iJRASET
International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 6 **Issue:** V **Month of publication:** May 2018

DOI: http://doi.org/10.22214/ijraset.2018.5243

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 6.887
Volume 6 Issue V, May 2018- Available at www.ijraset.com

Influence of Optimum Number of Sag-Rods and Sag-Rod Spacing on Deformations of Zee Profile

Kanchan S Takale[1], Prof. R. V. R. K. Prasad[2], Dr. Ramesh V. Meghrajani[3]
[1]*Mtech Student, Civil Engg. Dept., KDKCE, Nagpu*
[2]*Asso. Professor, Civil Engg. Dept., KDKCE, Nagpur,*
[3]*Principal Consultant, NEO Infrastructure Consultants, Nagpur*

Abstract: An unbraced compression flange of any single-web flexural member tends to buckle laterally under vertical loading. Zee profile being point symmetric is more liable to lateral buckling because its shear centre and the its point of load application is different. Sag-rods is a widely and popularly adopted technique of bracing system to curb the lateral torsional buckling of Zee profile. Roof bracing system of sag rods is commonly installed in roof framing to curb the unbraced length of the Zee purlin. It is a practical approach and diminutive solid theory is available for the suitability of number of sag rods. Sag-Rods are being used on a rule of thumb. It has practically proven to be effective in minimizing the lateral deformations by reducing the unbraced length of the Zee profile. This reduced unbraced length is adopted for design calculations. Also, the spacing in between the sag rods is considers to be in the range of L/3 to L/4. It is a dilemma to choose the optimum one. This paper discusses the deformations of Z purblind under various load combinations, positioning of sag-rods, requirement of number of sag-rods and their optimum spacing for a Zee profile.
Keywords: DL (Dead Load), WS (Wind Suction), LL (Live Load), WP (Wind Pressure), Ixx (Moment of Inertia in X direction), Iyy (Moment of Inertia in Y direction)

I. INTRODUCTION

Study confirms that cold formed sections bid the benefits of lighter sections, economy and fast construction. Their capabilities of easy manufacturing (line production) and faster installations has conquered the steel industry. Cold formed designs and sections are globally endorsed because of the standardization in geometric configurations and connections. Further, cold formed Zee sections are most prevalently cast-off as purlins and girts for their overlapping competence and economical design. On the other side, cold formed steel sections are susceptible to distortional buckling. Methods have been established to encounter the distortional buckling. But its efficacy and optimization are still a dilemma.

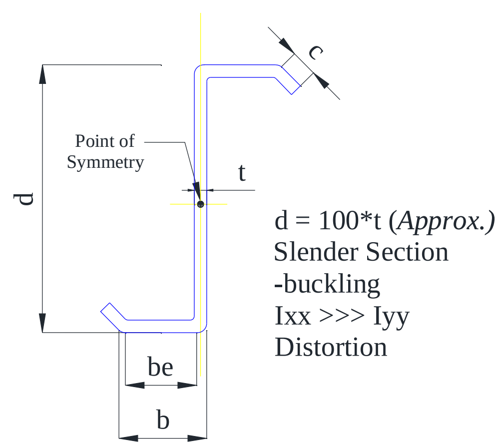


Fig. 1 Geometry of cold-formed Zee profile

From Fig. 1 it is observed that cold formed steel has higher Ixx to Iyy ratio. This leads to distortional bucking in the member. Being a point symmetric geometry, the distorted shape of the Zee profile is complex. Its complexity increases with change in boundary conditions. Experiments have been performed with one of the flanges connected to the roofing material. The deformed shape studies

ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 6.887
Volume 6 Issue V, May 2018- Available at www.ijraset.com

of one flange restrained are plenty. Practically, there is a time lapse between the installation of roof framing system (purlins, sag rods, roof bracings, etc) and roof sheeting. This time is critical for the member to sustain with both flanges unbraced.

