COMPATIBILITY CHECK OF ELASTIC CRITICAL MOMENT EVALUATION OF ROLLED CHANNEL SECTION BEAM

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ABSTRACT

Design policies for eccentrically loaded beams with open channel cross-sections aren't available in Indian code IS 800-2000 General Construction in Steel-Code of Practice (THIRD REVISION). General solution for Elastic Critical Moment, Mcr has determined with the aid of the use of expression given in ANNEX-E (CL.8.2.2.1, IS 800:2007) for mono symmetric beams. Results so acquired are tested with Finite Element (FE) simulations on the idea of a parametric take a look at the use of ANSYS software program14.0.

A variant of maximum 0.3% is observed between the analytical end result and ANSYS result for slender beams however a massive distinction was observed for stocky beams. There is a reduction in design strength with an increase in span of the beam. The strength curve for channel beam proposed by means of IS 800: 2007 seems to be an awesome choice, however it does no longer claim to be accurate for beams with a ratio L/h<20.

Key words: Elastic Critical Moment, Slenderness, Reduction factors and Design beam capacity.

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1. INTRODUCTION

Beside mono symmetric I sections, rolled channel steel section are often used as beam to guide light loads in the shape of purlin to support roof over truss shape, staging to support bridge decks, etc.[20] The structural conduct of channel section is different from doubly symmetric section or mono symmetric I section because its shear centre and centre of gravity do no longer coincide.[12] In steel structure layout of laterally unsupported beam is quite complex because of diverse reasons consisting of lateral buckling of complete beam between the supports, nearby buckling of flanges and longitudinal buckling of web.[19] When a beam which is extra rigid about its major axis than its minor axis subjected to bending about its principal axis, lateral torsional buckling will occur about the minor axis of the beam. Lateral torsion buckling will generally tend the compression flange to buckle in the course transverse to the load earlier than the steel yields results in pulling beam sideways, whereas the tension flange will hold the beam in its plane.[1]

The lateral torsional buckling happens in a case for channel sections, where the shear centre does not coincide with the vertical axis of the centre of gravity of the section.[8] The load is generally subjected eccentrically on the web which reasons a torsional moment in the beam, which makes it tough to discover elastic critical moment Mcr.[4] Indian standard code for General Construction In Steel-Code Of Practice (Third Revision) IS 800-2007 has furnished guidelines to calculate elastic lateral torsional buckling moment or theoretical elastic critical moment for doubly symmetric section and cross section mono symmetric about its minor axis subjected to bend about its principal axis. Indian standard code IS 800-2007 doesn’t offers any components to calculate theoretical elastic critical moment for channel beams.[17] Whereas channel section is a mono-symmetrical section that's symmetric about its major axis. However new design rule was already proposed for design bending ability for channel section subjected to eccentric loading, however with restriction of span to section depth ratio.[8]

Stability of steel beam conjointly depends on bending distribution, point of application of load and degree of the mono symmetry of the section referred as Wagner’s parameter.[5] Coefficients C1, C2 and C3 are respectively influenced by these parameters that are given for a few selected load circumstances.[5] Since, because the slenderness ratio decreases, extra fibers of the beam become inelastic (increasing the degree of plasticity) and only the elastic element of the cross section remains potent in supplying resistance to lateral buckling.[6] In stocky beams buckling may be ruled by distorsion of web.[7] The effect of bracing relies not only on the stiffness of the restraint but also on the modified slenderness of the section. The load application had more influence on elastic critical moment and this impact is of the larger magnitude when the beam is rigid about major axis.[9] Channel section has been analysed for Mcr, utilising 3 factor formula of Eurocode-3 and verified with diverse softwares akin to ADINA, COLBEAM, LTBEAM, SAP2000 and STAAD pro however failed to establish any conclusion.[11] In present state of affairs, most of the commercial Structural engineering program consider lateral torsional buckling during the analysis of potential of steel beams. ANSYS application as a modern day approach established on FEM simulation and modeling is used for evolved engineering simulation rationale. The method has three phases preprocessing, solution and postprocessing.[22].

