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Structural performance of cold formed hollow flanged plate girders with corrugated web

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Abstract— The proposed cold formed hollow flanged plate girders with corrugated web are aiming to fulfill economy with strength and safety by reducing the dead load of the structure. Different hollow sections are used as flange like rectangular and trapezoidal with web corrugations. Flexural behavior of these sections is studied in detail. Parametric study was also done and the best section was chosen. Behavior of these sections are also studied when they are provided with double corrugated web, concrete filled double corrugated web and curved flange, and how it affects the load carrying capacity.

Index Terms— , Cold formed steel, Corrugated web, Hollow flange, Double corrugation, Curved beam,Concrete filled web, Buckling analysis, ANSYS.

1INTRODUCTION

The necessity for long span horizontal structural members are increasing day by day in today's developing construction and building infrastructures. So structural steel used in these members should have high strength but it have many weaknesses like less buckling resistance, large deflections, excessive vibrations etc. In order to overcome these disadvantages it is a better alternative to use corrugated web sections.

There are many advantages of using corrugated web sections like, it have greater in-plane and out-of-plane shear buckling strength and provide higher stability against asymmetrical loads. Since we can reduce the thickness of web in corrugated profile it leads to significant weight reduction than that with conventionally used hot rolled sections. The corrugated profile can also prevent the buckling failure of the web. In practical application the web carries mainly the compressive stress and transmits the shear, but the flange carries the external loads. Thus results in resistance of shear by the web and resistance to bending moment by the flange. I shaped beams sections are effective in carrying bending moment and shear force in the plane of web. The main characteristics of corrugated web sections are its less bending capacity and adequate out of plane stiffness. So the corrugated web sections can be effectively used instead of conventional beam sections. When the corrugated sheets acts as web in a beam sections it mainly carries the vertical shear while flanges are subjected to moment. Another important advantage of corrugated webs is it helps to avoid the use of transverse stiffeners

Trapezoidally corrugated webs are used here,it have in plane as well as inclined sub panels.Figure 1 shows the corrugated web profile used in this study. In order to provide more stability against lateral buckling double corrugated webs and double corrugated webs encased with concrete are studied here. Due to this strengthening method it will increase the load carrying capacity of beam. The load carrying capacity of curved beam, that is when the lower flange is curved was also studied here.

There are many advantages of using cold formed steel sections over conventional hot rolled sections like it is light weight, high strength to weight ratio and to any shape it can be fabricated. In order to enhance the use and structural performance of cold formed steel sections and open sections, hollow flanged sections can be more effectively used. The use of hollow flanged sections enhance the torsional rigidity of open I sections and also avoid the formation of weaker elements with free edges.The hollow sections alsocan locate steel area effectively away from neutral axis and provide more second moment of area, thus leads to higher flexural capacity about the major axis.

2 ANALYTICAL STUDY

2.1 Methods and Materials

Non linear finite element analysis was done on ANSYS Work Bench 16.1. in order to study the buckling behavior of the sections studied. The dimensions of the flange and corrugated profile are as below and other properties are also provided

Length of girder = 1200 mm
Depth of web = 300 mm
Thickness of web = 3 mm
Thickness of flange = 4 mm
Depth of hollow flange = 50 mm
Width of hollow flange = 100 mm
Yield st rength of web = 210 MPa
Yield strength of flange = 340 MPa

