

CHAPTER 6

CONCLUSIONS

6.1 GENERAL

Analytical and experimental investigations were carried out to study the behaviour of cold-formed steel beams with plain web, trapezoidally corrugated web, concrete encased plain web and concrete encased trapezoidally corrugated web. Load versus deflection curve, load versus strain curve, moment versus curvature curve and moment versus lateral buckling curve were plotted. Load carrying capacity, lateral buckling resistance, displacement ductility and failure mechanism were studied.

6.2 CONCLUSIONS

The following conclusions could be made from the various experiments conducted on the structural behaviour of cold-formed steel beams with plain web, trapezoidally corrugated web, concrete encased plain web and concrete encased trapezoidally corrugated web.

6.2.1 Effect of Web Corrugation Angle in the Steel Beams with Plain and Trapezoidally Corrugated Web

Based on the experimental investigation carried out on beams with plain web, 30^0 and 45^0 corrugated web the following conclusions are arrived.

- The load carrying capacity of the beams with 150 mm depth ($d_w/t_w=60$) having 30^0 and 45^0 corrugated web are 25% and 23% respectively more than the specimens having plain web.
- The load carrying capacity of the beams with 200 mm depth ($d_w/t_w=80$) having 30^0 and 45^0 corrugated web are 16% and 12% respectively more than the specimens having plain web.
- Lateral buckling resistance of the beam with 45^0 corrugation has shown higher resistance to lateral buckling.
- Displacement ductility of the beams with 150 mm depth ($d_w/t_w=60$) having 30^0 corrugated web and 45^0 corrugated web are 22% and 6% respectively less than the specimens having plain web.
- Displacement ductility of the beams with 200 mm depth ($d_w/t_w=80$) having 30^0 corrugated web and 45^0 corrugated web are 25% and 29% respectively less than the specimens having plain web.
- The beams with plain web failed by shear buckling of web. In the specimens with 45^0 trapezoidal corrugated web, failure occurred due to local flange buckling initially and local shear buckling of corrugated web occurred on further loading. The specimens with 30^0 trapezoidal corrugated web failed by local flange buckling.

Steel beam with trapezoidally corrugated web having 30^0 corrugation has performed well when compared to the beams having plain web and 45^0 corrugated web. But, the displacement ductility of the beams with corrugated web is less than the beams with plain web.

6.2.2 Effect of Concrete Encased Web in the Beams with Plain and Trapezoidally Corrugated Web

- The load carrying capacity of the beams with 150 mm depth ($d_w/t_w=60$) having encased 30° and 45° corrugated web are 54% and 53% respectively more than the specimens having encased plain web.
- The load carrying capacity of the beams with 200 mm depth ($d_w/t_w=80$) having encased 30° and 45° corrugated web are 67% and 63% respectively more than the specimens having encased plain web.
- Lateral buckling resistance of the beam with 30° corrugation has shown higher resistance to lateral buckling.
- Displacement ductility of the beams with 150 mm depth ($d_w/t_w=60$) having encased 30° corrugated web and 45° corrugated web is 1.6 times and 1.5 times respectively more than the specimens having encased plain web.
- Displacement ductility of the beams with 200 mm depth ($d_w/t_w=80$) having encased 30° corrugated web and 45° corrugated web is 3.6 times and 3.5 times respectively more than the specimens having encased plain web.
- In the beams with encased trapezoidally corrugated web, failure was typically in the form of flexural cracks originating from the bottom of the specimen and extending towards the top of the specimen. The majority of cracks were formed between the zone of two point loading and some cracks was also observed near the end supports.

Steel beam with encased trapezoidally web not only increases the moment carrying capacity but also the ductility. The super elastic property of encased corrugated web beams enhances the usage of it in the earthquake resistant structures.

6.3 CONTRIBUTIONS

- Steel beams with plain web failed by shear buckling of web and it is eliminated by using steel beams with trapezoidal corrugated web.
- Steel beams with trapezoidally corrugated web having 30° corrugation have higher moment carrying capacity and lateral buckling resistance, when compared with steel beams with plain web.
- Steel beam with concrete encased trapezoidally web not only increases the moment carrying capacity but also the ductility. The super elastic property of encased corrugated web beams enhances the usage of it in the earthquake resistant structures.

6.4 SCOPE FOR FURTHER WORK

- Experimental investigation may be carried out for cyclic load.
- An extension of the present work may be undertaken using different types of corrugation.
- Investigation may be carried out on cold formed steel beams and concrete encased steel beams with triangular corrugated web.

APPENDIX 1

MIX DESIGN

A1.1 MIX DESIGN

The mix design has been done for M30 grade of concrete for the encasing the cold-formed trapezoidally corrugated web beam.