II. LOAD COMBINATIONS AND GENERAL ARRANGEMENT OF SAG-RODS

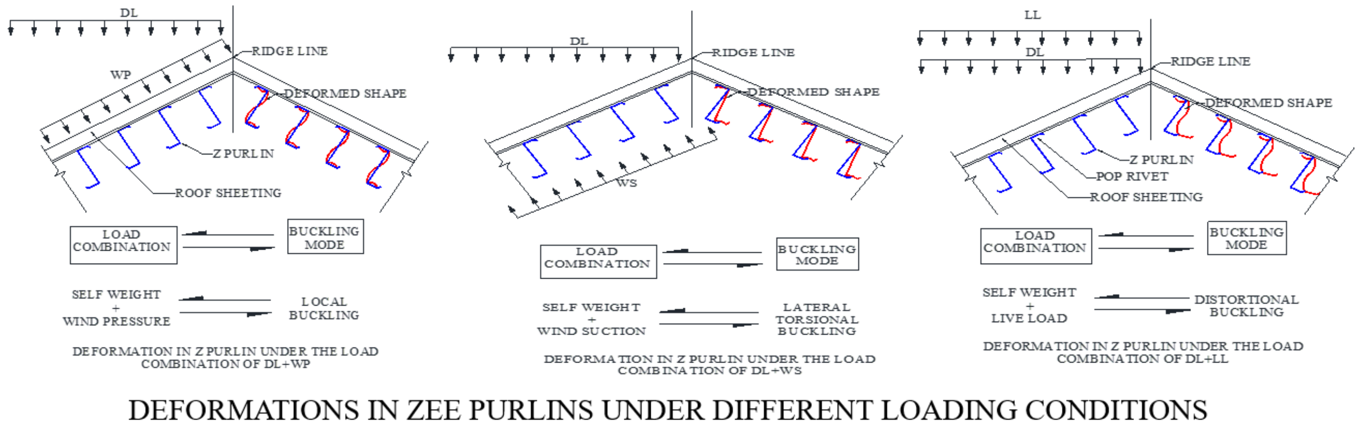


Fig. 2 Deformations inZee profile under different loading conditions

Fig. 2 presents the deformations of Z purlins under different loading conditions. The top flange of the Zee purlins is assumed to be fixed to the roofing material. The lateral torsional and distortional buckling behaviour shows the lateral displacement of the Z section starting from the unbraced flange. Analysing the loading conditions, the combination of DL+WS is more vulnerable to distortion for the unbraced flange of Z purlin. Under this combination, the unbraced flange not only laterally displaces, but also experiences a reverse crushing behaviour. This condition has lead to drastic failures.

Fig. 3 Structure failure due to storm in Delhi [Image courtesy to client]

Fig. 3 shows a structure failure due to storm in Delhi, India. A closure observation on the picture detects the absence of sag-rods and loosened cable bracing and absence of roof and wall bracing at critical points. The structure was under construction and hence, more susceptible to failure as discussed above. A denser bracing system must have been provided to prevent such disasters. Arrangements of temporary bracings would be innovative for under construction sites.

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 6.887
Volume 6 Issue V, May 2018- Available at www.ijraset.com