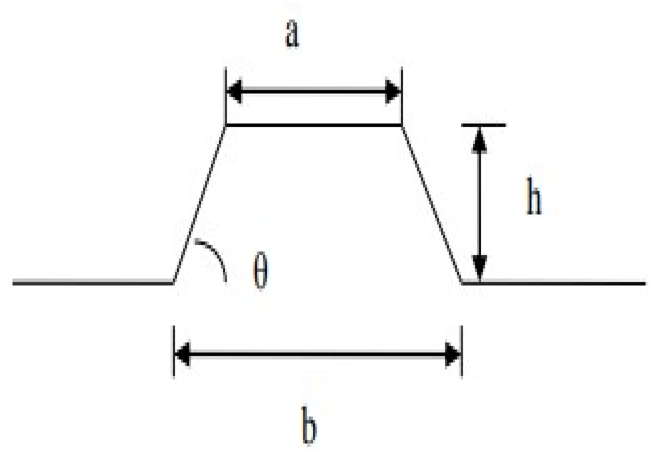

Figure .1. Corrugated web profile

Figure 1 shows the corrugated web profile used in the analysis. For the basic model used in the analysis, a= 100 mm, b= 200 mm, h = 25 mm and θ = 30^0. Supports are simply supported and midpoint loading was done on these sections.

3.RESULTS AND DISCUSSIONS

3.1 Effect of corrugation angle

Three girders having corrugation angle 30^0, $45^0$and 60^0 are studied here. Other geometric parameters and weight of each specimen are kept constant here.

TABLE 1
EFFECT OF CORRUGATION ANGLE

Angle Of Corrugation	Ultimate Load (kN)	Deflection (mm)
30^0	235.52	7.5157
45^0	230.4	9.347
60^0	218	10.468

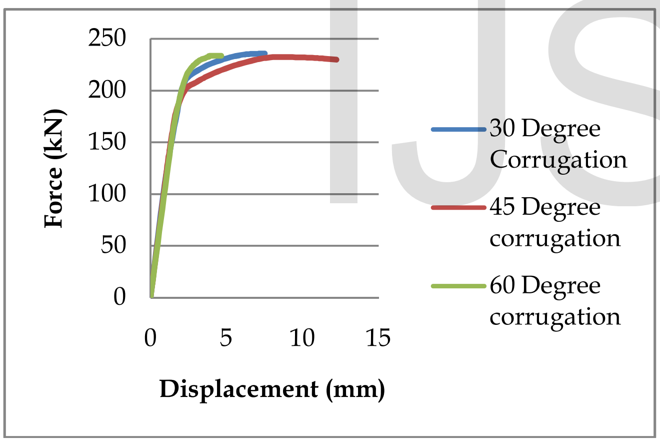

Figure . 2. Load v/s Deflection curve for varying angle of corrugation

From the above study , the load carrying capacity is more for the section having 30^0 corrugation. Also the displacement is small for this angle. From the table it is clear that load carrying capacity decreases as the angle of corrugation increases. I t is because when the angle of corrugation increases it behave more likely to rectangular corrugation profile which leads to increase in load carrying capacity and decrease in corresponding deflection

3.2 Effect of shape of hollow flange

How the shape of hollow flange affects the load carrying capacity is studied here. Different hollow flanges as shown in Figure 3, Figure 4 and Figure 5 are modeled and analyzed.