Concrete Mix Design (Grade –M30)

The grade of concrete used in the present study is M30. Mix design of the concrete is carried as per the specific code IS 10262 – 2009. Table A 1.1 shows Mix proportion by weight and Table A1.2 shows the Mix design details of OPC.

Ordinary Portland Cement Concrete (OPCC)

Step: 1 Stipulation for Proportioning

Grade designation	: M 30
Type of cement	: OPC 53 grade
Exposure condition	: Severe
Type of aggregate	: Crushed angular aggregate
Type of chemical admixture	: Super plasticizer (Glenium B-233)

Step: 2 Test Data for Materials

Specific gravity of

Cement : 3.08

Fine aggregate : 2.71

Coarse aggregate : 2.75

Step: 3 Target Strength for Mix Proportioning

$$f'_{ck} = f_{ck} + 1.65 s$$

$$f'_{ck} = 30 + 1.65 * 5 \text{ (s = 5 N/mm}^2 \text{, from Table 1 of IS 10262)}$$

$$f'_{ck} = 38.25 \text{ N/mm}^2$$

Step: 4 Selection of Water – Cement Ratio

From Page 20, Table 5 of IS 456, maximum- water cement ratio = 0.45

Water- cement ratio of 0.4 is adopted.

Step: 5 Selection of Water Content

From Table 2 of IS 10262, maximum water content for 20 mm aggregate

$$= 186 \text{ kg (for 25 – 50 mm slump)}$$

From Page 2 of IS 10262, estimated water content for 100 mm slump

$$= 186 + (6 * 186 / 100)$$

$$= 197 \text{ kg}$$

As super plasticizer is used, the water content can be reduced up to 20 %.

Based on trials with super plasticizer, water content reduction of 20% has been achieved. Hence, the arrived water content = $197 * 0.8$

$$= 157.6 \text{ liters}$$

Step: 6 Calculation of Cement content

$$\text{Water-Cement ratio} = 0.4$$

$$\text{Cementitious material content} = 157.6 / 0.4$$

$$= 394 \text{ kg/m}^3$$

From Table 5 of IS 456, minimum cement content for 'severe' exposure conditions is 320 kg/m^3 , $394 \text{ kg/m}^3 > 320 \text{ kg/m}^3$, hence OK

Step: 7 Proportion of Volume of Coarse and Fine Aggregate Content

From table 3, volume of coarse aggregate corresponding to 20 mm size aggregate and fine aggregate (Zone III) for water-cement ratio of 0.50 = 0.66

$$\text{Volume of coarse aggregate} = 0.62$$

$$\text{Volume of fine aggregate} = 0.38$$

Step: 8 Mix Calculation

$$\text{Volume of concrete} = 1 \text{ m}^3$$

$$\text{Volume of cement} = (\text{Mass of cement} / \text{Specific gravity. of cement}) * (1/1000)$$

$$= (394 / 3.08) * (1/1000)$$

$$= 0.1279 \text{ m}^3$$

$$\begin{aligned}
 \text{Volume of water} &= (\text{Mass of water/ Sg. of water}) * (1/1000) \\
 &= (157.6 / 1)*(1/1000) \\
 &= 0.1576 \text{ m}^3
 \end{aligned}$$

Volume of chemical admixture (at 0.7% by weight of cementitious material)

$$\begin{aligned}
 &= (\text{Mass of admixture / Sg. of admixture})*(1/1000) \\
 &= (394*0.007/1.09)*(1/1000) \\
 &= 0.00253 \text{ m}^3
 \end{aligned}$$

$$\begin{aligned}
 \text{Volume of all in aggregate} &= (1-(0.1279+0.1576+0.00253)) \\
 &= 0.711 \text{ m}^3
 \end{aligned}$$

$$\text{Mass of coarse aggregate} = 0.711*0.62*2.75*1000=1212.25 \text{ kg/ m}^3$$

$$\text{Mass of fine aggregate} = 0.711 *0.38*2.71*1000=732.18 \text{ kg/m}^3$$

$$\text{Mass of super plasticizer} = 2.57 \text{ kg/m}^3$$

Table A 1.1 Mix Proportion by weight

Water	Cement	Fine aggregate	Coarse aggregate
157.6 kg/m ³	394 kg/m ³	732.18 kg/m ³	1212.25 kg/m ³
0.4	1	1.86	3.07

Table A 1.2 Mix design details of OPC

Sl. No	Particulars	Quantity
1	Cement	394 kg/m ³
2	Fine aggregate	732.18 kg/m ³
3	Coarse aggregate	1212.25 kg/m ³
4	Water	157.60 kg/m ³
5	Super plasticizer	2.57 kg/m ³
6	Water-binder ratio	0.4
7	Mix Proportion	1 : 1.86 : 3.07