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Behaviour of Cold-Formed Z Purlins with Sag-Rods in Pre-Engineered Buildings

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Abstract: Zee profile has a complex deformation behaviour and the severe buckling issues leads to reduction in strength of the member. Lateral torsional buckling is the governing deformation leading to overall distortion of the member. It is important to eliminate or delay these buckling problems to achieve higher sustainability of the structure. Use of Sag-rods is a common practice adopted to curb this lateral torsional buckling and to reduce the unbraced length of the member. In this paper the deformed shape of the Zee profile is thoroughly observed. While analysing, both the flange widths are kept unbraced since a standard practice of providing 300mm spacing in roofing connection along the length of the purlin is not genuinely practiced everywhere. The influence of one and two sag rods on the deformed shape of Zee profile is observed. The focus was set on the longitudinal deformations of the member with regards to the distribution of deformations along the length of the member. A comparative study of the same is presented in this paper.
Keywords: BM (Bending moment), TD (Total deformation), XD (X-directional deformation), YD (Y-directional deformation), ZD (Z-directional deformation).

I. INTRODUCTION

The use of cold-formed steel structures is very popular around the world for its faster and standard manufacturing and construction techniques offering economy. However, the behaviour of these thin gauged members is characterised by a range of buckling modes such as local buckling, lateral torsional buckling and distortional buckling specially in case of roof framing members, viz., purlins. Zee profile is the most recommended section for purlins due to its special characteristic of overlapping and nesting into each other forming an intact system of roof bracings. But, Zee profile has a complex deformation behaviour and the severe buckling issues leads to reduction in strength of the member. Lateral torsional buckling is the governing deformation leading to overall distortion of the member. Therefore, it is important to eliminate or delay these buckling problems to achieve higher sustainability of the structure.