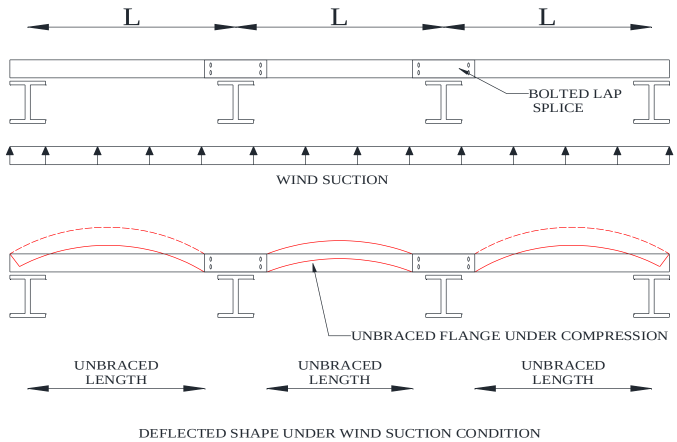


Fig. 4 Deflected shape of Zee profile under wind suction condition

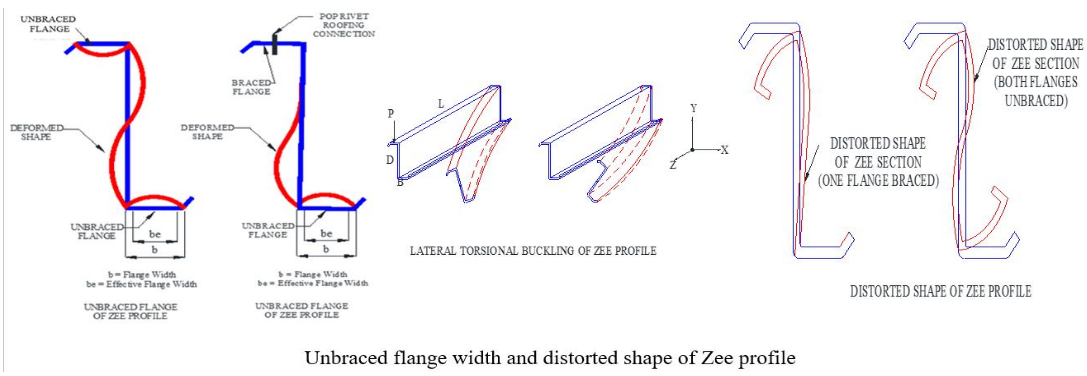


Fig. 5 Unbraced flange width and distorted shape of Zee profile

In local buckling, some part of the compression flange and the web buckles when the stresses reach a certain limit; that part than ceases to carry its share of the load. In distortional buckling, the compression flange and the adjacent stiffening lip move away from the original position as a unit thus weakening the section.

SP6(5)-1980 quotes that failure occurs at a stage when the stress at the supported edge reaches yield stress. For design purposes the total force is assumed to be distributed over lesser width with uniform stresses.

The unbraced length of the Zee profile is the unsupported length in between the overlaps in one span. The purlin member is connected at the main frames only. The purlin for the entire length of bay is free for displacements and rotations. However, this condition is valid for the roof time lapse period i.e., until the roof covering is installed. Once the roof covering is installed, one of the flanges gets constrained. The other flange remains unbraced even after the installation of roofing. The large deformations of the purlin member are due to this unbraced flange of the member.

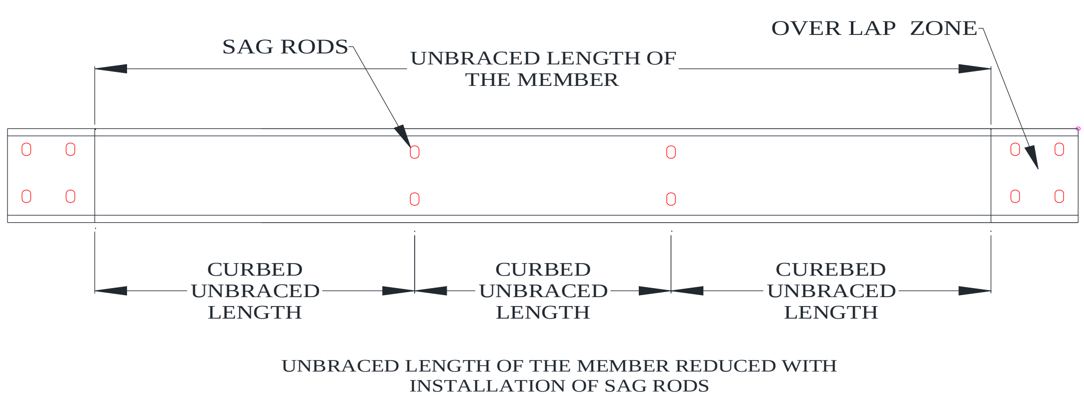
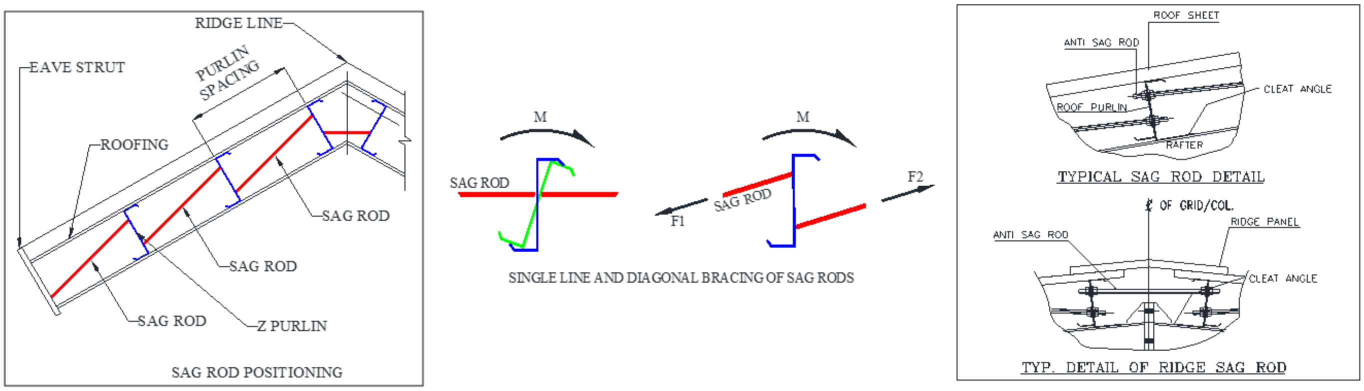


