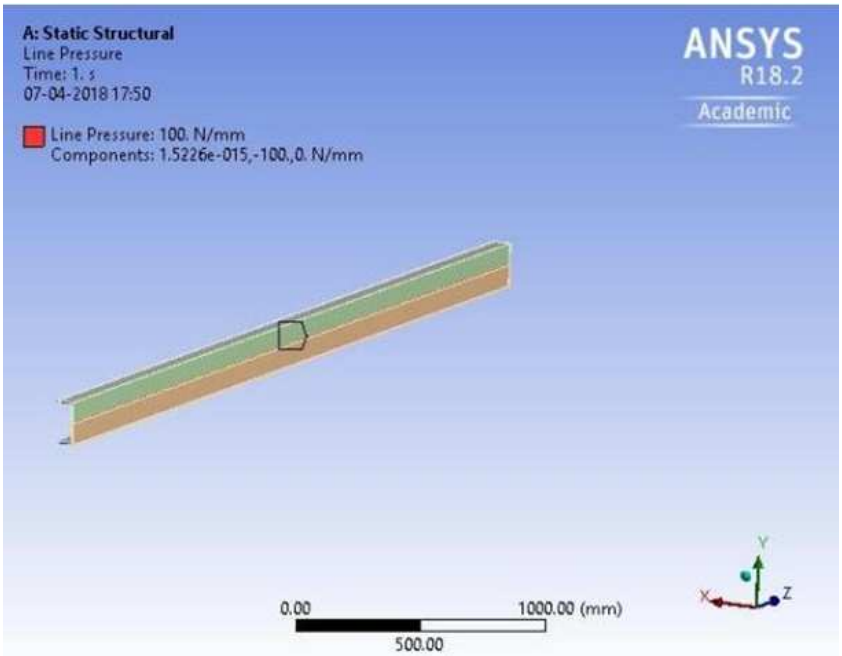


Figure 5.14 Uniformly distributed load on middle web of ISMCP 300

Table 5.19 showing relative slenderness obtained for different lengths calculated theoretically, Analytically using ANSYS and using New design rule (snijder) for ISMCP 300 on mid web.

ISMCP300 LENGTHmm	RELATIVE SLENDERNESS (ANSYS) λ_{ANSYS}	RELATIVE SLENDERNESS (IS CODE) λ_M	RELATIVE SLENDERNESS (NEW DESIGN RULE) λ_{MT}
1600mm	*0.374*	0.295	-
2200mm	*0.467*	0.384	-
3000mm	*0.579*	0.485	-
4000mm	*0.699*	0.590	1
5000mm	*0.801*	0.678	1

NOTE:

- Modified relative slenderness $\lambda_{MT} = \lambda_{LT} + \lambda_T$
- TORSION Term λ_T depends on the Relative Slenderness

$$\lambda_T = 1 - \lambda_{LT} \qquad \text{IF } 0.5 \le \lambda_{LT} < 0.8$$
$$\lambda_T = 0.43 - 0.29\lambda_{LT} \qquad \text{IF } 0.8 \le \lambda_{LT} < 1.5$$
$$\lambda_T = 0 \qquad \text{IF } \lambda_{LT} \ge 1.5$$

- Here λm is less than 0.5, since new design rule is valid for slenderness value greater than 0.5

Table 5.20 showing reduction factor calculated using is code and new design rule with respect to relative slenderness obtained theoretically and by new design rule (snijder). for ISMCP.300 on mid web.

RELATIVE SLENDERNESS (IS CODE) λ_M	RELATIVE SLENDERNESS (NEW DESIGN RULE) $\lambda_{MT} = \lambda_M + \lambda_T$	REDUCTION FACTOR IS CODE χ LT	REDUCTION FACTOR (NEWDESIGN RULE) χ MT
0.295	-	-	-
0.384	-	-	-
0.485	-	-	-
0.590	1	0.717	0.666
0.678	1	0.658	0.666

