CHAPTER 3

EXPERIMENTAL INVESTIGATION

3.1 INTRODUCTION

The details of the experimental work carried out on the cold-formed steel beams with plain web, trapezoidally corrugated web, concrete encased plain web and concrete encased trapezoidally corrugated web are presented in this chapter. The experimental investigation includes material testing, fabrication of test specimens, test set-up and testing procedure.

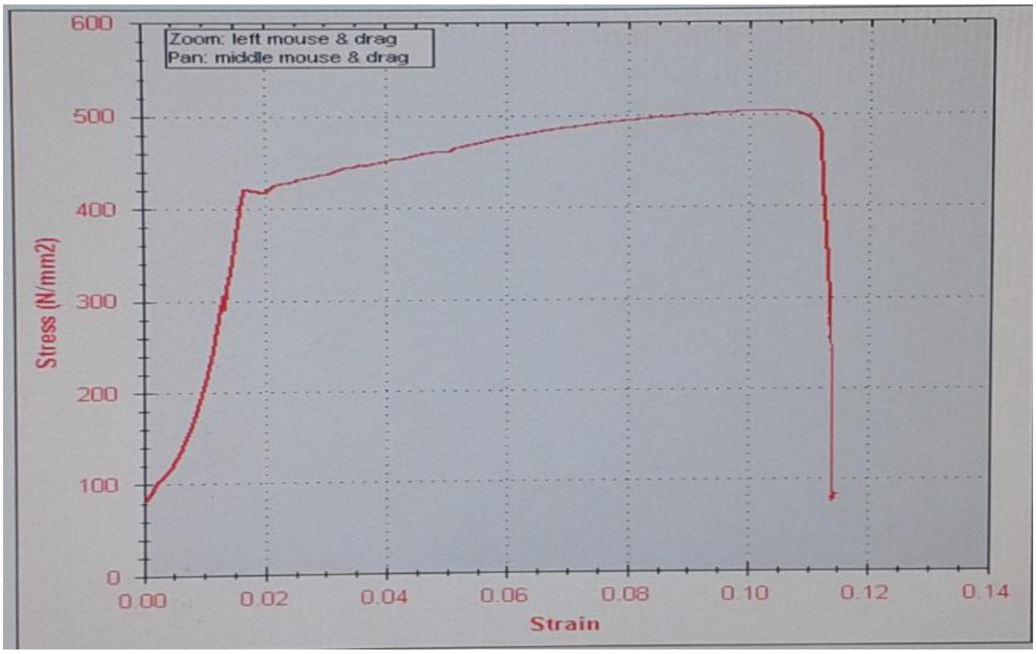
3.2 MATERIAL PROPERTIES

3.2.1 Cold-Formed Steel

Tension tests were conducted on coupons cut from the beam section to study the material properties of the beam sections used for the fabrication of test specimens. These tension test coupons were prepared and tested according to ASTM 370 standards. The test set-up and stress-strain behaviour of the material are shown in the Figure 3.1. The results of coupon tests are given in Table 3.1.

(a) Specimen Set-up

(b) Specimen after test



(c) Stress-Strain Behaviour of Coupon

Figure 3.1 Test Set-up and Stress Strain Behaviour of Coupon

Table 3.1 Results of Coupon Tests

Description	Thickness (mm)	E (N/mm^2) x 10^5	F_y (N/mm^2)	F_u (N/mm^2)	F_u/F_y
Cold-Formed Steel Beam	2.5	2.010	422	503	1.19

3.2.2 Concrete

3.2.2.1 Materials used

Cement

Cement conforming to IS 12269-1987, Ordinary Portland Cement with 53 grade was considered for the concrete mix.

Properties of Cement

The Ordinary Portland Cement which conforms to IS 12269 –1987 was used for making concrete.

Fine aggregate

Natural river sand with fraction passing through 4.74 mm sieve and retained on 600 μ sieve was used and tested as per IS 2386-1968(Part-3). The fineness modulus of sand is 2.68 and the specific gravity is 2.71.

Coarse aggregate

Hard crushed granite stone coarse aggregates conforming to graded aggregate of size 20 mm as per IS 383-1970 was used. Its specific gravity is 2.75. The coarse aggregates were tested as per the procedure given in IS 2386-1963 (Part 3).