Fig. 6 Unbraced flange width of the member reduced with installation of sag-rods

ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 6.887
Volume 6 Issue V, May 2018- Available at www.ijraset.com



SAG-ROD POSITIONING AND DETAILS AT RIDGE

Fig. 7 Sag-rod positioning and details at ridge

Fig. 7 shows the positioning of sag-rods. Diagonal bracing of sag-rod is more effective in stress reversal condition. The alignment of sag-rods plays an important role in transferring the stresses. The purlins should be rested entirely on cleat angle and not directly on rafters as shown in ridge detail.

III. SUITABILITY OF NUMBER OF SAG-RODS IN ZEE PURLINS

TABLE I Zee profiles available in India

ZEE PROFILES AVAILABLE IN INDIA								
	PARAMETER	SYMBOL	UNIT	Z1	Z2	Z3	Z4	Z5
1	OVERALL DEPTH	D	mm	200	200	230	230	250
2	WIDTH OF FLANGE	B	mm	60	60	60	60	70
3	LENGTH OF LIP	L	mm	20	20	20	20	22
4	THICKNESS OF MEMBER	t	mm	1.5	1.6	2	2.2	2.5
5	INNER RADIUS OF CURVATURE	r	mm	3	3	3	3	3

TABLE II Deformations in Zee Profiles

MAXIMUM TOTAL DEFORMATIONS					
LENGTH	**ZEE PROFILES**				
m	**Z1**	**Z2**	**Z3**	**Z4**	**Z5**
5	21.6	28.1	18.7	16.4	11.4
5.5	25.8	34.4	24.0	21.1	14.5
6	14.9	43.3	30.3	26.6	18.2
6.5	36.0	53.6	37.4	32.8	22.5
7	65.9	65.6	45.6	39.9	27.3
7.5	69.0	79.3	54.8	47.8	32.8
8	79.1	93.9	64.8	56.6	38.8
8.5	87.3	110.9	76.0	66.1	45.4
9	80.5	128.7	88.1	76.5	52.6
10	114.4	169.5	115.3	99.6	68.8
13	125.5	332.5	220.9	188.8	131.8

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 6.887
Volume 6 Issue V, May 2018- Available at www.ijraset.com

TABLE II gives the total deformations of Zee purlins under a constant load of 3500 N. The fixity of the overlap is considered at boundaries while simulating the model on ANSYS. Practical studies give 25% to 30% more deformations than mentioned in TABLE II. The deformations are in mm.