2. 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 study has been carried out wherein channel beams with targeted dimensions, lengths and load conditions has been modeled and analyzed using FEM simulation based computer program ANSYS workbench 14.0. Four cross sections were chosen ISMCP 125, ISMCP150, ISMCP175 and ISMCP200 of 5 exceptional lengths i.e., 1600mm, 2200mm, 3000mm, 4000mm, and 5000mm. A uniformly dispensed load of 1KN/m is applied on each beam on the top flange, the center and the bottom of the web respectively. Theoretical elastic critical moment was calculated using method given in code IS: 800:2007, ANNEX E and Clause 8.2.2 for mono symmetric section and then validated making use of ANSYS workbench 14.0.

2.1. Elastic Critical Moment of a Section Symmetrical About Minor Axis[17]

The guideline is only valid for major axis bending where the cross-section is uniform and symmetrical about the minor axis. It will for that reason no longer be 100% correct for channel beams.

\[ M_{cr} = c_1 \frac{\pi^2 E I_{yy}}{L^2 L_T^2} \left[ \left( \frac{K}{K_w} \right)^2 \left( \frac{I_w}{I_{yy}} \right) + \frac{G I_T (L_{LT})^2}{\pi^2 E I_{yy}} + \left( C_2 y_g - C_3 y_f \right)^{0.5} \right] - \left( C_2 y_g - C_3 y_f \right) \]

Where:

- \( C_1 \) = Coefficient depending on the shape of the moment diagram
- \( C_2 \) = Coefficient depending on the point of load application relative to the shear centre
- \( C_3 \) = Coefficient depending on the symmetry of the cross-section around the weak axis
- \( K, K_w \) = effective length factors of the unsupported length accounting for boundary conditions at the end lateral supports.
- \( K = 0.5 \) (For complete restraint against rotation about weak axis)
  - \( K = 1.0 \) (For free rotation about weak axis)
  - \( K = 0.7 \) (For one end fixed and other end free)
- \( K_w \) = Factor for warping restraint. Unless special provisions to restrain warping of the section at the end lateral supports are made, Kw should be taken as 1.0.
- \( y_g \) =distance between the point of application of the load and the shear centre of the cross section in y- direction and is positive when the load is acting towards the shear centre from the point of application.
- \( y_f = y_s - 0.5 \int_A (z^2 - y^2) ydA/I_z \)
- \( y_s \) = coordinate of the shear centre with respect to centroid and is positive when the shear centre is on the compression side of the centroid.
- \( y, z \) = coordinates of the elemental area with respect to centroid of the section
- \( h \) = overall height of the section
- \( I_{yy} \) = Moment of inertia around y axis (minor axis)
- \( I_w \) = Warping constant
- \( I_t \) = Torsion constant
- \( G \) = Shear Modulus
- \( E \) = Youngs Modulus
2.2. Design Strength of Laterally Unsupported Beams [17]

Beam experiencing bending about its major axis and when its compression flange is not restrained against lateral buckling, may just fail through lateral torsional buckling earlier than reaching its bending strength. The effect of lateral torsional buckling on flexural strength doesn’t need to be viewed when the non dimensional slenderness ratio for lateral torsional buckling is less than 0.4. The design bending capacity of a laterally unsupported beam as governed via lateral torsional buckling, according to the Indian code (IS 800:2007) can be obtained from the expression mentioned below.

\[ M_d = \beta_b Z_p F_{bd} \]

With

\[ \beta_b = 1.0 \text{ for plastic and compact sections} \]
\[ = \frac{z_e}{z_p} \text{ for semi-compact sections} \]

Where \( z_e \) and \( z_p \) are the plastic section modulus and elastic section modulus with respect to extreme compression fibre and \( F_{bd} \) is the design bending compressive stress.