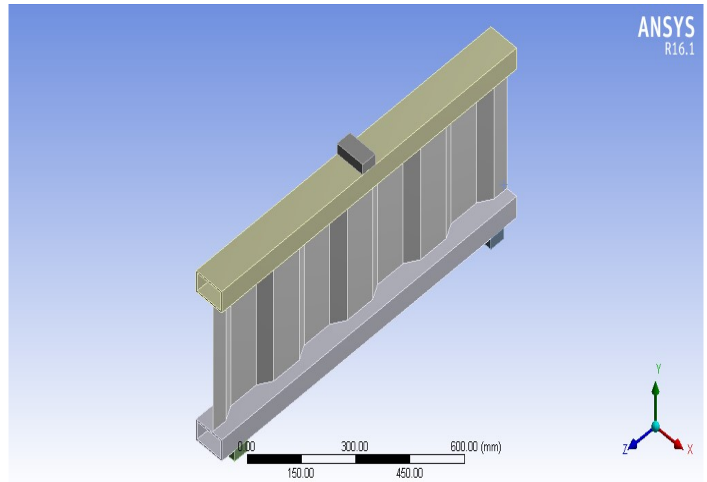

Figure .3. Plate girder with rectangular hollow flange

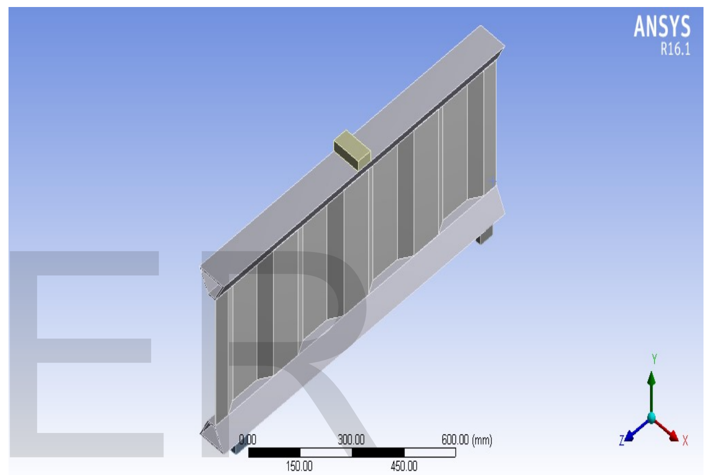

Figure. 4. Plate girder with trapezoidal hollow flange

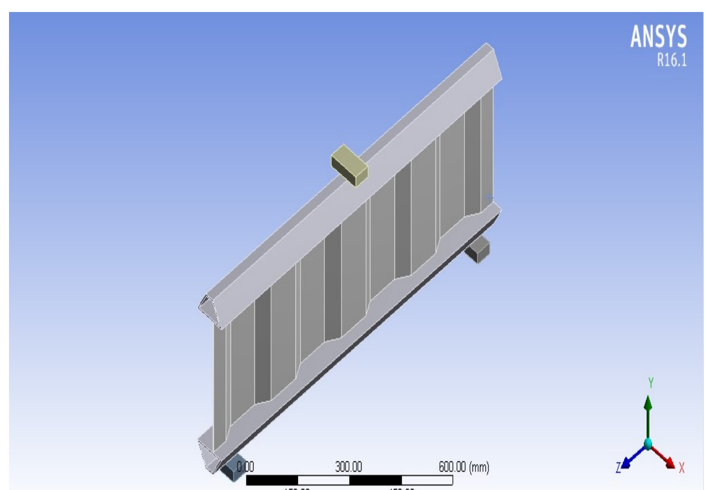

Figure. 5. Plate girder with inverted trapezoidal hollow flange

By conducting the buckling analysis on these three specimens, following results were obtained.

TABLE 2
EFFECT OF SHAPE OF HOLLOW FLANGE

Shape Of Hollow Flange	Ultimate Load (kN)	Deflection (mm)
Rectangular	235.52	7.5157
Trapezoidal	176.12	4.0225
Inverted trapezoidal	126.29	16.48