TABLE III Suitability of number of sag rods for Zee profiles

SUITABILITY OF NUMBER OF SAG RODS FOR AVAILABLE ZEE PROFILES IN INDIA						DEFLECTION CRITERION		
LENGTH	**Z1**	**Z2**	**Z3**	**Z4**	**Z5**	**LENGTH**	**l/200**	**l/180**
m	NUMBERS					mm	mm	mm
4	0	0	0	0	0	4000	20	22.22
4.5	0	0	0	0	0	4500	22.5	25.00
5	1	1	1	1	1	5000	25	27.78
5.5	1	1	1	1	1	5500	27.5	30.56
6	2	2	2	2	2	6000	30	33.33
6.5	2	2	2	2	2	6500	32.5	36.11
7	2	2	2	2	2	7000	35	38.89
7.5	2	2	2	2	2	8000	40	44.44
8	2	2	2	2	2	8500	42.5	47.22
8.5	3	3	3	3	3	9000	45	50.00
9	3	3	3	3	3	10000	50	55.56
10	3	3	3	3	3	12000	60	66.67
13	4	4	4	4	4	13000	65	72.22

TABLE III gives the suitability of number of sag-rods. The deflection criterion of L/200 is used for purlins with sag-rods and L/180 for purlins without sag-rods. Purlins of length up to 8000 mm are most commonly used. 8000 mm length members are easy for transportation and fits for the minimum requirement of two sag-rods only. Further increase in the length will require more number of sag-rods leading to uneconomical design. However, as per requirement, purlins up to a length of 13 metres can be cold-rolled in India at some places. Accordingly, the number of sag-rods should be used for an intact roofing system.

IV. OPTIMUM SPACING OF SAG-RODS IN ZEE PURLINS

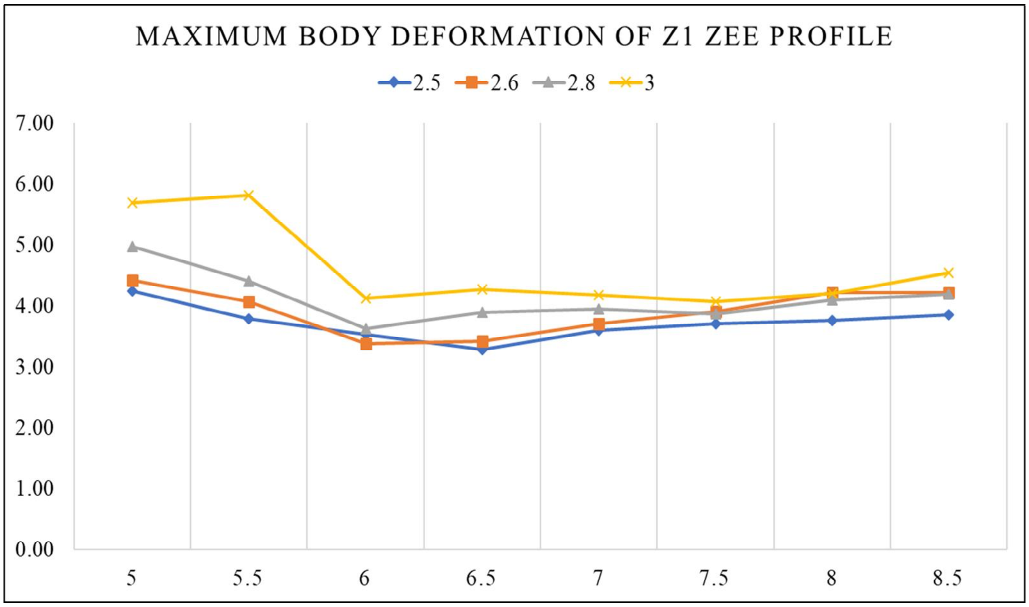


Fig. 8 Maximum body deformation of Z1 profile

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 6.887
Volume 6 Issue V, May 2018- Available at www.ijraset.com

The above graph is for Z1(200*60*20*15) Zee profile. It depicts that for 2500 mm of spacing, the minimum deformation observed is for a length of 6.5 m. The same profile is gives lesser deformations with 2600, 2700 and 2800 mm spacing for a length of 6m. For a length of 7.5 m, any of the four spacings would give approximately same deformation values.