The design bending compressive stress is given by

\[ F_{bd} = \chi_{LT} \frac{F_y}{Y_m} \]

\( F_y \) = yield stress

Where \( \chi_{LT} \) is the reduction factor to account for lateral torsional buckling given by

\[ \chi_{LT} = \frac{1}{\Phi_{LT} + \left[ \Phi_{MT}^2 - \lambda_{MT}^2 \right]^{0.5}} \]

In which \( \Phi_{LT} = 0.5 \times [1 + \alpha_{LT}(\lambda_{LT} - 0.2) + \lambda_{MT}^2] \)

The values of imperfection factor \( \alpha_{LT} \) for lateral torsional buckling of beams is given by

\( \alpha_{LT} = 0.76 \) for rolled channel section
\( \alpha_{LT} = 0.49 \) for welded section

\( Y_m = \) partial safety factor for material = 1.10

The non-dimensional slenderness ratio \( \lambda_{LT} \), is given by

\[ \lambda_{LT} = \frac{M_{pl}}{M_{cr}} \]
Where

\[ M_{cr} = \text{elastic critical moment} \]
\[ M_{pl} = \text{plastic moment resistance} \]

3. PARAMETRIC STUDY

The study was conducted by considering four (Indian standard medium weight parallel flange channel) ISMCP beams with different cross section size of ISMCP 125, ISMCP 150, ISMCP 175 and ISMCP 200. Three beams having different length of 1600mm, 2200mm, 3000mm, 4000mm and 5000mm.

The physical properties considered in the study are

- Unit mass of steel, \( \rho = 7850 \, \text{kg/m} \)
- Modulus of elasticity, \( E = 2.0 \times 10^5 \, \text{N/mm}^2 \) (Mpa)
- Poisson ratio, \( \mu = 0.5 \)
- Modulus of rigidity, \( G = 0.769 \times 10^5 \, \text{N/mm}^2 \) (Mpa)
- Co-efficient of thermal expansion, \( \alpha_t = 12 \times 10^{-6} / \text{C} \)

3.1. Sectional Properties of Hot Rolled Beams

![Sectional Properties of Hot Rolled Beams](image)

Table 1 Showing sectional properties if ISMCP channel sections

<table>
<thead>
<tr>
<th>Property</th>
<th>ISMCP 125</th>
<th>ISMCP 150</th>
<th>ISMCP 175</th>
<th>ISMCP 200</th>
</tr>
</thead>
<tbody>
<tr>
<td>Depth, ( D ) mm</td>
<td>125</td>
<td>150</td>
<td>175</td>
<td>200</td>
</tr>
<tr>
<td>Breadth, ( B ) mm</td>
<td>65</td>
<td>75</td>
<td>75</td>
<td>75</td>
</tr>
<tr>
<td>Web thickness, ( t ) mm</td>
<td>5.3</td>
<td>5.7</td>
<td>6</td>
<td>6.2</td>
</tr>
<tr>
<td>Flange thickness, ( T ) mm</td>
<td>8.1</td>
<td>9.0</td>
<td>10.2</td>
<td>11.4</td>
</tr>
<tr>
<td>Root 1 ( mm )</td>
<td>9.5</td>
<td>10</td>
<td>10.5</td>
<td>11</td>
</tr>
<tr>
<td>Root 2 ( mm )</td>
<td>5</td>
<td>5</td>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td>( I_{xx} ) ( cm^4 )</td>
<td>321</td>
<td>794</td>
<td>1240</td>
<td>1840</td>
</tr>
<tr>
<td>( I_{yy} ) ( cm^4 )</td>
<td>69.8</td>
<td>120</td>
<td>138</td>
<td>156</td>
</tr>
<tr>
<td>Mass, ( M ) kg/m</td>
<td>13.1</td>
<td>16.8</td>
<td>19.6</td>
<td>22.3</td>
</tr>
<tr>
<td>Sectional area, ( a ) ( cm^2 )</td>
<td>16.7</td>
<td>21.3</td>
<td>24.9</td>
<td>28.5</td>
</tr>
</tbody>
</table>
3.2. Load Case
Uniformly distributed load has been considered and applied at different levels of web at top, middle and bottom. Load of 100 kN/m is applied for total of five different spans of beam.

![Figure 1 Linearly distributed load application][15]

3.3. Boundary Condition
Beams are modelled with the boundary conditions known as fork support conditions. This type of boundary conditions is given to allow warping in flanges and to resist torsion in the webs at the supports.

![Figure 2 Fork support condition][15]

3.4. Validation using ANSYS 14.0

![Figure 3 Eigen value of ISMCP 175, 1600mm beam length][22]
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ANSYS is Finite Element software used for simulation purpose. In this study Eigen values are evaluated for an Indian standard medium weight parallel flange channel beam by creating its model, applying boundary condition and a uniformly distributed load of 100 KN/m. the figure shows the buckling load factors of ISMCP 175 for different lengths 1600,2200,3000,4000 and 5000mm obtained in ANSYS.