II. GEOMETRICAL CONFIGURATIONS AND GENERAL ARRANGEMENTS

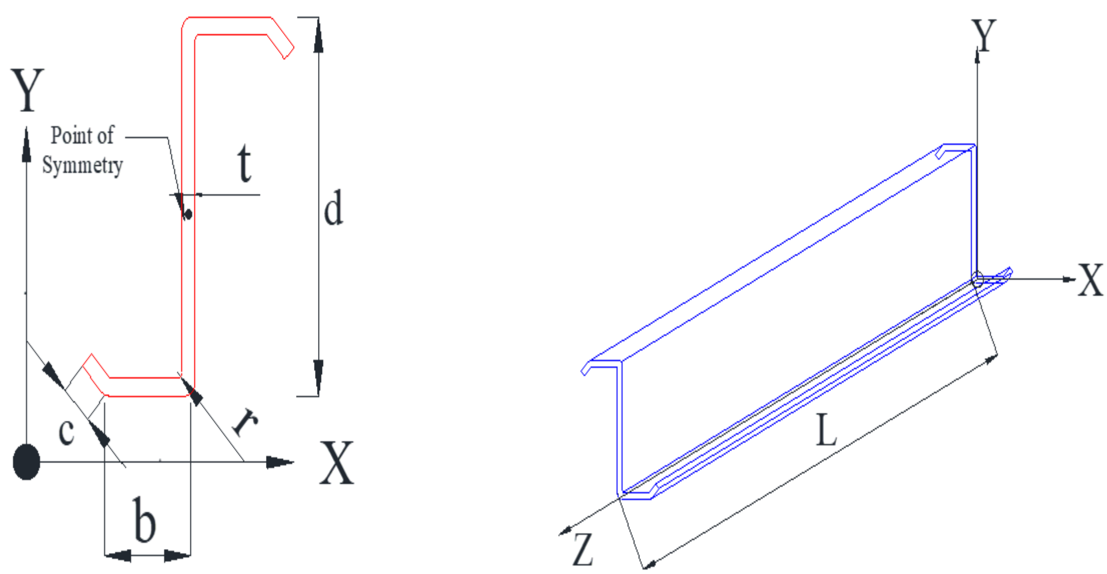

Fig. 1 Representation of Zee profile on global axis of ANSYS

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TABLE I

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

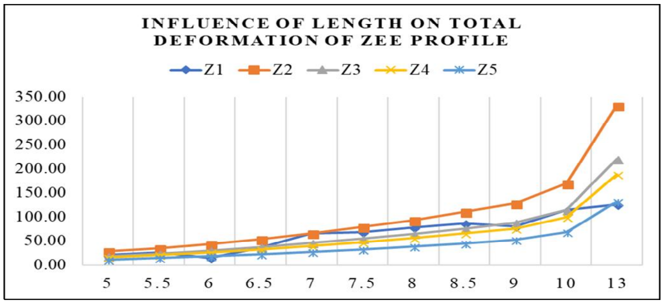

Fig. 2 Influence of length on total deformations in Zee profiles available in INDIA

TABLE II Zee profile selected for analysis

	PARAMETER	SYMBOL	UNIT	Z1
1	Overall depth	d	mm	200
2	Width of flange	b	mm	60
3	Length of lip	c	mm	20
4	Thickness of member	t	mm	1.5
5	Inner radius of curvature	r	mm	3
6	Length of the member	L	mm	8000

The study from boundary conditions revealed that the practical condition of constraining four cleat holes is the best suit for the definition of the problem. The exact boundary condition under which the Zee profile will be simulated is Pin-Pin with 1 additional constraint at each end. The ideal loading condition was found to be SETUP B under which a force in KN is applied on the entire top flange of the Zee Profile.

As the length of the member increases, the deflection increases. However, the maximum total deformations are found to be least for Z5(250*70*22*25) of all members. But this being a heaviest section of all available sections, is avoided under normal condition. Under huge wind pressure, like coastal areas prone to cyclones and mountainous terrain, use of section Z5 is recommended if no other member fits in. For section Z1(200*60*20*15), which is a typical section, the deformations are observed to fall from 5.5 m of length to 6.5m of length. The use of section is recommended to be used under all normal conditions for the best suited length range of 5.5m to 7.5m.

The comparison of Zee profile with and without lip element showed that Zee profiles with lip elements have higher strengths as the deformations observed under identical loading conditions are less of Zee profile with lip elements compared to Zee profiles without lip element. The Zee profile with lip element at 30° experiences the minimum deformations. In practice, the Zee profile with 45° is used. A comparison of Zee profile with 30° and 45° lip angle was made. The Zee profile with 30° lip angle is found to be more stable in regards of the deformations. Suitability of a 30° lip element while overlapping may be further studied to justify why the 45° lip angle Zee Profiles. Also, the load carrying capacities of the two may be compared. For further simulations, Zee profile with 45° lip angle is considered. However, a range of 30°-60° lip angle Zee Profiles is acceptable.

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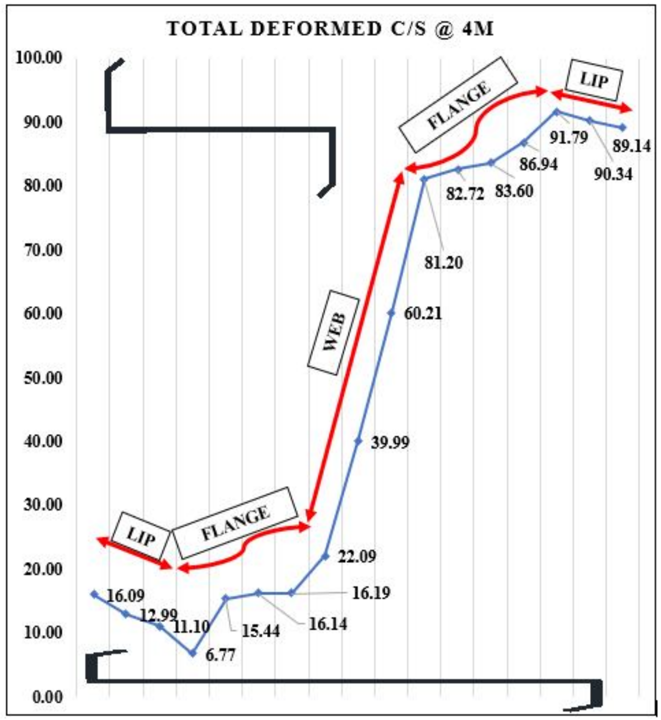

Fig. 3 Portrayal of deformed shape of Zee profile with both flanges unbraced

The portrayal of deformed shape of Zee profile give the deformed shape of Zee profile at a cross-section cut at the midspan length of the member. *(4m)*. The entire cross-section is housed in 17 points. Point 1-2-3 *(16.09-12.99-11.10) mm* house for lower lip, point 3-4-5-6-7 *(11.10-6.77-15.44-16.14-16.19) mm* houses for bottom flange, point 7-8-9-10-11 *(16.19-22.09-39.99-60.21-81.20) mm* house for web, point 11-12-13-14-15 *(81.20-82.72-83.60-86.94-91.79) mm* house for top flange and points 15-16-17 *(91.79-90.34-89.14) mm* houses for upper lip.

III. STUDY DEFORMED SHAPE OF ZEE PROFILE WITHOUT SAG RODS

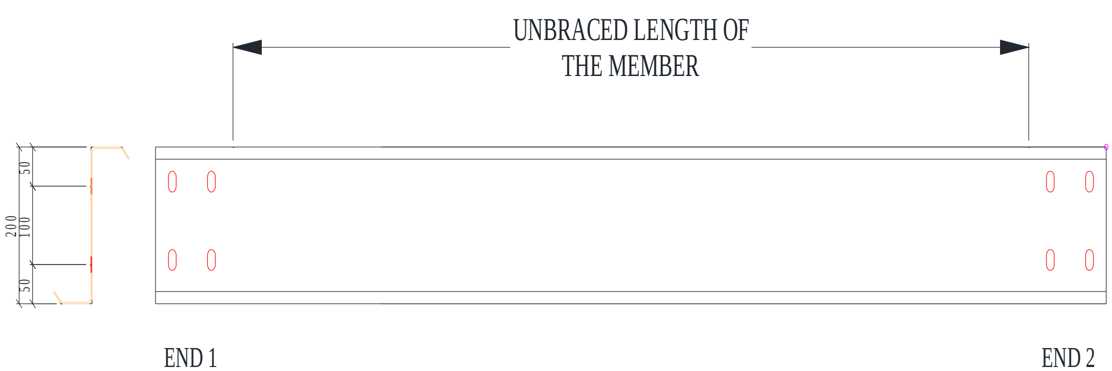

Fig. 4 Geometrical configuration of Zee profile without Sag-rods

To study the deformations at various cross-sections of the Zee profile, six sections have been considered viz., C/S @ 0-0, C/S @ CC *(Connection Centre)*, C/S @ 1M, C/S @ 2M, C/S @ 3M and C/S @ 4M along the length of the member starting from end 1.
From Fig. 5, it is observed that the maximum deformation occurs at midspan at the outer edge of top flange. Local buckling can be observed in both the unbraced flanges. The, web however presents a straight line. Studies suggests that under lateral torsional buckling the cross-sectional elements may show a rigid behaviour. In Fig. 5, the appeared behaviour in the web is rigid like. It is possible for the web element to behave as a rigid body under lateral torsional buckling, which in the above example exist. To ensure the result, a study of deformed shape of only web element is performed.

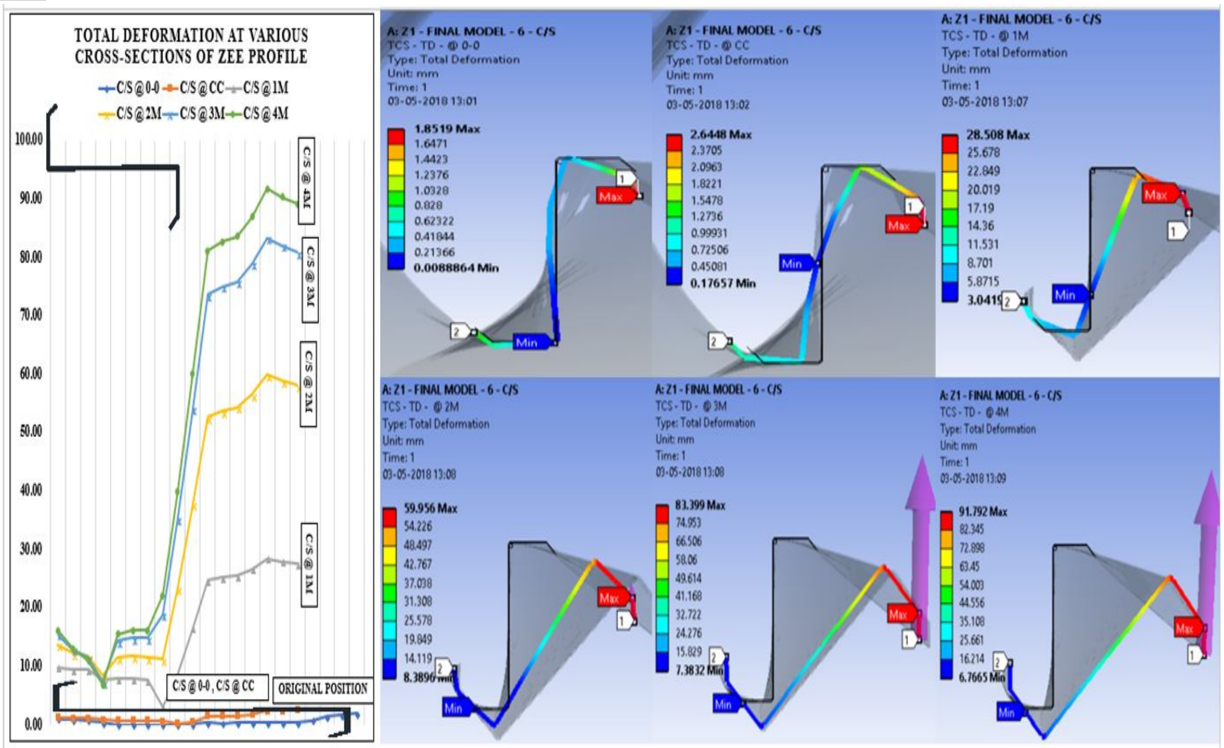

Fig. 5 Total cross-sectional deformation of Zee profile without sag-rods

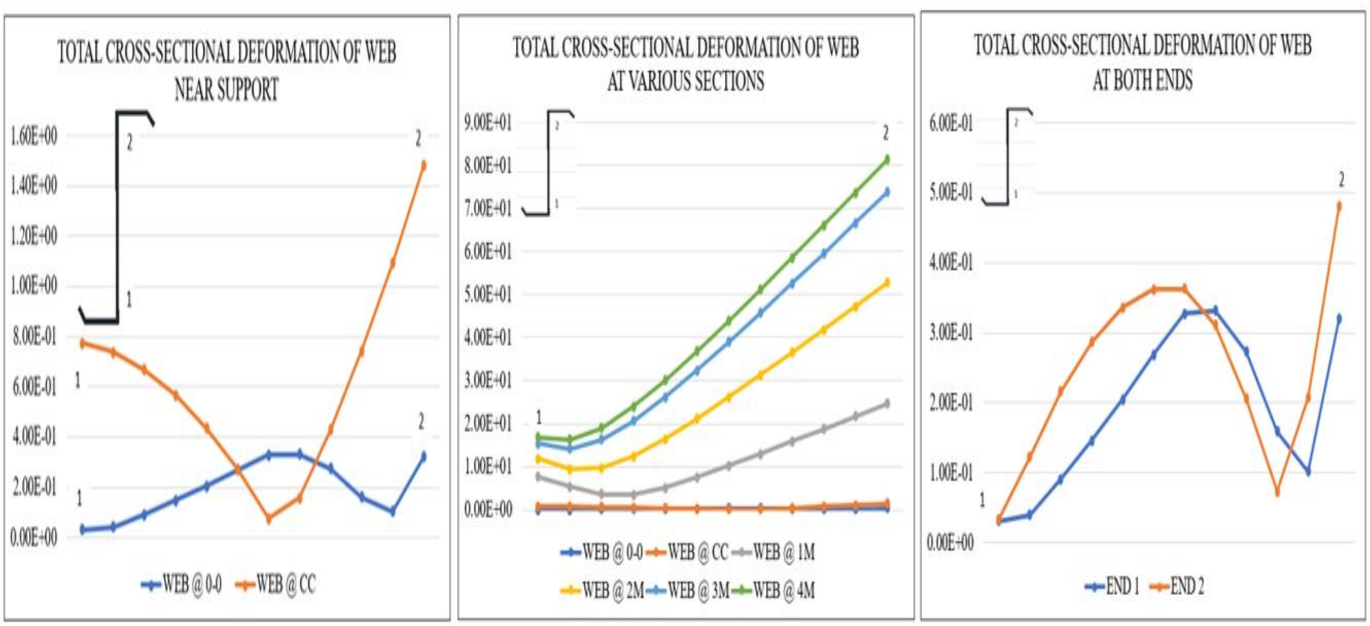

Fig. 6 Local buckling in web of Zee profile at various cross-sections

From Fig. 6, local buckling is observed in the web at C/S @ 0-0 where point 1 is pinned vertex. The maximum total deformation is observed at point 2. It must be noted that, local buckling is observed at the point 1 where the pinned vertex as the name suggests, is restricted to lateral displacements in all directions. From Fig. 5, the rigid cross-sectional behaviour of the web is observed at all the sections subjected lateral torsional displacements. The section WEB @ 0-0 and WEB @ CC has been discussed above. A comparison of web cross-section is done at End 1 and End 2. The behaviour is similar, local buckling is observed. The slight variation in the curvature is the effect of variation in directional deformations (Z-directional deformations causing torsional effect longitudinally).

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IV. STUDY DEFORMED SHAPE OF ZEE PROFILE WITH SAG RODS

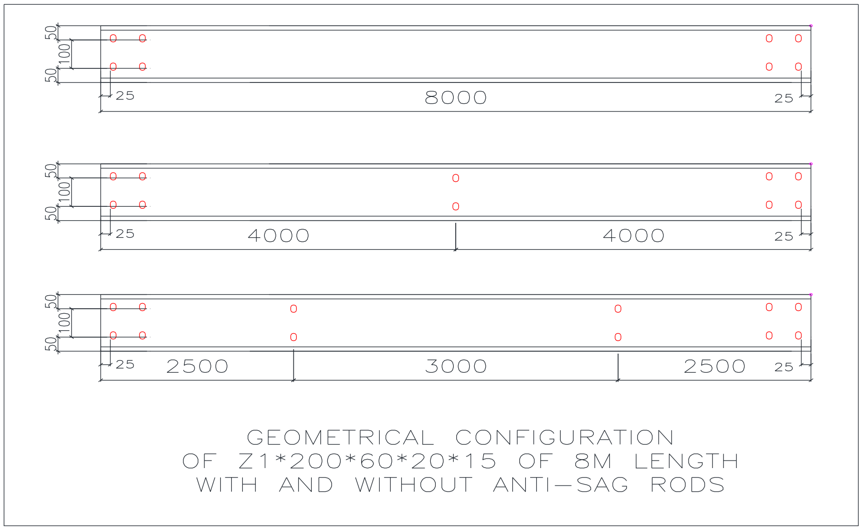

Fig. 7 Geometrical configuration of Zee profile with sag-rods

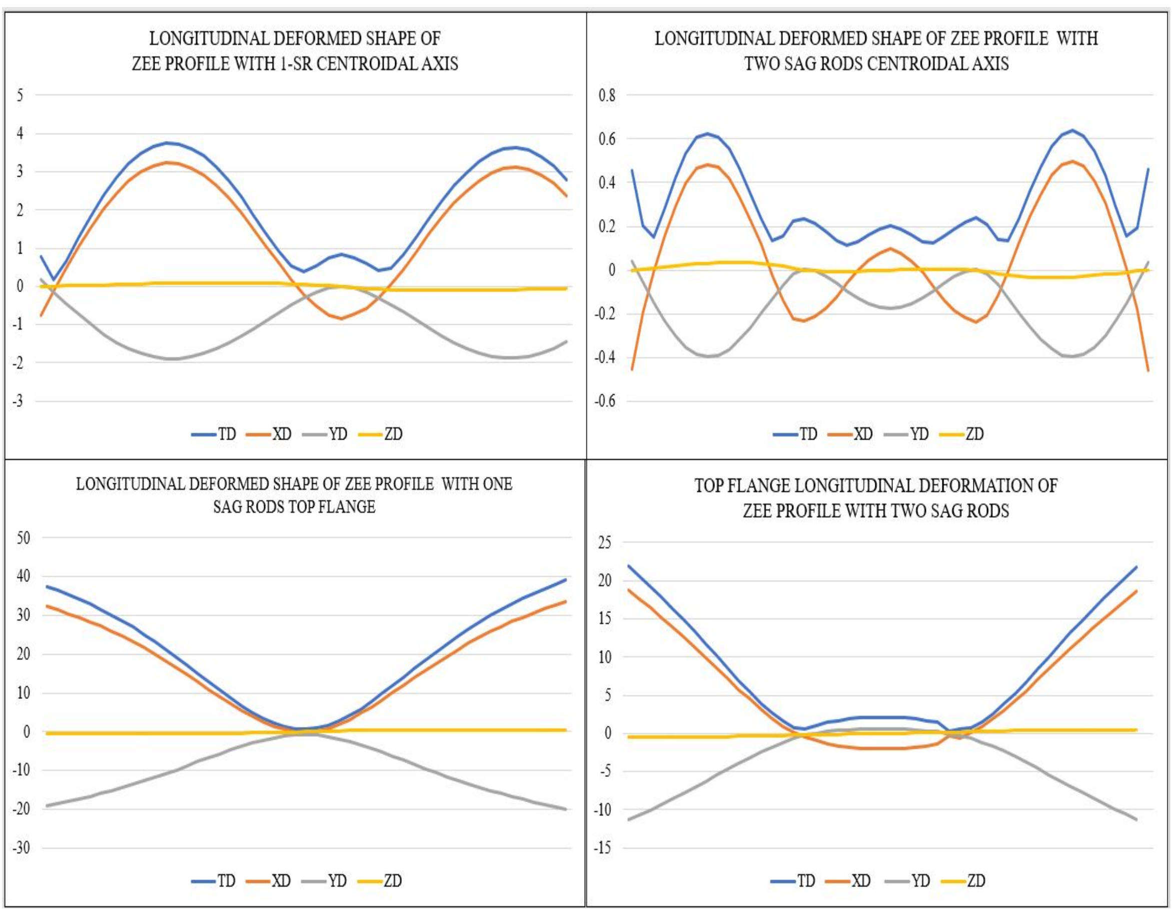

Fig. 8 Longitudinal total deformations of centroidal axis and top flange of Zee profile with 1-SR and 2-SR

1) With one sag rod, the maximum deformation of the member is reduced from 99.917mm to 39.127mm. the maximum total deformation is on the end points with two one rods.
2) Twisting behaviour of the member is observed.
3) Uneven distribution of deformations along length.

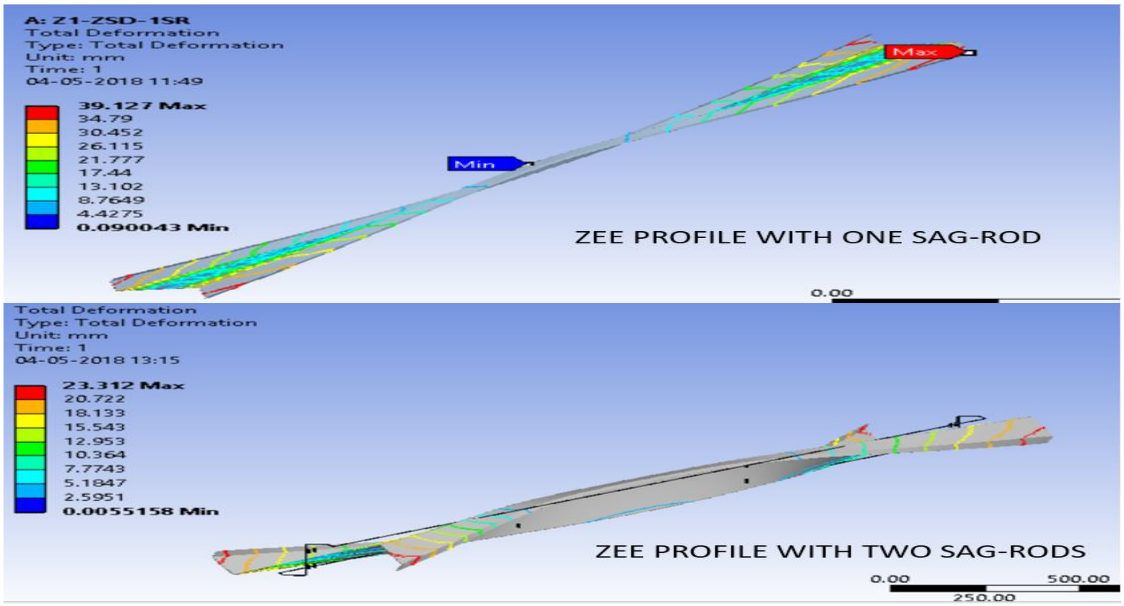

Fig. 9 Twist formed at the ends of the Zee profile showing maximum total deformation

4) With two sag rods, the maximum deformation of the member is reduced from 99.917mm *(with no sag rod)* and 39.127mm *(with two sag rods)* to 23.00mm. The maximum total deformation is on the end points with two sag rods.
5) Twisting behaviour of the member is observed.
6) Even distribution of deformations along length.
7) Maximum deformations on the end points can be taken care of by overlapped section

The comparative study is performed on Zee section profile Z1(200*60*20*15) of 8 metres length.

It is observed that the maximum deformation of Zee profile with one sag rod is at the end points and not on the midspan. That would generate a negative bending moment at the support. This negative bending moment is the peak value of BM in the member. At this junction, the effect of this comparatively huge BM can be reduced with overlap. An overlap at the junction will impart the benefit of doubled cross-sectional area and correspondingly doubled strength.

V. CONCLUSIONS

TABLE III Influence of sag-rods on deformations of Zee profiles

COMPARATIVE STUDY OF ZEE PROFILE WITH AND WITHOUT SAG RODS					
PARAMETER			0-SR	1-SR	2-SR
Total Deformation		Minimum	0.006	0.090	0.006
	mm	Maximum	99.917	39.127	23.312
C/S @ 0-0		Minimum	0.006	0.695	0.466
	mm	Maximum	2.213	37.871	23.005
C/S @ CC		Minimum	0.132	0.492	0.362
	mm	Maximum	3.202	37.459	22.487
C/S @ 4M		Minimum	6.369	0.995	0.183
	mm	Maximum	99.917	0.316	4.023
Centroidal		Minimum	0.561	0.185	0.114
	mm	Maximum	43.989	3.738	0.637
Top Flange Outer Edge		Minimum	1.686	0.752	0.615
	mm	Maximum	99.917	39.127	21.921
Stress		Minimum	0.639	0.777	0.292
	Mpa	Maximum	364.750	271.180	166.940
Strain		Minimum	0.00005	0.00001	0.00001
		Maximum	0.00220	0.00136	0.00084

From TABLE III, it is observed that use of sag-rods not only reduces the total deformations in the Zee profile but also reduces the stresses generated in the member. Use of sag-rods cannot completely eliminate the deformations of slender sections such as Zee sections. But, it can considerably reduce the deformations to the limiting value as prescribed in the codes.

VI. ACKNOWLEDGMENT

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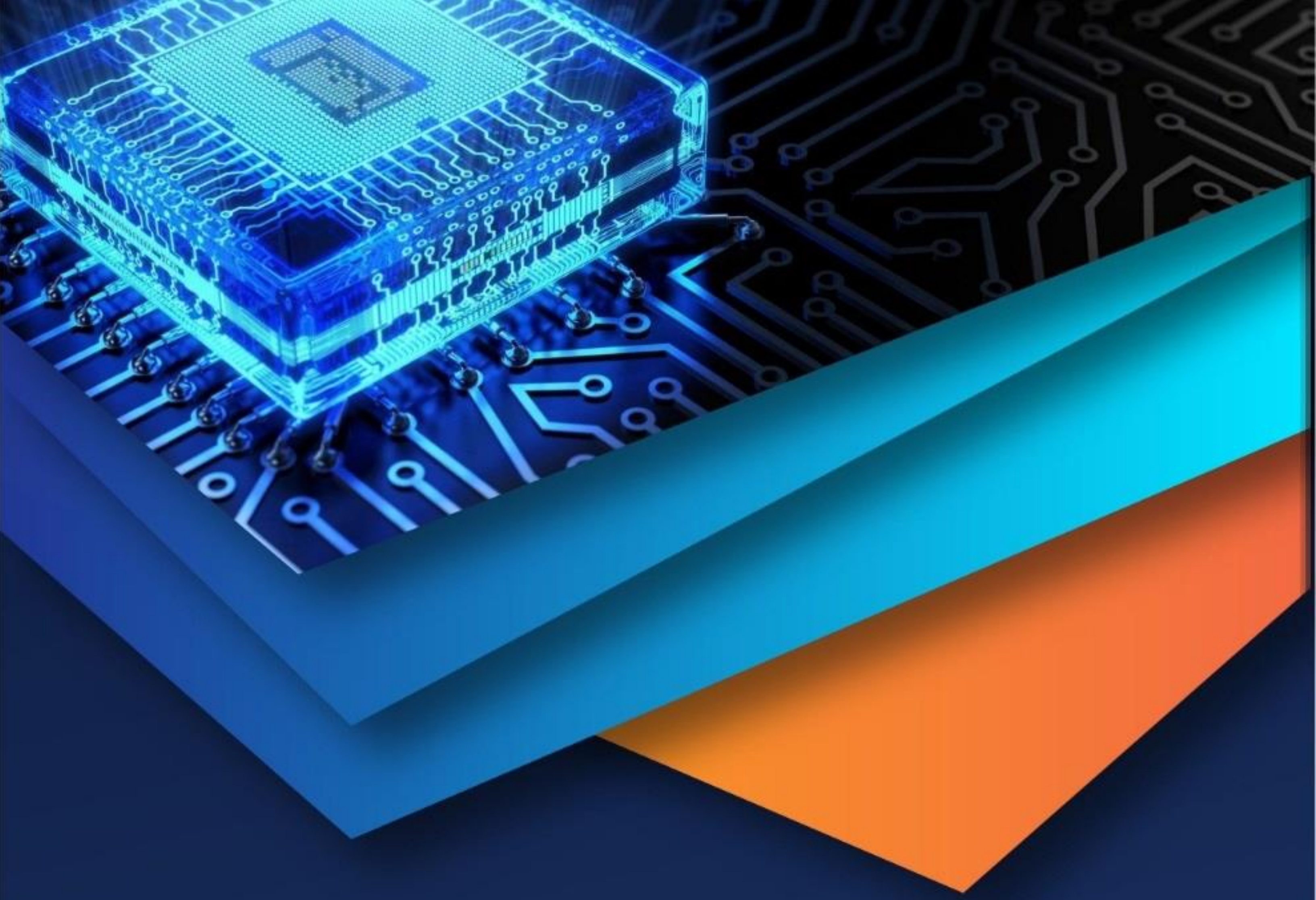

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