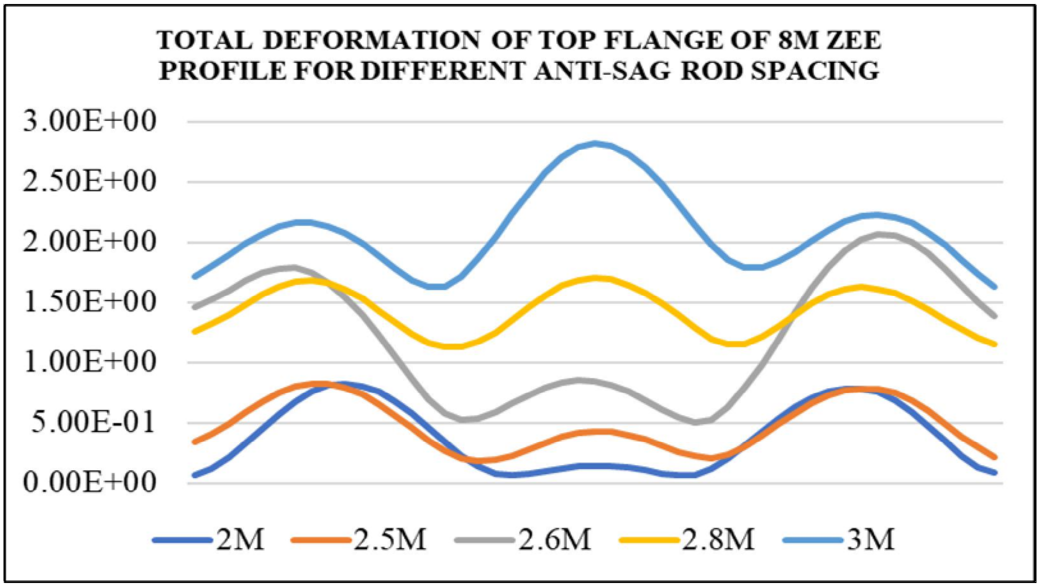


Fig. 9 Total deformation of top flange of 8m Zee profile for different sag-rod spacings

From above graph, the curve of smoothest fit of distribution of deformations is considered to be the optimum spacing of the sag-rods. However, if the overlap is to be considered, the optimum spacing will shift to the lower range than the optimum. In the above case, with overlaps, the optimum spacing would range in between 2600-2800 mm. Overlap design is variable, hence instead of concluding a precise spacing of sag-rods, a flexible range of spacing is provided.
Here only 8m lengths are considered as these are the most common amongst the long member lengths.

