Load Carrying Capacity Of Corrugated Web Beam

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Abstract - *A corrugated web beam is a built-up beam with 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 reached. The use of corrugated webs is a potential method to achieve adequate out of plane stiffness and bending resistance without using stiffeners. There are different types of corrugated web profiles such as triangular, trapezoidal, semi-circular etc. The study deals with a semi-circular corrugated web beam. The load carrying capacity of the beam is studied under different cases by performing a non-linear static analysis using commercial finite element software ANSYS 15.0 finite element software. There are many parameters that influence the bending and buckling behaviour of the corrugated web profile steel section such as web thickness(t_w), depth of web (d) and corrugation radius (r_o). This study is to investigate the static behaviour of semi-circular corrugated web beams by varying the corrugation radius.*

Key Words: **ANSYS, Corrugated Web, Corrugation Radius, Load Carrying Capacity, Finite Element Analysis, SOLID 185**

1.INTRODUCTION

In structural and fabrication technology, new techniques of optimized steel structure design have been developed. One of the developments in steel structure design is the introduction of corrugated web beams. Beams in bending develop tension and compression in their flange. Beams generally carry vertical gravitational forces but can also be used to carry horizontal loads (i.e., loads due to an earthquake or wind). The loads carried by a beam are transferred to columns, walls or girders, which then transfer the force to adjacent structural compression member.

Beams with corrugated webs have been used in buildings and bridges, and have been proven to be economical. The use of corrugated webs allows for the use of thinner beams without the need for stiffeners, thus, considerably reduce the cost of beam fabrication and improves its fatigue life[8]. Welding of intermediate stiffeners could add to the fabrication cost and result in increase of the self weight of the girder. Use of stiffeners could, however, be eliminated if corrugated webs are used instead of plain web plates.

The corrugated profile in the web provides a kind of uniformly distributed stiffening in the transverse direction of a girder, which increases the out-of-plane stiffness and ultimate strength. This can be explained in detail. The I-section beams or H-piles are commonly used in structural steel works. Ordinary shapes of these beams are constructed 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[9]. 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 greater part of the material for the flanges and thinner web, materials saving could be achieved without weakening the load-carrying capability of the beam. Nevertheless, as the compressive stress in the web exceed the critical point prior to the occurrence of yielding, the flat web loses its stability and deforms transversely[1],[2]. This could be improved by using corrugated web, an alternative to the plane web, which produces higher stability and strength without additional stiffening and use of larger thickness.

The general shape-rolling process adopted for the ordinary beams with flat web cannot be implemented for the trapezoidal or triangular corrugated web type. At present, the web is welded continuously at the joints on the two flanges that produce an I-cross section. Nevertheless, strong joints could hardly be produced for beams with thinner web, even by the use of state of art welding technology that could possibly do the job. Higher cost will certainly be incurred that make it impractical especially for a longer span. Thus, the curve wave-like corrugation was introduced to substitute the trapezoidal and triangular corrugation, as it seems more suitable to be manufactured. However, to date, the same welding method is being used in producing this corrugation shape where the hot rolled beam of the similar type has not yet been produced by any manufacturer. Although, few successful laboratory trials have been seen in some research works, but the design of the roll process and tools are not fully addressed[3],[4].

The objectives of this work is to find the load carrying capacity of a corrugated web beam of given corrugation radius and to conduct a comparative study by comparing it with an ordinary flat web I-beam of same span. A typical semi-circular corrugated web beam is as shown in fig 1.

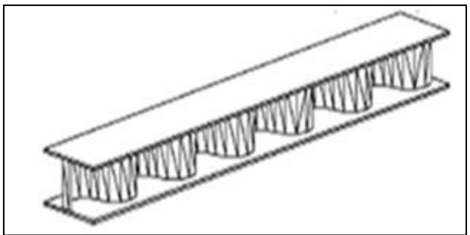

Fig-1: Semi-circular corrugated beam

2. FINITE ELEMENT ANALYSIS

The main objective of this is the study of corrugated steel beams by analyzing a semi - circular corrugated web beam and comparing the results with the experimental data. A non-linear analysis with incremental load acting is conducted to obtain the load-deflection curve. The analysis has been conducted based on the details from et al Khalid[4].

The geometry of the beam consists of a flange and a web. The various geometric attributes are listed below

Length of the beam- 600mm
overall depth of beam, d - 106mm
thickness of the flange, t_f - 6mm
width of the flange, b_f - 75mm
thickness of the web, t_w - 4mm
radius of corrugation, r_0 - 24.50mm

The comparison between experimental and finite element analysis is plotted graphically as shown in fig.2. On comparing the ultimate loads in both cases an error of 17.21% was encountered. This is mainly attributed to the amount of welding applied on the joints and also extreme heats produced in welding process, which could change the mechanical behaviour of the beam.

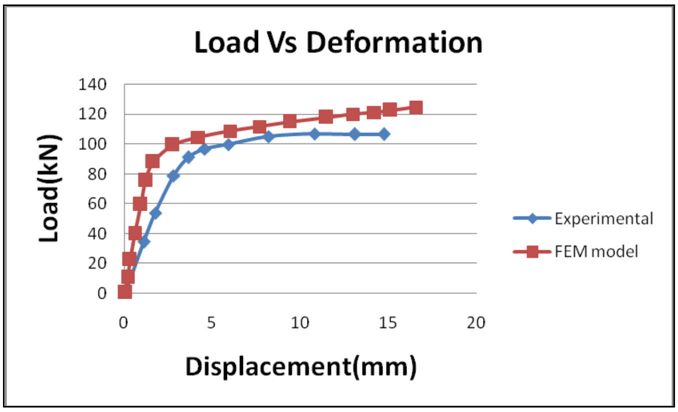

Fig -2: Load Vs Displacement

The models are built with three-dimensional ANSYS solid element SOLID 185, by incorporating all the nodes, element, material properties, dimensions and boundary conditions. It is defined by eight nodes having three degrees of freedom at each node: translations in the nodal x, y, and z directions. In addition, this element is well suited for modelling the large deflection of steel plates. The geometric boundaries of the corrugated web beam such as flange width, web height and beam length, etc. are easily incorporated in this solid element. Moreover, both in-plane and normal loads are permitted and a consistent tangent stiffness matrix option is available for use in large deflection analyses. Solid 185 has the advantage that it can follow a curved surface (semi-circular beam). This element avoids the problem deriving from the high order solid element degeneration to the shape of pyramid, for which the due consideration should be given so as to minimize the stress gradients.

3. COMPARATIVE STUDY

3.1 Geometry

A corrugation radius of 30mm radius and an ordinary plane web I beam section were modelled and analysed to develop the benchmark results. The geometric parameters are shown in the table 1[4].

3.2. Material Property

For the materials attributes, the elasto-plastic isotropic stress potential model was adopted throughout this study. It is a non-linear Von Mises material model applicable to a general multi-axial stress state and supports three hardening

Table-1:Geometric Properties

Model	Length Of Beam L(mm)	Overall Depth Of Beam(mm)	Thickness of Flange t_f(mm)	Width of Flange b_{ff}mm)	Thickness of Web t_w(mm)	Radius of corrugation r_o(mm)
sc_30	600	106	6	75	4	30
I-section	600	106	6	75	4	---

definitions. The modulus of elasticity (E = 200 N/mm^2) and the Poisson ratio (ν = 0.3) have been used as the elastic input data, while the other required material properties are shown in table 2[1],[2],[3],[4].

The flanges are made from a flat bar section(M2) and the web is made from pipe section(M3). A bilinear material property is adopted.

Table-2: Material Property

Material	Designation	E(kN/mm^2)	σy(N/mm^2)
Flat Bar	M2	200	346.4
Pipe	M3	200	322

3.3 Loads and Boundary Conditions

A Point load was applied in the negative Y-direction (Global Y) on the line feature along the centre line of the beam span at an equal distance from both the supported ends. It should be emphasized that the load was applied in the same direction as occurred in the experimental tests where during loading the movement was governed by the machine's jacks in a single direction. The model is simply supported at the ends.

4. RESULTS AND DISCUSSIONS

The various results obtained from the finite element analysis were compared to verify the finite element models created and to see if it could closely reflect the behaviour of such beams in the real condition. Nevertheless, the failure mechanism of the finite element models may show a slight difference compared to the experimentally tested beams due to the idealistic behaviour of the models.

4.1 Load Vs Deformation

The relationship between load and maximum deflection at mid span under the action of concentrated load for different radius of corrugation for the beams with corrugated web and equivalent flat web are shown in fig 3.

The load-deflection curves of the steel beams with plain web and corrugated web are shown in Figure 2 . The specimens with plain web I section, failed at a load of 106.31 kN with a central deflection of 13.65 mm and the other specimen, sc_30 failed at an average load of 125.881kN with the corresponding average deflection of 16.834mm.

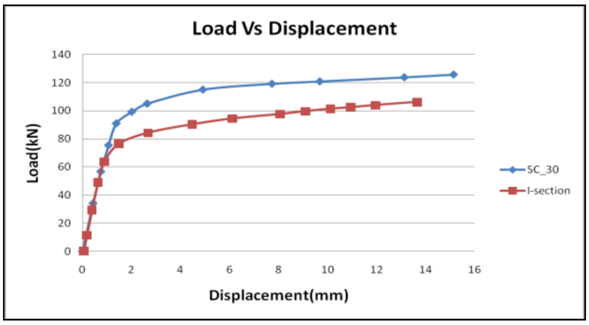

Fig 3: Load Vs Deformation

4.2 Strength Capacity Of Specimens

The trajectory of strength capacity of the specimens is shown in Figure 4. For the specimens with given thickness, the load carrying capacity of the beam having corrugated web is 18.41% more than the specimens having plain I - web respectively.

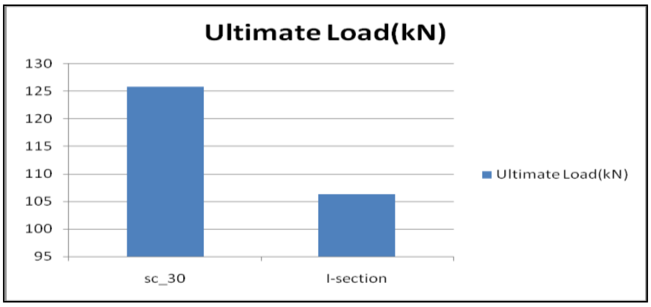

Fig 4: Comparison in strength

5. CONCLUSIONS

Different types of corrugation profiles and their significance were observed. A detailed study on previous literature was conducted which gave a clear idea on the methods of numerical and experimental analysis, the softwares used and the difference in behavior under loads among the different types of corrugations, specifically semi-circular corrugations. Solid 185 of ANSYS element family has been used for analyzing the corrugated web beam. The Properties of the element were studied in detail. The Geometric properties of the corrugated beam was studied and the dimensions of the model were fixed.

The load carrying capacity of structural beams with semicircular corrugated webs vertical directions has been studied computationally using a non-linear finite element software ANSYS 15.0. The effects of web corrugation to the load capacity were reported. Comparisons of results were also made between both methods of study to evaluate the accuracy of the developed finite element model. Based on results obtained, the following conclusions are drawn:

1. The beams with semi-circular corrugated web could sustain 18.41% higher load than the geometrical identical plane web I-beams under three point bending, within the range of corrugation radius taken.

2. The bending capacity of structural beams is further enhanced by using corrugated web.

However, the design of beams with semicircular corrugation profile is limited by the flange's width and cycle length. Thus, the corrugation sizes need to be optimised in order to accommodate wider range of applications and considering the manufacturability of these corrugated web beams. Finally, the influences of variables such as the flange thickness and material properties, cycle length and amplitude, and mode of analysis are areas open for future research.

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