Table 2 Variation (%M) of Elastic Critical Moment obtained theoretically, $M_{cr}$ (KN-m) and using FEM Simulation software ANSYS, $M'_{cr}$ (KN-m) through Eigen buckling factors, (x) w.r.t different span for different channel section beams subjected to UDL of 1KN/m applied on Top web of the beam.

<table>
<thead>
<tr>
<th>Length(mm)</th>
<th>ISMCP 125</th>
<th>ISMCP 150</th>
<th>ISMCP 175</th>
<th>ISMCP 200</th>
</tr>
</thead>
<tbody>
<tr>
<td>x</td>
<td>$M_{cr}$</td>
<td>$M'_{cr}$</td>
<td>%M</td>
<td>$M_{cr}$</td>
</tr>
<tr>
<td>1600</td>
<td>0.1030</td>
<td>32.92</td>
<td>32.96</td>
<td>0.12</td>
</tr>
<tr>
<td>2200</td>
<td>0.0400</td>
<td>23.72</td>
<td>24.20</td>
<td>1.98</td>
</tr>
<tr>
<td>3000</td>
<td>0.0161</td>
<td>17.67</td>
<td>18.15</td>
<td>2.64</td>
</tr>
<tr>
<td>4000</td>
<td>0.0070</td>
<td>13.57</td>
<td>14.00</td>
<td>3.07</td>
</tr>
<tr>
<td>5000</td>
<td>0.0037</td>
<td>11.06</td>
<td>11.44</td>
<td>3.32</td>
</tr>
</tbody>
</table>

Figure 4 Graph showing variation in Elastic critical moment calculated theoretically and using ANSYS w.r.t different span and cross section of channel section beam subjected to UDL on Top web of the beam.

Table 3 Variation (%M) of Elastic Critical Moment obtained theoretically, $M_{cr}$ (KN-m) and using FEM Simulation software ANSYS, $M'_{cr}$ (KN-m) through Eigen buckling factors, (x) w.r.t different span for different channel section beams subjected to UDL of 1KN/m applied on Mid web of the beam.

<table>
<thead>
<tr>
<th>Length(mm)</th>
<th>ISMCP 125</th>
<th>ISMCP 150</th>
<th>ISMCP 175</th>
<th>ISMCP 200</th>
</tr>
</thead>
<tbody>
<tr>
<td>x</td>
<td>$M_{cr}$</td>
<td>$M'_{cr}$</td>
<td>%M</td>
<td>$M_{cr}$</td>
</tr>
<tr>
<td>1600</td>
<td>0.147</td>
<td>49.07</td>
<td>47.04</td>
<td>4.32</td>
</tr>
<tr>
<td>2200</td>
<td>0.053</td>
<td>32.4</td>
<td>32.07</td>
<td>1.03</td>
</tr>
<tr>
<td>3000</td>
<td>0.02</td>
<td>22.4</td>
<td>22.5</td>
<td>-</td>
</tr>
<tr>
<td>4000</td>
<td>0.00828</td>
<td>16.26</td>
<td>16.56</td>
<td>-</td>
</tr>
<tr>
<td>5000</td>
<td>0.004181</td>
<td>12.805</td>
<td>13.07</td>
<td>-</td>
</tr>
</tbody>
</table>
Compatibility Check of Elastic Critical Moment Evaluation of Rolled Channel Section Beam

Figure 5 Graph showing variation in Elastic critical moment calculated theoretically and using ANSYS w.r.t different span and cross section of channel section beam subjected to UDL on Mid web of the beam.

Table 4 Variation (%M) of Elastic Critical Moment obtained theoretically, $M_{cr}$ (KN-m) and using FEM Simulation software ANSYS, $M'_{cr}$ (KN-m) through Eigen buckling factors, (x) w.r.t different span for different channel section beams subjected to UDL of 1KN/m applied on Bottom web of the beam.

<table>
<thead>
<tr>
<th>Length(mm)</th>
<th>ISMCP 125</th>
<th>ISMCP 150</th>
<th>ISMCP 175</th>
<th>ISMCP 200</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>x</td>
<td>$M_{cr}$</td>
<td>$M'_{cr}$</td>
<td>%M</td>
</tr>
<tr>
<td>1600</td>
<td>0.206</td>
<td>67.91</td>
<td>65.92</td>
<td>3.02</td>
</tr>
<tr>
<td>2200</td>
<td>0.0697</td>
<td>42.22</td>
<td>42.17</td>
<td>0.12</td>
</tr>
<tr>
<td>3000</td>
<td>0.0247</td>
<td>27.62</td>
<td>27.79</td>
<td>-</td>
</tr>
<tr>
<td>4000</td>
<td>0.00978</td>
<td>19.16</td>
<td>19.56</td>
<td>-</td>
</tr>
<tr>
<td>5000</td>
<td>0.004814</td>
<td>14.651</td>
<td>15.04</td>
<td>2.59</td>
</tr>
</tbody>
</table>

Figure 6 Graph showing variation in Elastic critical moment calculated theoretically and using ANSYS w.r.t different span and cross section of channel section beam subjected to UDL on Bottom web of the beam.
Table 5 Variation of Elastic Critical Moment (%M) obtained theoretically and using FEM Simulation software ANSYS w.r.t different L/D ratio for different channel section beams subjected to UDL of 1KN/m applied on Top web of the beam.

<table>
<thead>
<tr>
<th>L/D RATIO</th>
<th>ISMCP125 %M</th>
<th>L/D</th>
<th>ISMCP150 %M</th>
<th>L/D</th>
<th>ISMCP175 %M</th>
<th>L/D</th>
<th>ISMCP200 %M</th>
</tr>
</thead>
<tbody>
<tr>
<td>12.80</td>
<td>-0.12</td>
<td>10.67</td>
<td>4.75</td>
<td>9.14</td>
<td>9.12</td>
<td>8.00</td>
<td>9.89</td>
</tr>
<tr>
<td>17.60</td>
<td>-1.98</td>
<td>14.67</td>
<td>2.20</td>
<td>12.57</td>
<td>4.41</td>
<td>11.00</td>
<td>7.02</td>
</tr>
<tr>
<td>24.00</td>
<td>-2.64</td>
<td>20.00</td>
<td>0.85</td>
<td>17.14</td>
<td>2.16</td>
<td>15.00</td>
<td>4.76</td>
</tr>
<tr>
<td>32.00</td>
<td>-3.07</td>
<td>26.67</td>
<td>1.52</td>
<td>22.86</td>
<td>0.39</td>
<td>20.00</td>
<td>1.84</td>
</tr>
<tr>
<td>40.00</td>
<td>-3.32</td>
<td>33.33</td>
<td>-3.86</td>
<td>28.57</td>
<td>-0.61</td>
<td>25.00</td>
<td>0.56</td>
</tr>
</tbody>
</table>

Figure 7 Graph showing variation in Elastic critical moment calculated theoretically and using ANSYS w.r.t different L/D ratio of channel section beam subjected to UDL on Top web of the beam.

Table 6 Variation of Elastic Critical Moment (%M) obtained theoretically and using FEM Simulation software ANSYS w.r.t different L/D ratio for different channel section beams subjected to UDL of 1KN/m applied on Mid web of the beam.

<table>
<thead>
<tr>
<th>L/D</th>
<th>ISMCP125 %M</th>
<th>L/D</th>
<th>ISMCP150 %M</th>
<th>L/D</th>
<th>ISMCP175 %M</th>
<th>L/D</th>
<th>ISMCP200 %M</th>
</tr>
</thead>
<tbody>
<tr>
<td>12.80</td>
<td>4.32</td>
<td>10.67</td>
<td>4.36</td>
<td>9.14</td>
<td>7.55</td>
<td>8.00</td>
<td>8.02</td>
</tr>
<tr>
<td>17.60</td>
<td>1.03</td>
<td>14.67</td>
<td>1.62</td>
<td>12.57</td>
<td>3.52</td>
<td>11.00</td>
<td>5.04</td>
</tr>
<tr>
<td>24.00</td>
<td>-0.44</td>
<td>20.00</td>
<td>0.82</td>
<td>17.14</td>
<td>1.84</td>
<td>15.00</td>
<td>2.60</td>
</tr>
<tr>
<td>32.00</td>
<td>-0.81</td>
<td>26.67</td>
<td>-0.62</td>
<td>22.86</td>
<td>0.40</td>
<td>20.00</td>
<td>1.41</td>
</tr>
<tr>
<td>40.00</td>
<td>-2.03</td>
<td>33.33</td>
<td>-2.51</td>
<td>28.57</td>
<td>-0.65</td>
<td>25.00</td>
<td>0.52</td>
</tr>
</tbody>
</table>

Figure 8 Graph showing variation in Elastic critical moment calculated theoretically and using ANSYS w.r.t different L/D ratio of channel section beam subjected to UDL on Mid web of the beam.
Table 7 Variation of Elastic Critical Moment (%M) obtained theoretically and using FEM Simulation software ANSYS w.r.t different L/D ratio for different channel section beams subjected to UDL of 1KN/m applied on Bottom web of the beam.

<table>
<thead>
<tr>
<th>L/D</th>
<th>ISMCP125 %M</th>
<th>L/D</th>
<th>ISMCP150 %M</th>
<th>L/D</th>
<th>ISMCP175 %M</th>
<th>L/D</th>
<th>ISMCP200 %M</th>
</tr>
</thead>
<tbody>
<tr>
<td>12.80</td>
<td>3.02</td>
<td>10.67</td>
<td>7.20</td>
<td>9.14</td>
<td>10.58</td>
<td>8.00</td>
<td>10.93</td>
</tr>
<tr>
<td>17.60</td>
<td>0.12</td>
<td>14.67</td>
<td>3.06</td>
<td>12.57</td>
<td>4.83</td>
<td>11.00</td>
<td>5.24</td>
</tr>
<tr>
<td>24.00</td>
<td>-0.61</td>
<td>20.00</td>
<td>1.20</td>
<td>17.14</td>
<td>2.08</td>
<td>15.00</td>
<td>2.60</td>
</tr>
<tr>
<td>32.00</td>
<td>-2.04</td>
<td>26.67</td>
<td>0.84</td>
<td>22.86</td>
<td>0.57</td>
<td>20.00</td>
<td>1.08</td>
</tr>
<tr>
<td>40.00</td>
<td>-2.59</td>
<td>33.33</td>
<td>-10.47</td>
<td>28.57</td>
<td>-0.30</td>
<td>25.00</td>
<td>0.43</td>
</tr>
</tbody>
</table>

Figure 9 Graph showing variation in Elastic critical moment calculated theoretically and using ANSYS w.r.t different L/D ratio of channel section beam subjected to UDL on Bottom web of the beam.

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

\[ M_{cr} = c_1 \pi^2 E I_{yy} \left\{ \left( \frac{K}{K_w} \right)^2 \left( I_W \right) + \frac{G I_T (L_{LT})^2}{\pi^2 E I_{yy}} + (C_2 Y_g - C_3 Y_f) \right\}^{0.5} - (C_2 Y_g - C_3 Y_f) \]

- Elastic critical moment (ANSYS) \[ M_{cr,ANSYS} = (buckling load factor) \cdot bending \ moment = (\chi) \cdot \frac{wt^2}{8} \]

4. CONCLUSIONS

In the current study 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 four different Indian standard medium weight channel section (ISMCP), cross section details taken from Hot rolled steel section given in IS:808-1989.

The conclusions are presented below:
- It is observed that mono symmetric formula in IS 800:2007 is giving elastic critical moment conservative results vis-à-vis ANSYS result for slender beams but showing large variation for stocky beams.
- The results obtained from the IS code formula is compatible with ANSYS results for beams having length to depth ratio between range 20 to 40.
Stocky beams having length to depth ratio less than 20 is showing a percentage variation more than 5%.

The stocky beams have much higher post yielding capacity than slender beams.

The results obtained from ISCODE stipulation are on the safer side for slender beams for design purpose.

REFERENCES


Compatibility Check of Elastic Critical Moment Evaluation of Rolled Channel Section Beam


[18] Dimensions for Hot rolled steel beam, column, channel and angle sections ( Third Revision ) IS 808-1989