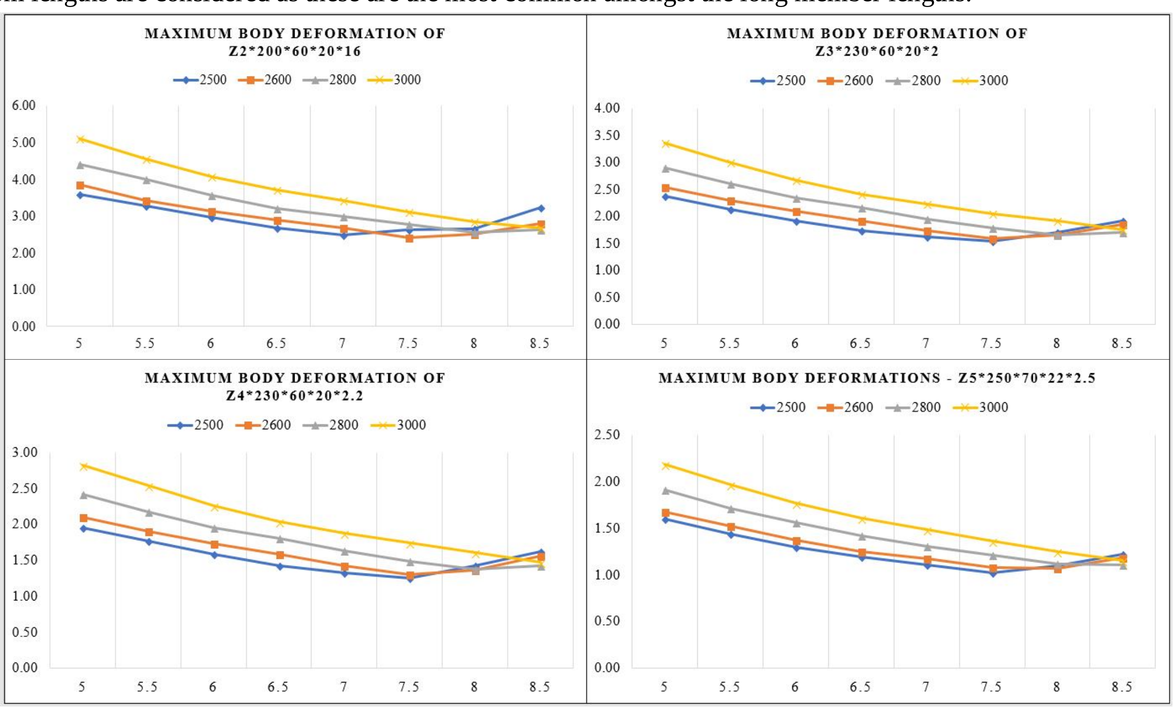


Fig. 10 Maximum deformation of Zee profiles under different spacings

From Fig. 10, all the Zee profiles available in India gives approximately similar deformations under a pre-defined range of sag-rod spacings for member lengths more than 7.5 m. Also, the deformations are least for the length of 7.5m in all cases.

V. CONCLUSION

Sag-rods reduce the unbraced length of the member. They diminish the lateral deformations of Z purlins by 65% to 70%. Diagonal bracing of sag-rod is more effective in stress reversal conditions. One sag-rod is required for member lengths up to 5.5m. Two number of sag-rods are required for member lengths of 5.5m to 8.0m. Three number of sag-rods are required for member lengths of 8m to 10m and four sag-rods for 10m and above.

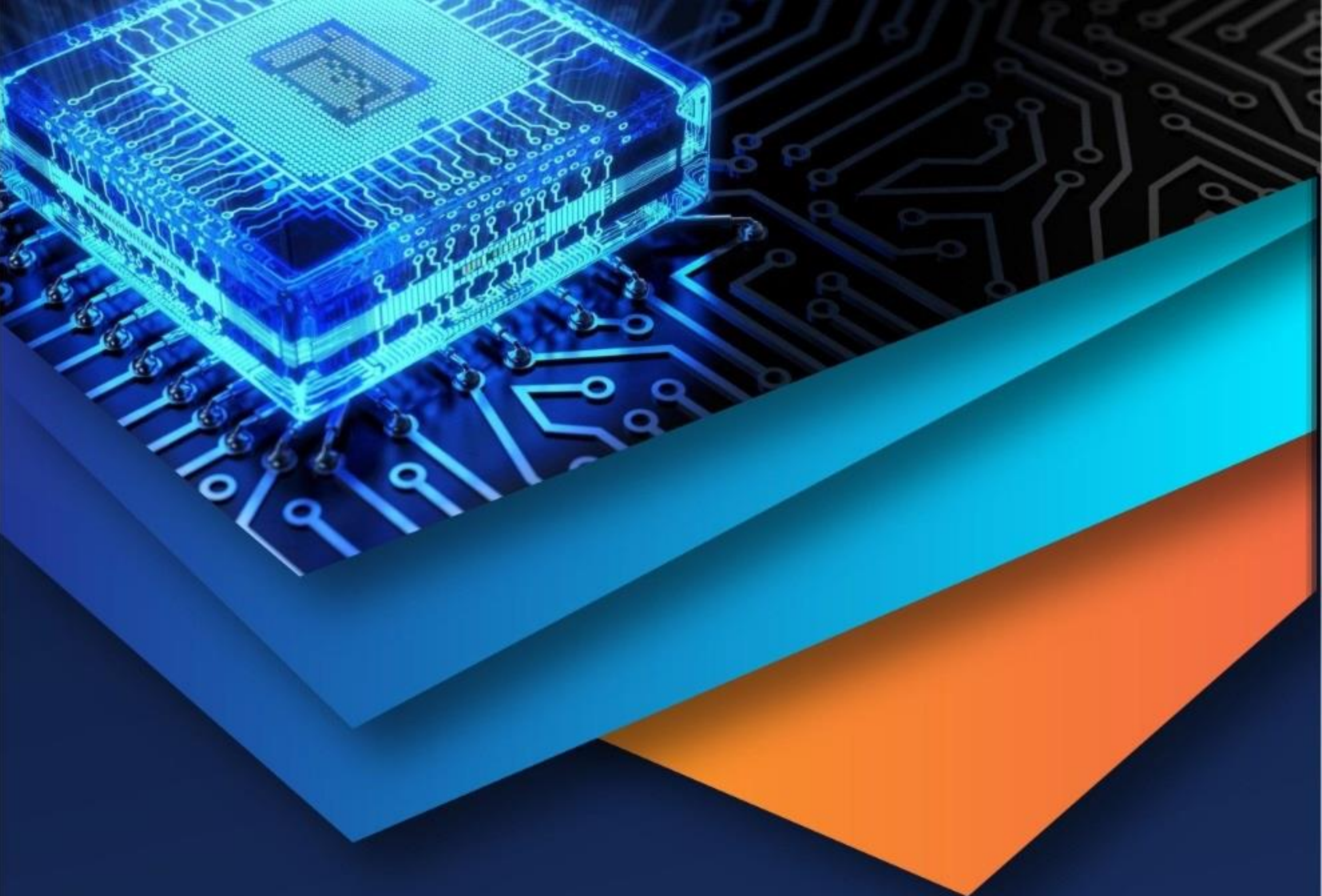
The optimum spacing of sag-rod is between 2600 mm to 2800 mm. Codal rule of L/3 fits into the range suggested. The maximum L/3 value while optimising the sag-rod spacing is limited to 3000 mm. This can lead to higher deflections. And the minimum value is limited to 2500 mm. Below this value, sag-rods are uneconomical.