5.3.8. UNIFORMLY DISTRIBUTED LOAD ON BOTTOM WEB OF ISMCP 300

- ISMCP 300 channel consists of 300mm channel depth and 90 mm flange width with 13.6mm and 7.8mm flange and web thickness.
- In this first 3D solid body of ISMCP 300 channel beam is created in ANSYS 14.0Workbench software and fork supported boundary condition were given at ends.
- ULD of 100kn/m is applied on bottom of the beam for different length of 1600mm, 2200mm, 3000mm, 4000mm and 5000mm.
- Mesh has been provided with element size of 50mm in beam.
- First the Static analysis is done then Eigen buckling values i.e., load multiple factors are obtained in workbech by applying point load of **100KN/m= 100N/mm**

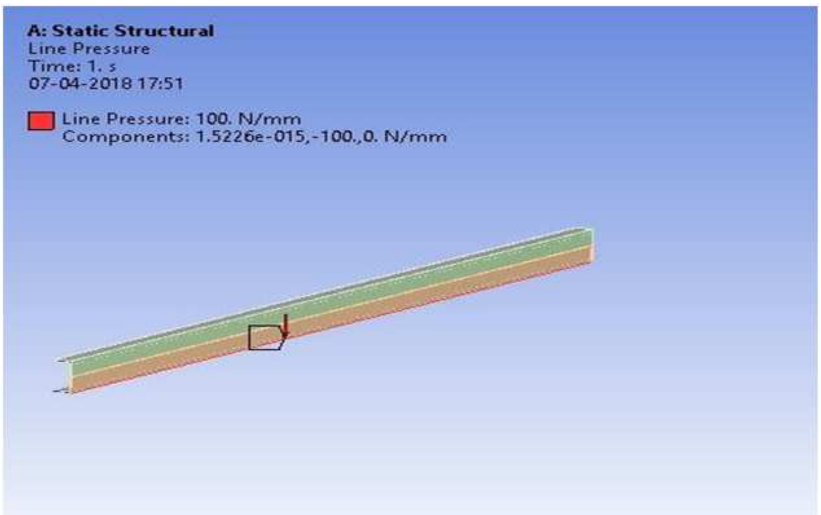


Figure 5.15 Uniformly distributed load on bottom web of ISMCP 300

Table 5.21 showing relative slenderness obtained for different lengths calculated theoretically, Analytically using ANSYS and using New design rule (snijder) for ISMCP 300 on mid web.

ISMCP300 LENGTH mm	RELATIVE SLENDERNESS (ANSYS) λ_{ANSYS}	RELATIVE SLENDERNESS (IS CODE) λ_M	RELATIVE SLENDERNESS (NEW DESIGN RULE) λ_{MT}
1600mm	0.312	0.216	-
2200mm	0.384	0.29	-
3000mm	0.485	0.38	-
4000mm	0.6	0.48	-
5000mm	0.703	0.569	1

NOTE:
- Modified relative slenderness $\lambda_{MT} = \lambda_{LT} + \lambda_T$
- TORSION Term λ_T depends on the Relative Slenderness

$\lambda_T = 1 - \lambda_{LT}$ IF $0.5 \le \lambda_{LT} < 0.8$

$\lambda_T = 0.43 - 0.29\lambda_{LT}$ IF $0.8 \le \lambda_{LT} < 1.5$

$\lambda_T = 0$ IF $\lambda_{LT} \ge 1.5$

- Here λm is less than 0.5, since new design rule is valid for slenderness value greater than 0.5

Table 5.22 showing reduction factor calculated using is code and new design rule with respect to relative slenderness obtained theoretically and by new design rule (snijder). for ISMCP300 on mid web.