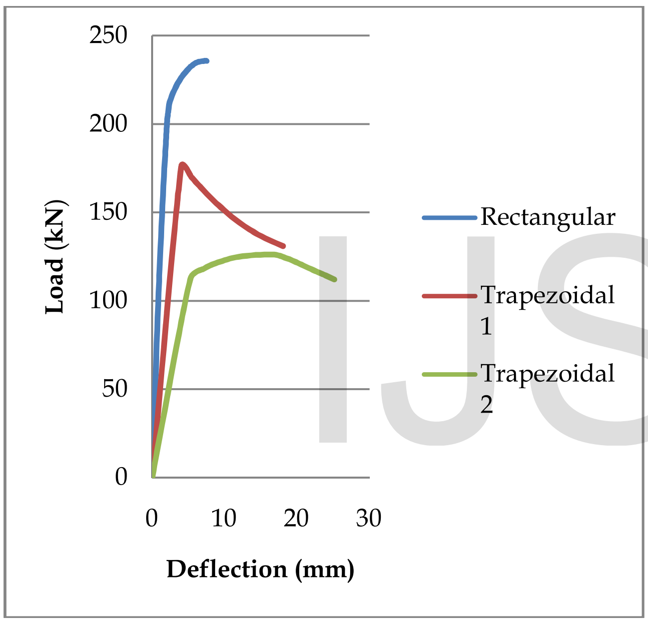

Figure. 6. Load v/s Deflection curve for varying shape of hollow flange

From this study it is clear that load carrying capacity is more for the rectangular hollow flange compared to trapezoidal and inverted trapezoidal hollow flange. The increase in load carrying capacity for rectangular hollow flange is due to its capacity to transfer the load evenly to the web portion.

3.3Effect of L/Dw Ratio

A parametric study was conducted on the effect of L/Dw ratio of web. Here the length of girder was kept constant. The length of girder used was 1200 mm for the basic model. Then the depth of web changed accordingly. The depth of web used for the basic model was 300 mm. The study was conducted by increasing the depth of web by 20 mm and alsodecreasing the same by 20 mm. The L/D ratios used for the analysis was 3.75, 4 and 4.3 having the depth of web 320 mm, 300mm and 280 mm respectively.

TABLE 3
EFFECT OF VARYING L/DW RATIO

L/Dw ratio	Ultimate load (kN)	Deflection (mm)
4.3	234.9	8.373
4	235.52	7.5157
3.75	236	6.937

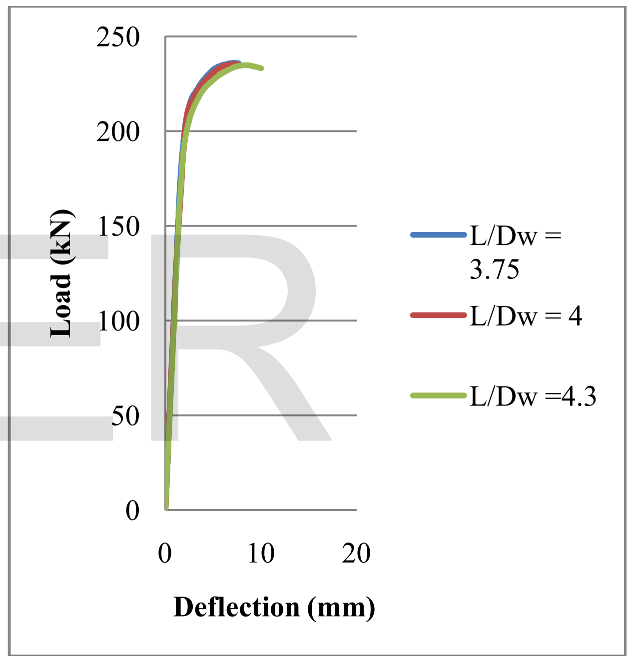

Figure. 7. Load v/s Deflection curve for varying shape of hollow flange

Comparing the L/Dw ratio, when the depth of web increased 20 mm, the load carrying capacity increase 0.2%, also when the depth of web decreased by 20 mm, the load carrying capacity decreased 0.26 %

3.4 Effect of curve depth

Effect of curved beams (bottom flange curved) on load carrying capacity were studied here. Models were created as in Figure 7 by providing curved profile for the bottom flange and analyzed. Three different models were created having curve depth of 50mm, 75 mm, and 100 mm. The results obtained are shown below.

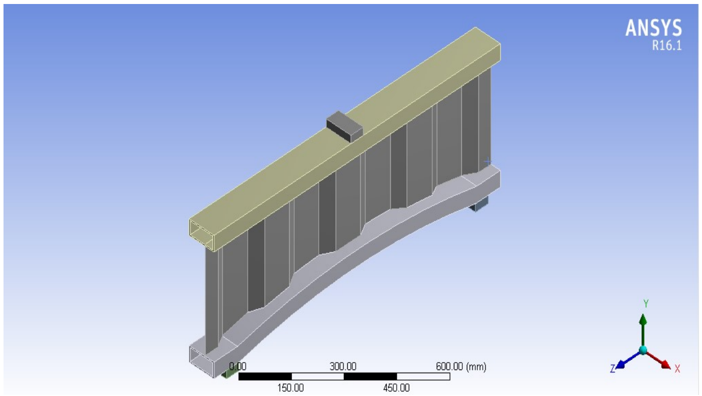

Figure. 8. Curved bottom flange , curve depth 50 mm
Table 1 Effect of curve depth

TABLE 3
EFFECT OF VARYING CURVE DEPTH OF BOTTOM FLANGE

Curve depth	Ultimate Load (kN)	Deflection (mm)
50	222.9	6.9284
75	217.9	8.437
100	216.84	8.0394

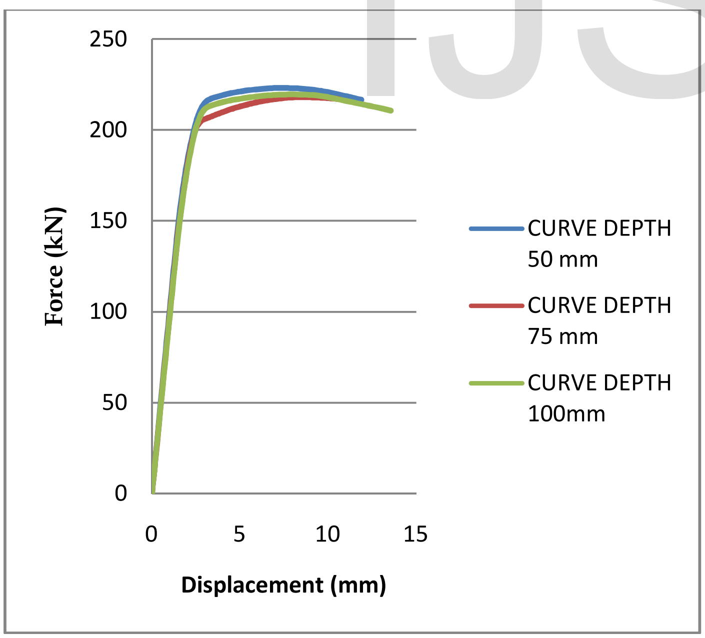

Figure. 9. Load v/s Deflection curve for varying depth of curvature of bottom flange

It can be concluded that load carrying capacity is more for the curve depth of 50 mm. The load carrying capacity decreases as the depth of curvature increases. When the depth of curvature of bottom flange increases, it leads to the decrease in the web depth thus the load carrying capacity was reduced.

3.5 Effect of concrete filled double plate web

In order to provide more stability against lateral buckling double plate webs are used by providing a minimum possible gap of 25 mm between plates. Double corrugated webs filled with concrete are used for both straight flange beams and curved flange beams. Double flat web without corrugation filled with concrete were also studied to compare the results. Concrete of grade M25 were filled between the gaps of double plate webs.

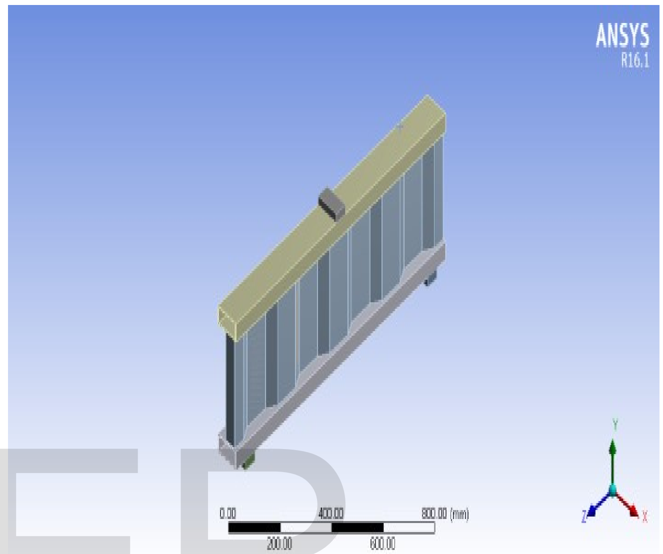

Figure. 10. Double corrugated web girder filled with concrete

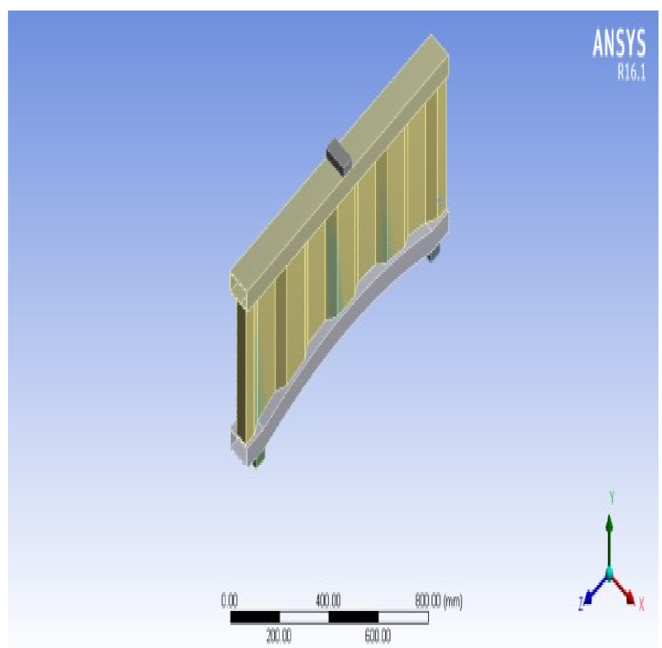

Figure. 11. Curved double corrugated web girder filled with concrete

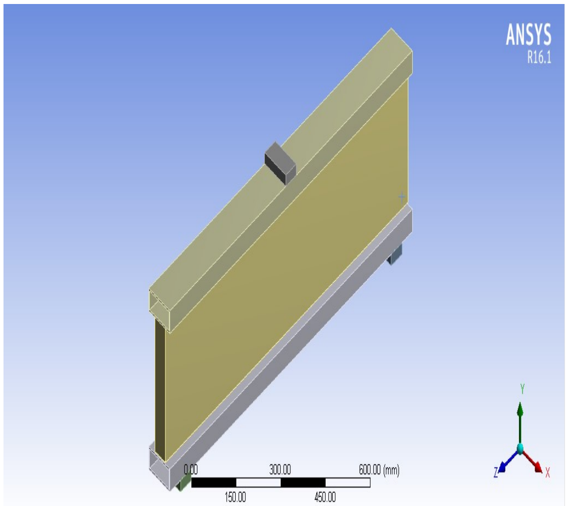

Figure. 12. Double flat web girder filled with concrete

Buckling analysis were carried out in these specimens without filling concrete and after filling concrete. The results obtained are as follows.

TABLE 4
EFFECT OF DOUBLE PLATE WEB WITHOUT FILLING CONCRETE

Type	Ultimate Load (kN)	Deflection (mm)
CW SB DOUBLE	313.69	8.4887
CW CB DOUBLE	299.57	8.1218
FW SB DOUBLE	308.11	3.9132

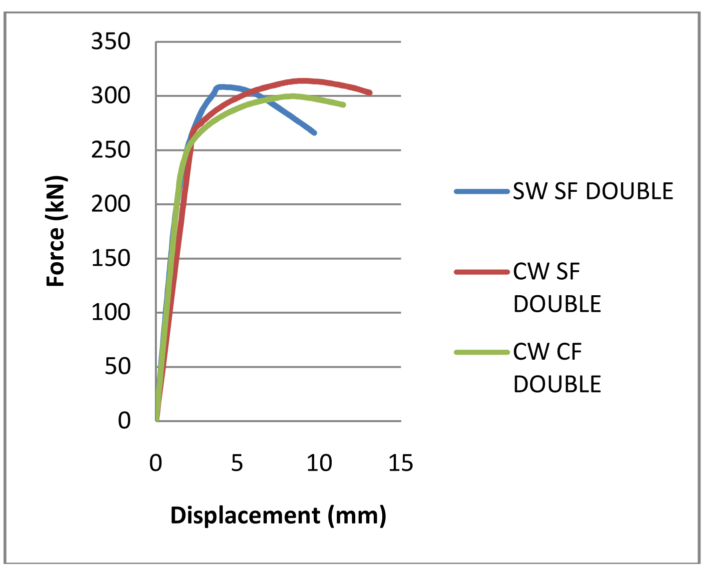

Figure. 13. Load v/s Deflection curve for double plate webs

TABLE 5
EFFECT OF DOUBLE PLATE WEB FILLED WITH CONCRETE

Type	Ultimate Load (kN)	Deflection (mm)
CW SB DOUBLE	315.94	2.9249
CW CB DOUBLE	315.56	40.442
FW SB DOUBLE	151.19	2.299

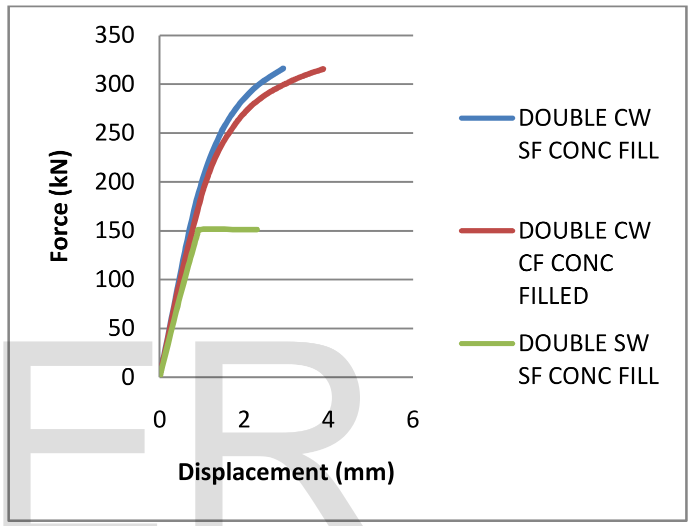

Figure. 14. Load v/s Deflection curve for double plate webs filled with concrete

From this analysis the load carrying capacity increases for double plate webs than that with single plate web having same weight. More load carrying capacity is for the beam having double corrugated web and straight flange. Its load carrying capacity increases also when it is filled with concrete in the space between web plates.

4.CONCLUSION

In this study it is proved structural efficiency of cold formed hollow flanged plate girders with corrugated webs over conventionally used plane webs.

In the study of effect of corrugation angle on load carrying capacity, better load carrying capacity was obtained for the corrugation angle of 30^0.

By studying different flange shapes for the hollow flanges used, better result was obtained for rectangular flange shape than that of trapezoidal flange shape because it transfer the load uniformly to the web.

Effect of curved beams on load carrying capacity was also studied by providing curved flange profile for the bottom flange. By studying different curve depths such as 50 mm, 75 mm and 100 mm, better load carrying capacity was obtained for the curve depth of 50 mm.

Single webs are replaced with double webs having 25mm gap in between the web plates and also concrete of grade M25 were filled in the gap. The efficiency of these sections on load carrying were studied both under straight and curved profile of bottom flange.

The result was that load carrying capacity is more for the specimen having double corrugated web and straight flange also its load carrying capacity increased when filled with concrete in the gap between the web plates.

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