VI. ACKNOWLEDGMENT

The author is grateful to Prof. RVRK Prasad for his wisdom of knowledge shared and practiced. Author is thankful to Dr. Ramesh V. Meghrajani for enlightening the core concepts of PEBs. Author extends a token a thanks to the complete team of NEO infrastructure Consultants for their cooperation.

REFERENCES

[1] IS800:2007 (Indian Standard General Construction in Steel – Code of practice
[2] 1975 (Indian Standard Code of practice for use of Cold-Formed Light Gauge Steel Structural Members in General Building Construction)
[3] SP:6(5)-1980 (Handbook for Structural Engineers – 5. Cold-Formed, Light-Gauge Steel Structures.
[4] IS875(Part3):2015 (Indian Standard Design Loads (Other than Earthquake) for Buildings and Structures – Code of Practice
[5] BS 5950-5:1998 (Structural use of steelwork in building – Part 5 Code of practice for design of cold formed thin gauged sections)
[6] AISI Manual – 1998 (Cold-Formed Steel Design Manual)
[7] Steel Designers Manual – 2003
[8] AISI/AISC 360-16 (Specification for Structural Steel Buildings)
[9] A Newman "Metal Building Systems – Design and Specification"
[10] Dr. N Subramanian "Steel Structures – Design and Practice"
[11] Alomir H. Favero Neto, Luiz C.M. Vieira Jr., Maximiliano Malite "Strength and stiffness of cold-formed steel purlins with sleeved and overlapped bolted connections", Thin-Walled Structures, March 2016
[12] Lei Zhang, Gen-Shu Tong "Lateral bucking of simply supported C-and Z-section purlins with top flange horizontally restrained", Thin-Walled Structures, 2015
[13] W. Ye, C.J. Wang, D. J. Mynors, K. A. Kibble, T. Morgan, B. Cartwright, "Load-deflection behaviour of sleeved joints in modified Z purlin system", Thin-Walled Structures, 2013.
[14] A. Biegus, "Causes of imminent failure damage and repair of Steel Building Purlins", ELSEVIER – Archives of Civil and Mechanical Engineering, 2015.
[15] Xiao-ting Chu, Jamie Rickard, Long-yuan Li, "Influence of lateral restraint on lateral torsional buckling of cold-formed steel purlins", ELSEVIER - Thin-Walled Structures, 2005.
[16] L Kemp, P E Dunaiski & W Bird, "Structural Behaviour of cold-formed profiles with emphasis on the Zeta-profile", ELSEVIER - Journal of Construction and Steel Research, 1995.



10.22214/IJRASET

45.98

IMPACT FACTOR: 7.129

IMPACT FACTOR: 7.429

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY