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# INVESTIGATION ON THE BEHAVIOUR OF ENCASED COLD-FORMED STEEL BEAM WITH TRAPEZOIDALLY CORRUGATED WEB

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## ABSTRACT

Built-up I-sections have been extensively used whenever standard I-sections could not satisfy the moment carrying and shear capacities required. In these built up sections it has been common practice to use more steel in webs rather flanges. In this paper it has been proposed to study the behaviour of encased cold-formed corrugated web beam. In these built up sections it common practice to use more steel in webs rather flanges. This results in uneconomical sections as steel is an expensive material. So introducing corrugated profile in web reduced the web instability and also the need for providing transverse stiffeners. But, even after corrugated webs and lateral stiffeners in unison effects like lateral torsional buckling were observed. Thus measures other than providing conventional transverse stiffeners and corrugated webs were to be found. Encasing the corrugated web of steel beam could improve the resistance to transverse deflections.

**Key words**: Encased, Cold-formed, Built up, Corrugated Web, Lateral-torsional buckling.

## INTRODUCTION

Light gauge elements have been used for built-up beams and in case of heavy loads thickness of the web plate required is more and also intermediate stiffener plates are to be used in case of heavy loads. So the dead weight of the structure increases. To reduce this and improve the structural efficiency, corrugated plates may be used. The use of corrugated webs is potential method to achieve adequate out-of plane stiffness and shear bulking resistance using without using stiffeners. Therefore, further lateral restraints have to be provided to control lateral buckling. But, lateral restraints cannot be further provided in the form of steel stiffeners because of limitation in welding in corrugated web. Thus, corrugated web encased

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with concrete can be used as a effective lateral restraint and further increasing load carrying capacity of beam. Additionally, the concrete acts as cover for the web and improves the fire resistance of the beam.

## Corrugated webs

A corrugated web beam is a built-up girder with thin walled corrugated webs and flange plates. The profiling of the webs avoids the failure of the beam due to loss of stability before plastic limit loading of the webs is reached. The primary characteristics of corrugated steel plates are negligible bending capacity and adequate out of plane stiffness. To take advantage of these characteristics, the corrugated steel plates have been considered an alternative to conventional concrete or steel girder webs. When used as the web, the corrugated steel web carries the vertical shear. The flanges carry the moment due to accordion effect.

Corrugated web beams have the potential to eliminate many costly web stiffeners. In addition, the use of thinner webs result in less raw material usage thus resulting cost savings estimated about 10-30% compared to conventional built-up sections and more than 30% compares to standard I-beams. A trapezoidally corrugated steel plate is composed of series of plane and inclined sub-panels. Fig. 1 shows a cross section of the trapezoidal corrugated girder with the variable quantities. An increase of the angle θ between the diagonal and the parallel strip of the web, causes the increase of the bending stiffness of the girder, but it also leads to a higher use of steel. The angle is also an important factor in the local and global buckling behaviour of the web girder. An important quantity of the cross section is the width of the web ‘a’, because it has an influence on the magnitude to transversal moments on flanges.

## Review of literature

Sedky Abdullah Tohamy et al.[1], studied the numerical analysis using ANSYS software on the efficiency of plate girder with corrugated web and found that the plate girder with trapezoidally corrugated web with $30^0$ corrugation has a higher load-carrying capacity compared with other corrugation angle. The lateral-torsional buckling of hot-rolled steel plate girder with corrugated webs numerically analysis using ANSYS. It was concluded that the lateral torsional buckling of corrugated web is better performed when compare with the models without corrugation. Kazemi Nia Korrani and Molanaei[2]. Investigation the lateral torsional buckling of trapezoid web profile. She also performed lateral torsional buckling

tests on two beams with normal flat web and two beams with trapezoid web profile. The experimental results of encased trapezoidally corrugated web and that of plain web are compared Lincy P. Abraham et al.[3] and concluded that encased corrugated web of steel beam with concrete could improve the resistance to transverse deflections. The ductility of cold-formed steel beam with plain web and corrugated web is compared with that of encased trapezoidally corrugated web Divahar and Joanna[4]. It is found that the beam with encased trapezoidally web not only increases the moment carrying capacity but also the ductility. Studied the moment carrying capacity of cold-formed steel beam with plain web is studied and compared with the capacity of beam with trapezoidally corrugated web having $30^0$ and $45^0$ corrugations Divahar et al.[5]

It is found that the cold-formed steel beam with trapezoidally corrugated web having $30^0$ corrugations have higher moment carrying capacity when compared with the beams having plain web and $45^0$ corrugated web. Korrani et al.[6] studied, the lateral-torsional buckling of hot-rolled steel plate girder with corrugated webs numerically using ANSYS software. It was concluded that the lateral torsional buckling of girder with corrugated web was less than the girder without corrugated web. Luo and Edlund et al.[7] studied, the shear capacity of hot rolled steel plate girders with trapezoidally corrugated webs numerically using a non-linear finite element method. It was concluded that the shear capacity increases slightly as the corrugation angle increases from $30^0$ to $60^0$. Ibrahim et al.[8] investigated the behaviour of hot-rolled steel plate girders with trapezoidally corrugated webs under fatigue loading. Girders were analysed under monotonic and cyclic four-point loading arrangements. It was concluded that the fatigue life of plate girders with corrugated webs have higher values, than the conventionally stiffened plate girders with full-depth stiffener.

## Test setup

The test specimens consist of cold-formed steel beams with plain web, corrugated web and encased corrugated web having $30^0$ corrugations. The span of the beam was 2000 mm and the cross sections of the I-beams are 200 mm x 100 mm x 2.5 mm. The yield strength of steel used is 330 N/mm$^2$ and encased with M30 grade concrete. The cold-formed steel beam is built up by welding the flanges and the web using intermittent welds of 4 mm thick. A pair of stiffeners was provided at both the load points to minimize local effect due to concentrated loads. Fig. 1 shows the fabricated specimens and Table 1 shows the details of the beams tested. A seven lettered designation is given to the specimens. First 4 letters represents the nature of web whether it is plain or corrugated or encased with concrete, $5^{th}$ one indicates the degree of corrugation of the web, $6^{th}$ one represents the depth of the beam

and the last one identifies the specimen in a particular series as two specimens were tested in each series. Fig. 2 shows the experimental setup.

**Fig. 1: Fabricated specimens**

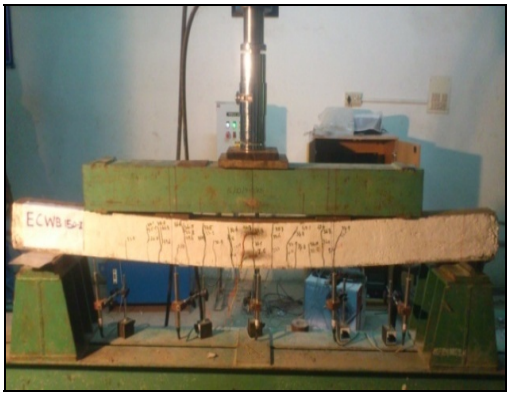
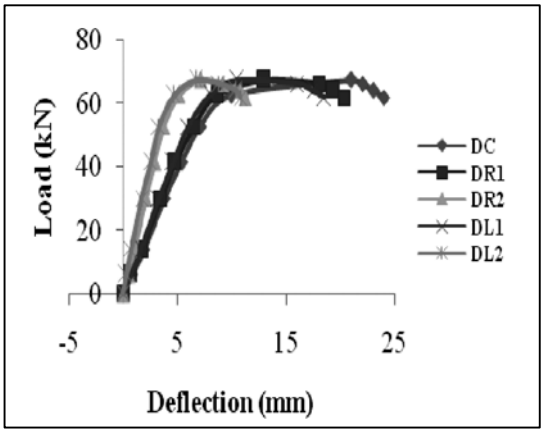


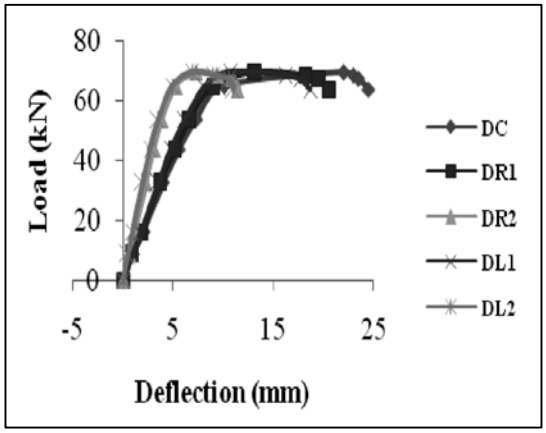
**Fig. 2: Experimental setup**

## Load-deflection behaviour of the specimens

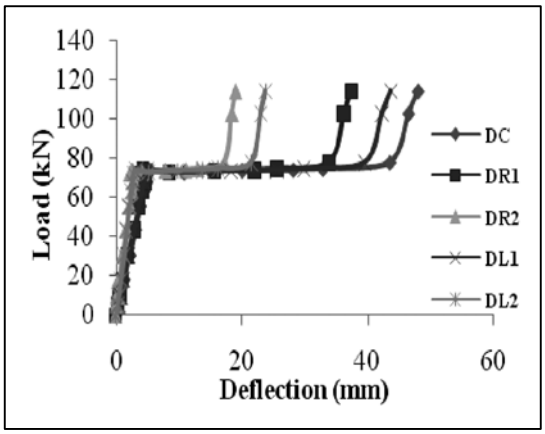
The experimental load-deflection curves of six concrete encased cold-formed steel beams with plain webs and corrugated webs are shown in Fig. 3 (a)-(f). The specimens with plain web EPWB $0^0$, 200-1 & 2 failed at an average load of 68.65 kN with a central deflection of 21.5 mm. The other specimens ECWB $30^0$, 200-1 & 2 and ECWB $45^0$,200-1 & 2 failed at an average loads of 74.65 kN & 72.55 kN and ultimate load of 114.85 kN & 111.95 kN with the corresponding average deflections of 45.5 mm and 47.15 mm respectively. It is observed that the beam with $30^0$ corrugated web has less deflection and higher load carrying capacity when compared with all other specimens.



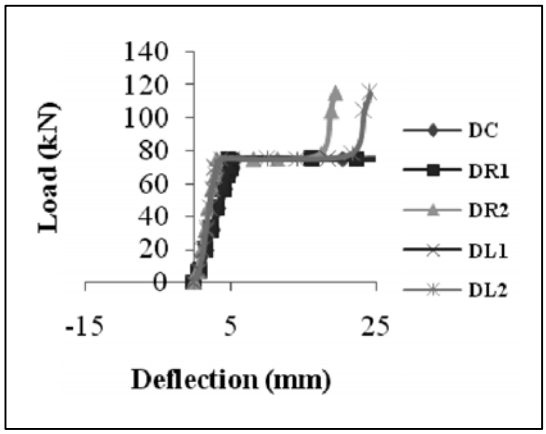

**(a) Specimen EPWB $0^0$, 200-1**



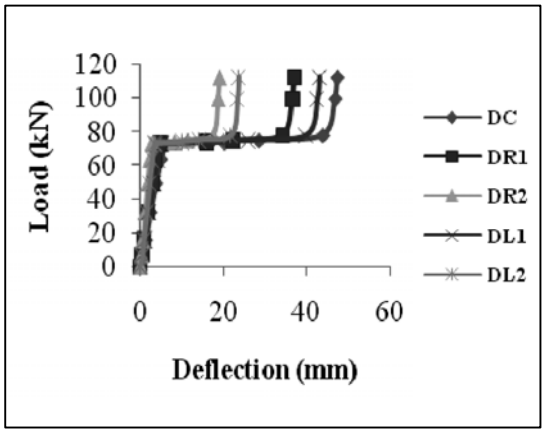

**(b) Specimen EPWB $0^0$, 200-2**



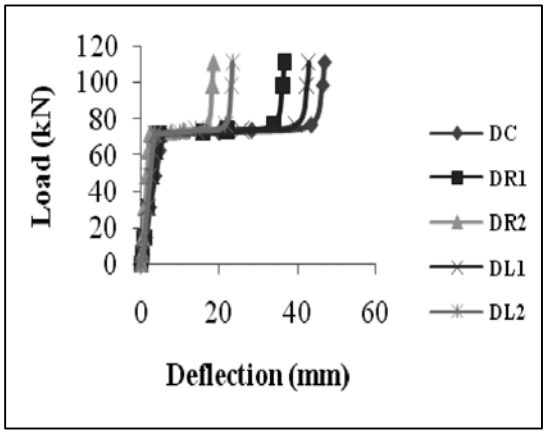

**(c) Specimen ECWB $30^0$, 200-1**




**(d) Specimen ECWB $30^0$, 200-2**




**(e) Specimen ECWB $45^0$, 200-1**




**(f) Specimen ECWB $45^0$, 200-2**

**Fig. 3: Load-deflection curves of the concrete encased specimens**

**Comparison of strength capacity of the concrete encased specimens with plain and trapezoidally corrugated web**

Ultimate load and maximum deflection of concrete encased beams with plain and corrugated web are given in Table 2. The beams with $30^0$ corrugated web has shown less deflection and higher load carrying capacity when compared with all the other specimens. For the specimens with 200 mm depth the load carrying capacity of the beam having $30^0$ corrugated web is 2.5% higher than the specimens having $45^0$ corrugated web where as 67.3% more than the specimens having plain web.

**Table 2: Strength capacities of the concrete encased specimens with plain and corrugated web**

| S. No. | Specimens | Ultimate load (kN) | Deflection (mm) | Average ultimate load (kN) | Percentage increase in average ultimate load (%) |
|---|---|---|---|---|---|
| 1 | EPWB $0^0$, 200-1 | 67.50 | 21.00 | 68.65 | - |
| 2 | EPWB $0^0$, 200-2 | 69.80 | 22.00 | | |
| 3 | ECWB $30^0$, 200-1 | 114.30 | 48.00 | 114.85 | 67.30 |
| 4 | ECWB $30^0$, 200-2 | 115.40 | 43.00 | | |
| 5 | ECWB $45^0$, 200-1 | 112.60 | 47.30 | 111.95 | 63.00 |
| 6 | ECWB $45^0$, 200-2 | 111.30 | 47.00 | | |

## CONCLUSION

The following observations and conclusions can be made on the basis of the experiments conducted on the six encased cold-formed steel beams with plain web and corrugated web.

- The load carrying capacity of the beam having $30^0$ corrugated web is 2.5% higher than the specimens having $45^0$ corrugated web where as 67.3% more than the specimens having plain web.
- A cold formed steel beam with corrugated web has less deflection than that of steel beams with plain web, respectively.

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