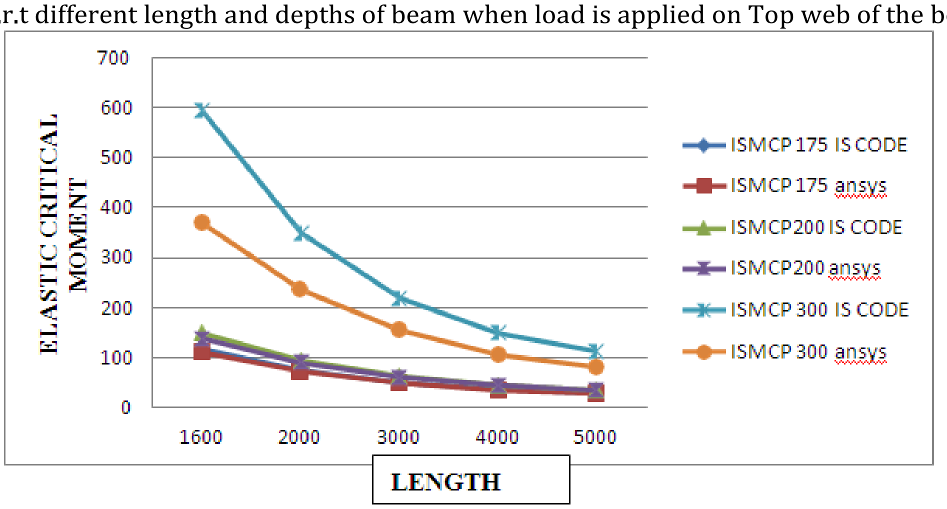
RELATIVE SLENDERNESS (IS CODE) λ_M	RELATIVE SLENDERNESS (NEW DESIGN RULE) λ_{MT}	REDUCTION FACTOR IS CODE χ_{LT}	REDUCTIONFACTOR (NEWDESIGN RULE) χ_{MT}
0.216	-	0.988	-
0.29	-	0.931	-
0.38	-	0.864	-
0.48	-	0.793	-
1	1.318	0.731	0.666

COMBINED GRAPHS FOR ALL BEAM LENGTHS AND DEPTHS:

A. Table 5.23 Buckling load factors (x) and Variation in **Elastic critical moment** calculated theoretically and compared with the values calculated using ANSYS w.r.t different length and depths of beam when load is applied on **Top web** of the beam.

length mm	ISMCP 175				ISMCP 200				ISMCP 300			
	x	M_{CR} (Kn-m)	$M_{CR,ANSYS}$ (Kn-m)	%M	x	M_{CR} (Kn-m)	$M_{CR,ANSYS}$ (Kn-m)	% M	x	M_{CR} (Kn-m)	$M_{CR,ANSYS}$ (Kn-m)	% M
1600	*2.267*	77.52	72.544	6.41	*2.808*	98.11	89.872	8.39	*7.118*	319.04	227.78	28.6
2200	*0.835*	52.89	50.518	4.48	*1.031*	66.04	62.43	5.46	*2.541*	119.1	153.73	26.7
3000	*0.328*	37.75	36.9	2.25	*0.413*	47.14	46.463	1.43	*0.938*	134	105.53	21.2
4000	*0.14*	28.46	28	1.61	*0.173*	35.44	34.76	1.91	*0.386*	98.13	77.2	21.3
5000	*0.073*	23.07	23	0.30	*0.090*	28.69	28.406	0.98	*0.198*	78.78	61.875	21.4

B. Graph 7.18 showing Elastic critical moment calculated theoretically and compared with the values calculated using ANSYS w.r.t different length and depths of beam when load is applied on Top web of the beam.



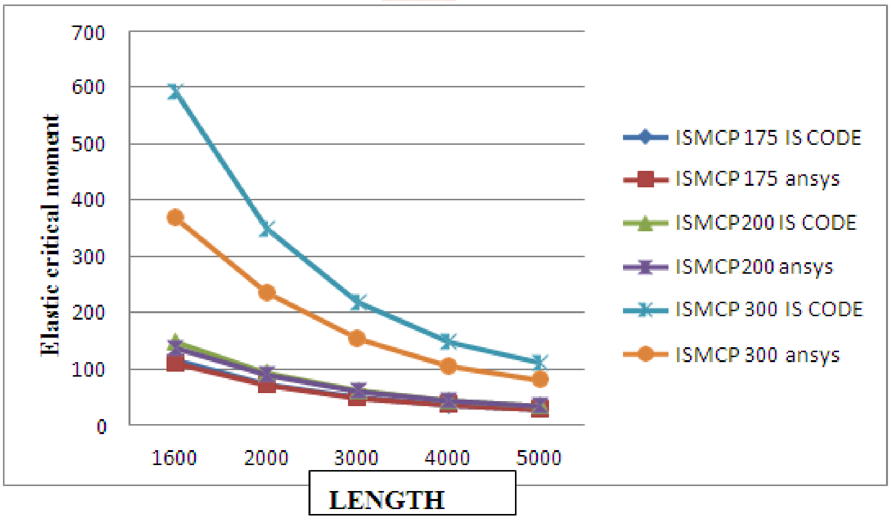
Note:

Elastic critical moment (ANSYS) $=(buckling\ load\ factor) * bending\ moment = (x) * \frac{wl^2}{8}$

C. Table 5.24 Buckling load factors (x) and Variation in Elastic critical moment calculated theoretically and compared with the values calculated using ANSYS w.r.t different length and depths of beam when load is applied on Mid web of the beam.

length mm	ISMCP 175				ISMCP 200				ISMCP 300			
	x	M_{CR} (Kn-m)	$M_{CR,ANSYS}$ (Kn-m)	% M	x	M_{CR} (Kn-m)	$M_{CR,ANSYS}$ (Kn-m)	% M	x	M_{CR} (Kn-m)	$M_{CR,ANSYS}$ (Kn-m)	% M
1600	*3.431*	116.27	109.79	5.57	*4.306*	147.94	137.81	6.85	*7.118*	593	368	37.7
2200	*1.183*	73.33	71.614	2.3	*1.478*	93.42	89.47	4.22	*2.541*	349.45	236.25	32.3
3000	*0.433*	49.83	48.742	2.18	*0.54*	62.44	60.75	2.7	*0.938*	219	154.45	28.4
4000	*0.175*	35.45	35.08	1.04	*0.218*	43.94	43.6	0.77	*0.386*	148	105.4	28.7
5000	*0.088*	27.62	27.531	0.32	*0.109*	34.5	34.213	0.83	*0.198*	111.93	80.313	28.2

D. Graph 7.19 showing Elastic critical moment calculated theoretically and compared with the values calculated using ANSYS w.r.t different length and depths of beam when load is applied on Mid web of the beam. Theoretical formula of Elastic critical moment is calculated using mono symmetric beam formula



Note:

- Theoretical formula of Elastic critical moment is calculated using mono symmetric beam formula

$$M_{cr} = \frac{c_1\pi^2 EI}{L^2_{LT}}\{[(\frac{K}{K_W})^2 (\frac{I_W}{I_{YY}}) + \frac{(L_{LT})^2}{\pi^2 EI_{YY}} + (C_2y_g - C_3Y_j)]0.5 - (C_2Y_g - C_3Y_j)\}$$

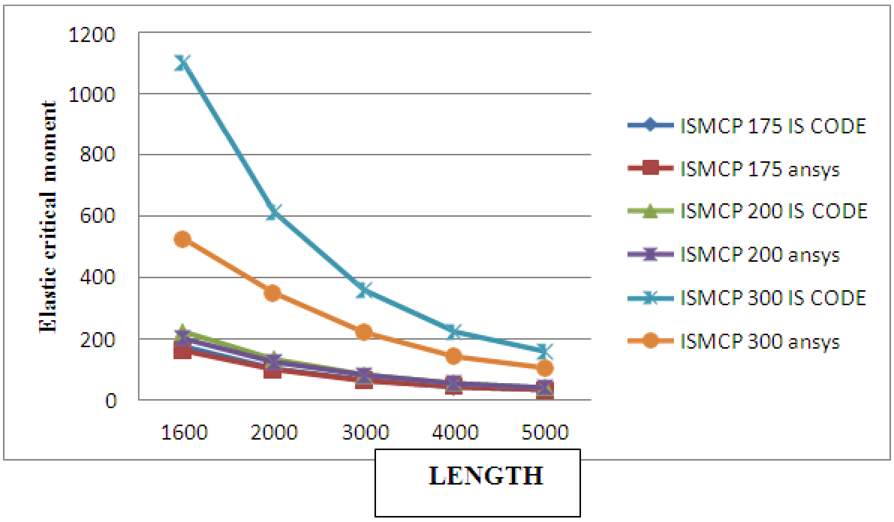
- Elastic critical moment (ANSYS) $=(buckling\ load\ factor) * bending\ moment =$

$$(x) * \frac{wl^2}{8}$$

E. Table 5.25 Buckling load factors (x) and Variation in Elastic critical moment calculated theoretically and compared with the values calculated using ANSYS w.r.t different length and depths of beam when load is applied on Bottom web of the beam.

