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Finite Element Investigation on Buckling Behaviour of Corrugated Web Beams-Ansys Workbench

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Abstract - *Beams with corrugated webs (CWB) have been extensively used in structural applications such as buildings and bridges. It usually comprise of wide thick plate flanges and a thin corrugated web. Under shear action three different modes of shear buckling can be realized in the web they are local, global or interactive. Webs of either trapezoidal, rectangular, triangular or sinusoidal shape are often used. In general, corrugated web beams can be more economical than conventional plate web. A study was conducted to investigate the strength behaviour of trapezoidal curved corrugated beams with different radius of curvature, web thickness& flange thickness. The objective was to compare the buckling strength of plate girders without corrugation and trapezoidally curved corrugated girders. The main advantage of corrugated web beams is the increased buckling resistance without the need to weld stiffeners to the web. This results in a decrease in the beam weight without compromise in strength, with reduction in costs of up to 30% being possible. In bridge construction the requirement for intermediate diaphragms which are used for transverse load transfer can be reduced by using corrugated webs. As a result hybrid bridges of different cross-sections can be constructed.*

Key Words**: *CWB, corrugated web, local, global, interactive***

1. INTRODUCTION

The structural purpose of steel in construction industry are becoming more popular and having higher importance due to their better durability, strength, uniform shapes and simplicity in construction. In steel structure, main issues raised are how to reduce the weight and cost of the component parts such as girder and beams. The inspection of web is usually considered for such requirements by comparing the thickness and the shape. Web in the beam carries most of the compressive stress and transmits shear. Major external loads are supported by flanges. It can decrease the cost and materials without reducing the load-carrying capacity of the beam. For the design of girders and beams thin web is efficient and economical. However, the sections have to be slender to carry the moments, and these slender section will cause the web buckling. Hence to avoid this buckling, corrugations to the web are used. The main purpose of using corrugated web is that no stiffening is needed because it permits the use of thinner plates. Hence it considerably reduces the cost of beam fabrication with improved weight saving. The corrugated profile in the web provides a kind of uniformly distributed stiffening in the transverse direction of a girder, which increases the ultimate strength and out-of-plane stiffness. This can be explained in detail. The I section beams are commonly used in structural steel works. Ordinary shapes of these beams are produced from two parallel flanges and a web where about 30–40% of the entire weight of a medium flange width or narrow flange type of beam is contributed by the web .In construction application, the web usually bears most of the compressive stress and transmits shear in the beam while the flanges support the major external loads. Thus, by using thinner web and greater part of the material for the flanges, materials saving could be achieved without weakening the load carrying capacity of the beam.

1.1 Corrugated web Beam

A corrugated web beam is a built-up beam consists of thin walled corrugated web. The profiling of the web avoids the failure of the beam due to loss of stability before the plastic limit loading of the web is arrived. The use of corrugated webs is a method to achieve adequate out-of plane stiffness and shear bulking resistance without using stiffeners. Corrugated web beams are fabricated by using two steel plates which acts as flanges and a corrugated steel sheet as web are welded to form a beam. An idea of using corrugated metal sheet for webs of plate girders emerged as early as in the 1930s. It was observed that sheet folds perpendicular to flanges produced web stiffening, which significantly increased critical stress, thus allowing the use of slender walls. Starting from the 1960s, the fabrication of plate girders with web folds located parallel to beam axes was considered. Such an orientation of the web folds, however, made it necessary to for transverse stiffeners to be welded into each site a concentrated load occurred. This disadvantage was not found in plate girders with webs, the folds of which were perpendicular to the flanges. As appropriate welding technologies were not available then, girders of that type did not become widely used. Fabrication automation in the late 1980s early 1990s made large-scale use of such girders possible. Currently, corrugated web I-girders are most commonly employed in the load carrying structures of single- or two-bay buildings. Figure 1 shows corrugated web beam used in single storey. The girders available on the market have webs that are 2.0, 2.5 and 3.0 mm in thickness and vary from 333 to 1500 mm in height. The mill-guaranteed yield strength of corrugated web steel is fy = 215N/mm^2.

Fig – 1 Corrugated Web Beam

1.2 Corrugation Profiles

The web of the girders can be corrugated using different profiles like rectangular corrugated web, trapezoidally corrugated web, sinusoidal corrugated web, etc. The aesthetics of the different configurations is completely different, but also the fabrication, the mechanical behaviour and the price of the different types have to be taken in account when making a choice for one of them. The thinner trapezoidally corrugated web beam section provides a higher resistance against bending and higher load carrying capacity besides more cost economical when compared with other types. Among these types trapezoidal corrugated profile has the maximum load carrying capacity

1.3 Objective of the Work

To conduct nonlinear static analysis of trapezoidally curved corrugated web beams with different parameters using ANSYS WORK BENCH 16.1 To compare the buckling strength of plate girders without corrugation and trapezoidally curved corrugated girders To compare buckling strength, stiffness and weight of corrugated web beams in straight and curved profiles and straight beam with flat web.

2 .VALIDATION

Based on the experimental investigation done by B Kovesdi, L. Dunai[12]"Determination of the patch loading resistance of girders with corrugated webs using nonlinear finite element analysis" validation is performed. The aim of previous study is to determine the patch loading resistance by different geometrical arrangements, loading lengths and loading positions by experimental and FEA.

Table -1: Properties of beam for validation

hw	500 mm
tw	6 mm
bf	225 mm
tf	20 mm
Fyw	379N/mm^2
fyb	373N/mm^2
Young's modulus(E)	2x10^{5}N/mm^2
Poisson's ratio	0.3
Length of the beam	1500 mm
Loading length	90 mm

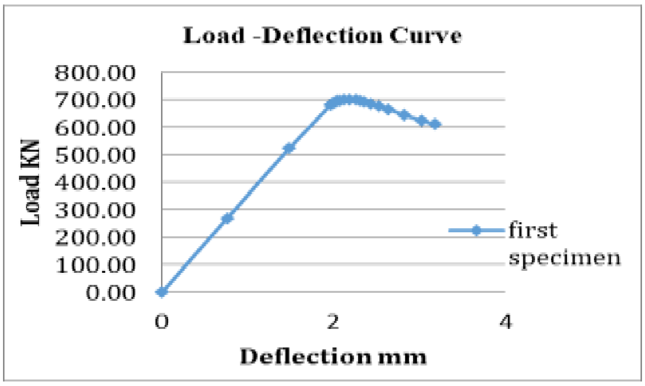

Chart -1: Load Deflection Curve of Validated Beam

Table -2: Comparison of validation result

	Patch loading Resistance (KN)
Previous Experimental Study	754.2
Validated result from ANSYS WORKBENCH 16.1	702
% Variation = 6.89	

The result which is obtained from ANSYS WORKBENCH 16.1 is approximately same as the results which is obtained from experimental investigation in previous study. Thus the ANSYS model is validated.

3. MODELLING OF TRAPEZOIDAL CORRUGATED CURVED BEAMS

The material properties of beam and geometry of trapezoidal section is same as that in the validated corrugated web beam. But the span is taken as 4.5m.

i. Variation in radius of curvature

ii. Variation in web thickness

iii. Variation in flange thickness

iv. Straight beam with corrugation

v. Straight beam without corrugation

3.1 Variation in Radius of Curvature

According to the material properties, trapezoidal curved corrugated web beams are modelled. Radius of curvature is chosen like 8000mm, 10000mm& 12000mm respectively. Geometry of the beam model and total deformation is shown in figure 2&figure 3respectively.

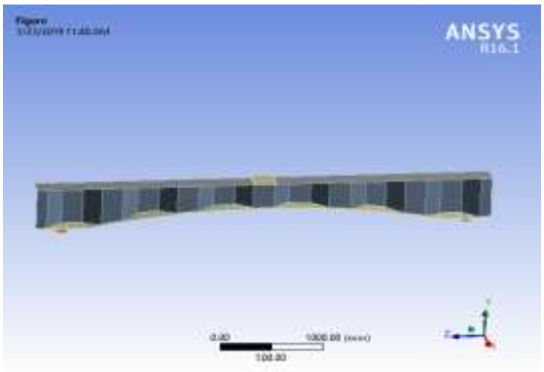

Fig -2: Geometry of TCC8

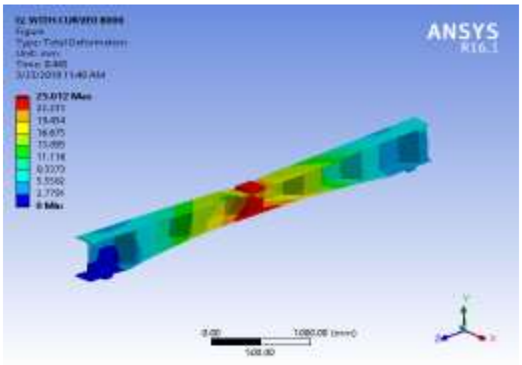

Fig-3: Total Deformation Sof TCC8

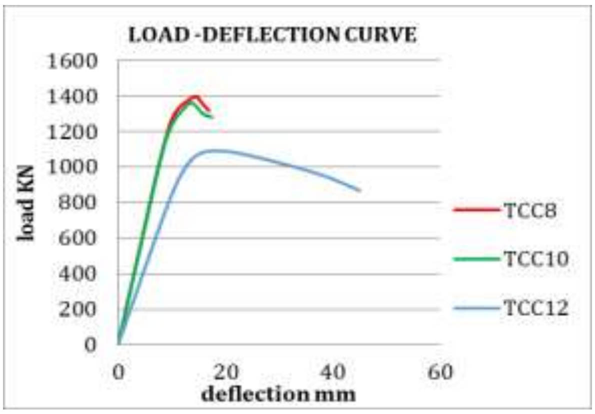

Chart-2: Combined Load Deflection curve

From the above chart 2 it can be understand that TCC10 has the maximum load carrying capacity and maximum stiffness compared with others.so this radius of curvature is provided for modelling of all other beams.

3.2 Variation in web thickness

According to the material properties, trapezoidal curved corrugated web beams are modelled. Web thickness is chosen like 4mm, 6mm, 8mm, 10mm, and 12mm respectively.

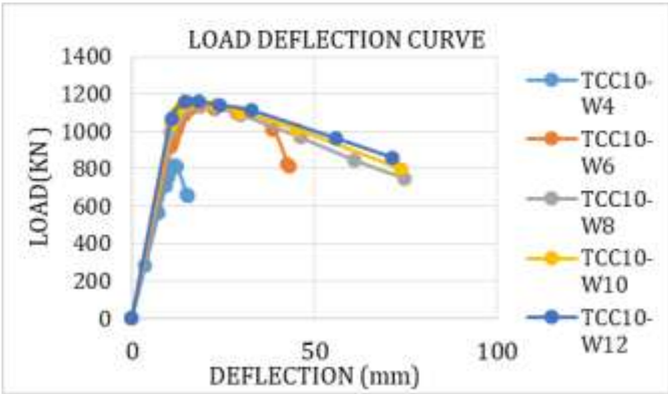

Chart-3: Combined Load Deflection curve

From the above chart 3, it can be understand that, at the starting point beam with 4mm web thickness has maximum stiffness. But the beam fails at a smaller load.as the web thickness increases up to 12mm and it can be notice that load carrying capacity and stiffness increases. It can be conclude that as the web thickness increases load carrying capacity also increases.

3.3 Variation in flange thickness

According to the material properties, trapezoidal curved corrugated web beams are modelled. Web thickness is chosen like 4mm, 6mm, 8mm, 10mm, and 12mm respectively.

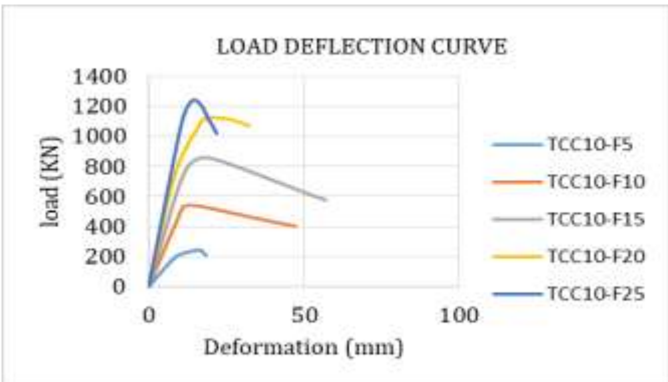

Chart-4: Combined Load Deflection curve

From the above chart 4 it can be understand that, beam with 10mm flange thickness has increased stiffness. But the beam fails at a smaller load.as the flange thickness increases up to 25mm, it can be notice that load carrying capacity and stiffness increases compared with beam with 15mm & 20mm flange thickness.

3.4 Straight Beam with Corrugation (SBC)

For making comparison with curved corrugated beams, straight beam with corrugation and straight beam without corrugation are modelled and analysed. Figure 4 shows the modelling details

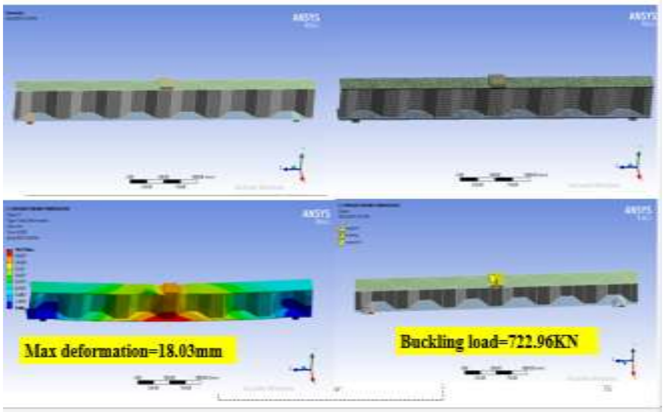

Fig-4: Geometry, Meshed Model, Maximum Deformation &Buckling Load of SBC

Beam fails at a load of 722.96KN and the corresponding deformation is 18.03mm.

3.4 Straight Beam Without Corrugation (SBWC)

Figure 5 shows the modelling details of straight beam without corrugation.

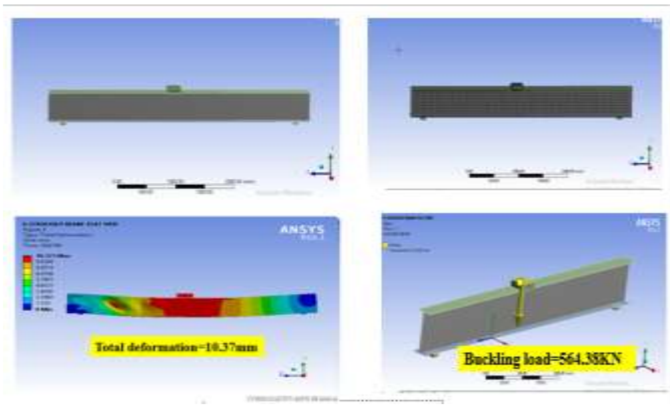

Fig-4: Geometry, Meshed Model, Maximum Deformation & Buckling Load of SBWC

Here buckling load is obtained as 564.38KN and the corresponding deformation is 10.37mm. Curved corrugated web beam having 6mm web thickness and 20mm flange thickness is used for comparing straight beam with corrugation and straight beam without corrugation.

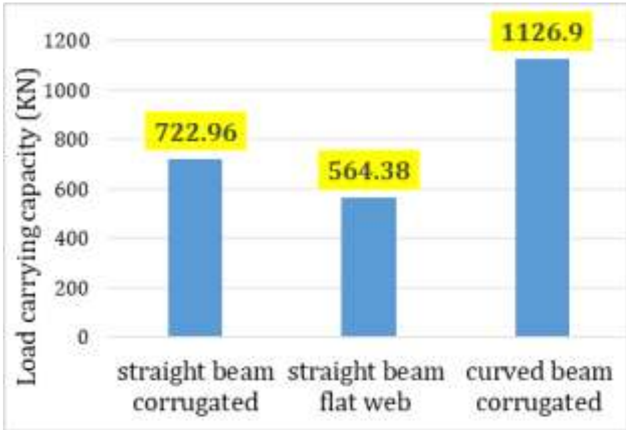

Chart-4: Comparison of Load Carrying Capacity

Load carrying capacity of straight beam with flat web, straight beam with corrugation & curved beam with corrugation are compared. Corrugated curved beam has the maximum load carrying capacity compared with the other two beam. Straight beam without corrugation has the lowest load carrying capacity. Introduction of curvature further enhanced the load carrying capacity.

Table -3: Results

No.	Models	Buckling Load (KN)	Deformation (Mm)	Weight (N)
1	TCC8	897.69	25.012	3598.46
2	TCC10	1128.4	18.69	4490.06
3	TCC12	1087.1	19.48	4800.34
4	TCC10-W4	813.82	12.39	4160.8
5	TCC10-W6	1128.4	18.69	4494.64
6	TCC10-W8	1144.2	18.556	4828.4
7	TCC10-W10	1153.4	18.546	5162.41
8	TCC10-W12	1160.5	18.441	5496.2
9	TCC10-F5	244.96	16.39	2147.8
10	TCC10-F10	541.91	12.376	2930.14

11	TCC10-F15	854.84	19.811	3712.39
12	TCC10-F20	1126.9	20.639	3800.34
13	TCC10-F25	1235.1	14.309	5276.89
14	SBC	722.96	18.03	3520.71
15	SBWC	564.38	10.37	2980.41

From table 3, Curved corrugated beam has the maximum weight compared with others. But curved corrugated girder doesn't require stiffners.so this weight will not be a problem. More stiffeners are required in case of straight beam without corrugation. The main purpose of using corrugated web is that it permits the use of thinner plates which require no stiffening; hence it considerably reduces the cost of beam fabrication with significant weight saving.

4. CONCLUSIONS

Validation is performed and the models are validated and 6.89%variation is found. Curved trapezoidal corrugated beam of radius of curvature 8000mm, 10000mm, 12000mm are modelled and analysed.10000mm radius of curvature have maximum load carrying capacity. Curved trapezoidal corrugated beam of radius of curvature 10000mm having 4mm, 6mm, 8mm, 10mm &12mm web thickness are modelled and analysed. Beam with 12mm web thickness have maximum load carrying capacity compared with other beams. As the web thickness increases total weight also increases, so optimum web thickness is taken for economical construction. Curved trapezoidal corrugated beam of radius of curvature 10000mm having 5mm, 10mm, 15mm, 20mm & 25mm flange thickness are modelled and analysed. Beam with 25mm web thickness have maximum load carrying capacity compared with other beams. For economical construction optimum flange thickness can be used. Load carrying capacity of straight beam with flat web, straight beam with corrugation & curved beam with corrugation are compared. Load carrying capacity of straight beam corrugated is 21.93% greater than straight beam with flat web. Load carrying capacity of curved beam corrugated is 49.91% significantly higher than straight beam with flat web. Load carrying capacity of curved beam corrugated is 35.84% greater than straight beam corrugated. So it can be conclude that curved corrugated web beams has enhanced load carrying capacity in comparison with straight beam with corrugation and straight beam without corrugation.

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