length mm	ISMCP 175				ISMCP 200				ISMCP 300			
	x	M_{CR} (Kn-m)	$M_{CR,ANSYS}$ (Kn-m)	% M	x	M_{CR} (Kn-m)	$M_{CR,ANSYS}$ (Kn-m)	% M	x	M_{CR} (Kn-m)	$M_{CR,ANSYS}$ (Kn-m)	% M
1600	*5.019*	174.28	160.61	7.8	*6.274*	223.1	200.77	10.0	*16.49*	1102.7	527.94	52.1
2200	*1.647*	103.77	99.644	3.9	*2.077*	132.16	125.71	4.88	*5.771*	613.86	349.15	43.1
3000	*0.569*	65.27	64.013	1.92	*0.728*	82.7	81.9	0.96	*1.95*	357.34	219.38	38.6
4000	*0.217*	43.94	43.4	1.22	*0.273*	55.4	54.68	1.29	*0.716*	223.51	143.2	35.9
5000	*0.105*	32.97	32.813	0.47	*0.131*	41.49	41.18	0.727	*0.334*	159.03	104.3	34.3

F. Graph 5.20 showing Elastic critical moment calculated theoretically and compared with the values calculated using ANSYS w.r.t different length and depths of beam when load is applied on Bottom web of the beam.



Note:
- Theoretical formula of Elastic critical moment is calculated using mono symmetric beam formula

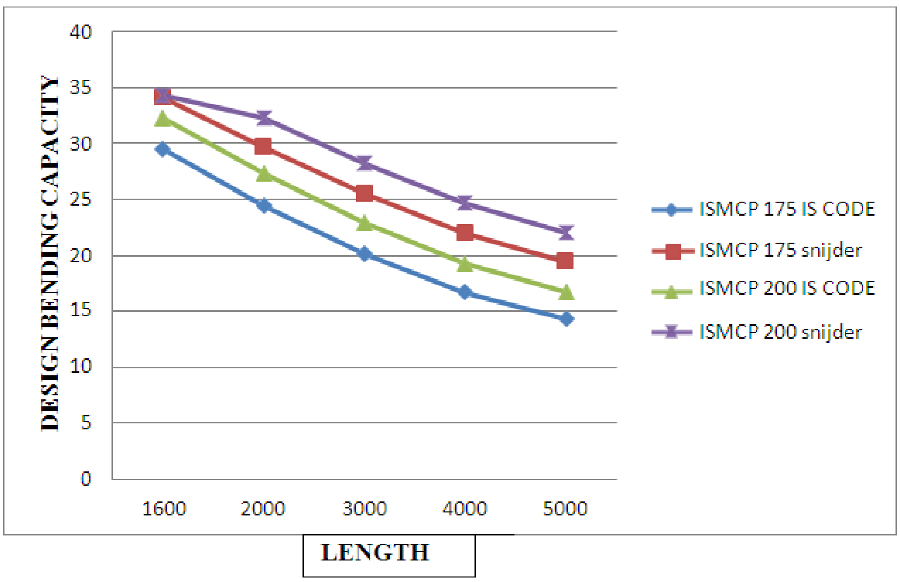
$$M_{cr} = \frac{c_1\pi^2 EI}{L^2_{LT}}\{[(\frac{K}{K_W})(\frac{I_W}{I_{YY}})+\frac{(L_{LT})^2}{\pi^2 EI_{YY}}+(C_2y_g-C_3Y_j)]\,0.5-(C_2Y_g-C_3Y_j)\}$$

- Elastic critical moment (ANSYS) $=(buckling\ load\ factor) * bending\ moment \quad =(x) * \frac{wl^2}{8}$

G. Table 5.26 showing comparison between theoretically calculated Design beam capacities using IS code and New design rule (snijder) w.r.t different beam lengths and depths of beam when load is applied on Top web of the beam.

ISMCP200 LENGTH mm	ISMCP 175		ISMCP 200		ISMCP 300	
	$M_{d,IS\ Code}$, (Kn-m)	$M_{d,Snijder}$ (Kn-m)	$M_{d,IS\ Code}$ (Kn-m)	$M_{d,Snijder}$ (Kn-m)	$M_{d,IS\ Code}$ (Kn-m)	$M_{d,Snijder}$ (Kn-m)
1600	29.522	34.108	32.305	34.314	43.691	49.049
2200	24.422	29.677	27.358	32.253	34.52	34.314
3000	20.145	25.507	22.928	28.234	35.86	34.314
4000	16.693	21.949	19.269	24.62	32.305	34.314
5000	14.323	19.424	16.745	22	29.574	34.159

H. Graph 5.21 showing comparison between theoretically calculated Design beam capacities using when load is applied on Top web of the beam.



5.2.1.1. Design bending capacity $_d = \beta_b Z_P {}^{F}bd = \beta_b Z_P * \chi_{LT} * \frac{F_y}{f}$

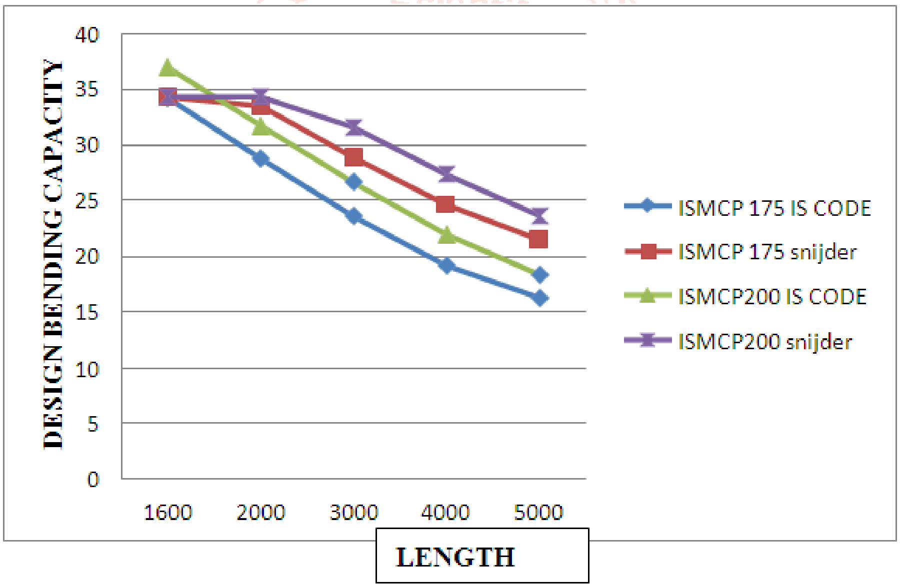
5.2.1.1.1. ISMCP 300 is not included in graph since beam has length to depth ratio L/d≤15

5.2.1.1.2. Empty value in table indicates slenderness of beam less than0.5

I. Table 5.27 showing comparison between theoretically calculated Design beam capacities using IS code and New design rule (snijder) w.r.t different beam lengths and depths of beam when load is applied on Mid web of the beam.

LENGTH mm	ISMCP 175		ISMCP 200		ISMCP 300	
	$M_{d,IS\ Code}$, (Kn-m)	$M_{d,Snijder}$ (Kn-m)	$M_{d,IS\ Code}$ (Kn-m)	$M_{d,Snijder}$ (Kn-m)	$M_{d,IS\ Code}$ (Kn-m)	$M_{d,Snijder}$ (Kn-m)
1600	34.26	34.314	36.942	34.314	47.71	-
2200	28.75	33.49	31.738	34.314	44.361	-
3000	23.597	28.853	26.586	31.583	40.703	-
4000	19.218	24.628	22	27.358	36.942	34.314
5000	16.281	21.485	18.394	23.7	33.902	31.314

J. Graph 5.22 showing comparison between theoretically calculated Design beam capacities using IS code and New design rule (Snijder) w.r.t different beam lengths and depths of beam when load is applied on Mid web of the beam.



Note:

5.2.1.2. Design bending capacity $M_d = \beta_b Z_P {}^{F}bd = \beta_b Z_P * \chi_{LT} * \frac{F_y}{f}$

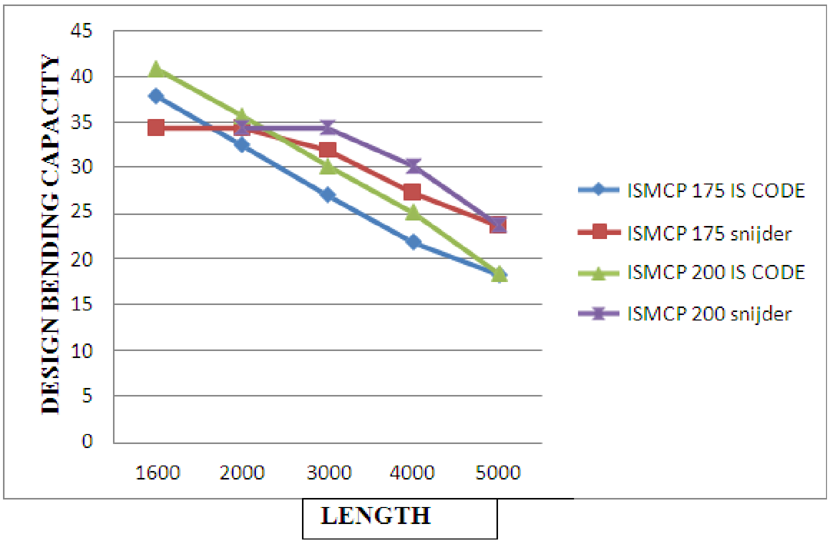
5.2.1.2.1. ISMCP 300 is not included in graph since beam has length to depth ratio L/d≤15

5.2.1.2.1. Empty value in table indicates slenderness of beam less than0.5

K. Table 5.28 showing comparison between theoretically calculated Design beam capacities using IS code and New design rule (snijder) w.r.t different beam lengths and depths of beam when load is applied on Bottom web of the beam.

ISMCP200 LENGTH mm	ISMCP 175		ISMCP 200		ISMCP 300	
	$M_{d,IS\ Code}$, (Kn-m)	$M_{d,Snijder}$ (Kn-m)	$M_{d,IS\ Code}$ (Kn-m)	$M_{d,Snijder}$ (Kn-m)	$M_{d,IS\ Code}$ (Kn-m)	$M_{d,Snijder}$ (Kn-m)
1600	37.818	34.31	40.85	-	50.904	-
2200	32.45	34.31	35.70	34.314	47.96	-
3000	26.94	31.89	30.24	34.314	44.515	-
4000	21.84	27.20	25.04	30.192	40.85	-
5000	18.34	23.64	18.39	23.17	37.66	23

L. Graph 5.23 showing comparison between theoretically calculated Design beam capacities using IS code and New design rule (Snijder) w.r.t different beam lengths and depths of beam when load is applied on Bottom web of the beam.



Note:

5.2.1.3. Design bending capacity $M_d = \beta_b Z_P {}^{F}bd = \beta_b Z_{P*} \chi_{LT} * \frac{F_y}{f}$

5.2.1.3.1. ISMCP 300 is not included in graph since beam has length to depth ratio L/d≤15

5.2.1.3.2. Empty value in table indicates slenderness of beam less than0.5

CONCLUSIONS & FUTURE SCOPE OF WORK

6.1. CONCLUSION:

In the current thesis various factors which will affect the lateral torsional buckling have been analyzed using codal formula given in IS: 800: 2007 ANNEX E in Clause 8.2.2.1 and validated with ANSYS simulation program which works on Finite element method. After analyzing the factors, the elastic critical moment, Mcr, have been evaluated for the three different Indian standard medium weight channel section (ISMCP),cross section details taken from Hot rolled steel section given in IS:808-1989.Various mono symmetric channels have been modelled using ANSYS software tools and the beam is subjected to uniformly load for laterally unrestrained condition.

The conclusions from this master's thesis project are presented below:

- It is observed that mono symmetric formula in code is giving elastic critical moment results upto 0.3% difference with ANSYS result for slender beams but showing larger difference for stocky beams.
- As the length of beam is increasing with constant cross section it is resulting in reduction in design capacity.
- The stocky beams seem to approach full plastic cross-section capacity for a load that the slender beams seem to approach elastic buckling.
- The stocky beams have much higher post yielding capacity than slender beams.
- The design curve for channel beam proposed by snijder seems to be a good choice, taking torsional effect into account, but it doesn't claim to be correct for beams with a ratio L/h<15.
- The results obtained from ISCODE stipulation are on the safer side for slender beams for design purpose.

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