Water

Potable tap water available in the laboratory with pH value of 6.0 and conforming to the requirements of IS 456-2000 was used for mixing concrete and curing the specimens as well.

Chemical admixtures

GLENIUM B233, marketed by M/s. BASF construction chemicals, Navi Mumbai was used as a superplasticizer. The properties of Superplasticizers Glenium B233 are given in the Table 3.2.

Table 3.2 Properties of GLENIUM B233 Superplasticizer*

Sl. No	Polycarboxylic ether	
1	Specific Gravity	1.09
2	Chloride ion content	Less than 0.2%
3	Recommended Dosage	0.5 to 1.5 liter per 100kg of cementitious material
4	pH	7 +/- 1
5	Aspect	Yellowish free flowing liquid

*Data taken from the product brochure of the supplier

Mix Proportion

M30 Grade of Concrete was chosen and the design mix adopted for the test specimens was 1: 1.86: 3.07 with a water-cement ratio of 0.4 and 0.7% of glenium superplasticizer were used.

3.2.2.2 Compression strength of concrete

Compressive strength tests were done on 150 mm cube concrete specimens at different ages as per the procedure specified in IS 516-1959. Figure 3.2 shows the experimental set-up for compression strength. Concrete cube specimens were tested at 28 days in a servo controlled 1000 kN UTM. Table 3.3 shows the cube compressive strength of concrete.

Figure 3.2 Experimental Set- up for Compression Strength.

Table 3.3 Cube Compressive Strength of Concrete

Sl. No	Age of Specimen	Cube		
		Load (kN)	Compressive Strength (N/mm^2)	Average Compressive Strength (N/mm^2)
1	28 days	811.20	36.05	35.95
2		796.35	35.39	
3		819.65	36.42	

3.2.2.3 Split tension strength of concrete

Tensile strength tests were done on 300 mm long with 150 mm diameter cylinder concrete specimens at different ages as per the procedure specified in IS 5816-1999. Table 3.4 shows the split tensile strength of concrete.

Table 3.4 Split Tensile Strength of Concrete

Sl. No	Age of Specimen	Cylinder		
		Load (kN)	Tensile Strength (N/mm^2)	Average Tensile Strength (N/mm^2)
1	28 days	207.82	2.94	3.13
2		233.97	3.31	
3		222.66	3.15	

3.3 TEST PROGRAM ON BEAMS

This program includes testing of 24 simply supported cold-formed steel beams. The beams were divided into three groups as A, B, C as outlined in Table 3.5. The beams under group A, B, C, were designed to be tested with plain web, 30^0 corrugated web and 45^0 corrugated web. A total of 24 cold-formed steel beams with plain web, trapezoidally corrugated web, concrete encased plain web and concrete encased trapezoidally corrugated web were tested. Out of the 24 specimens, 4 controlled specimens were tested with plain web, 8 specimens were tested with trapezoidally corrugated web, 4 specimens were tested with concrete encased plain web and the other 8 specimens were tested with concrete encased trapezoidally corrugated web.

Table 3.5 Test Beam Details

Sl. No	Description	Plain Web(A)	30^0 Corrugated Web (B)	45^0 Corrugated Web (C)
1	Beams without Concrete Encased Web	NPWB 0^0	NCWB 30^0	NCWB 45^0
2	Beams with Concrete Encased Web	EPWB 0^0	ECWB 30^0	ECWB 45^0

The details of the tests carried out are given in Figure 3.3. The specimens were tested under two point loading for its pure flexural behaviour. The spans of the beams were 2000 mm and the cross sections of the I-beams were 150 mm x100 mm x 2.5 mm and 200 mm x100 mm x 2.5 mm. The yield strength of steel used was 422 N/mm^2 and the web was encased with M30 grade concrete. The cold-formed steel beam was built-up by welding the flanges and the web using intermittent welds of 4 mm thickness.

Table 3.6 shows the details of the specimens tested. A six lettered designation was given to the specimens. First 4 letters represents the nature of the web whether it is plain or corrugated or encased with concrete, the 5th one indicates the degree of corrugation of the web, the 6th one represents the depth of the beam and the specimen in a particular series as two specimens were tested in each series. The details of cross section and longitudinal view of tested beam specimens are shown in Figure 3.4(a)-(c).

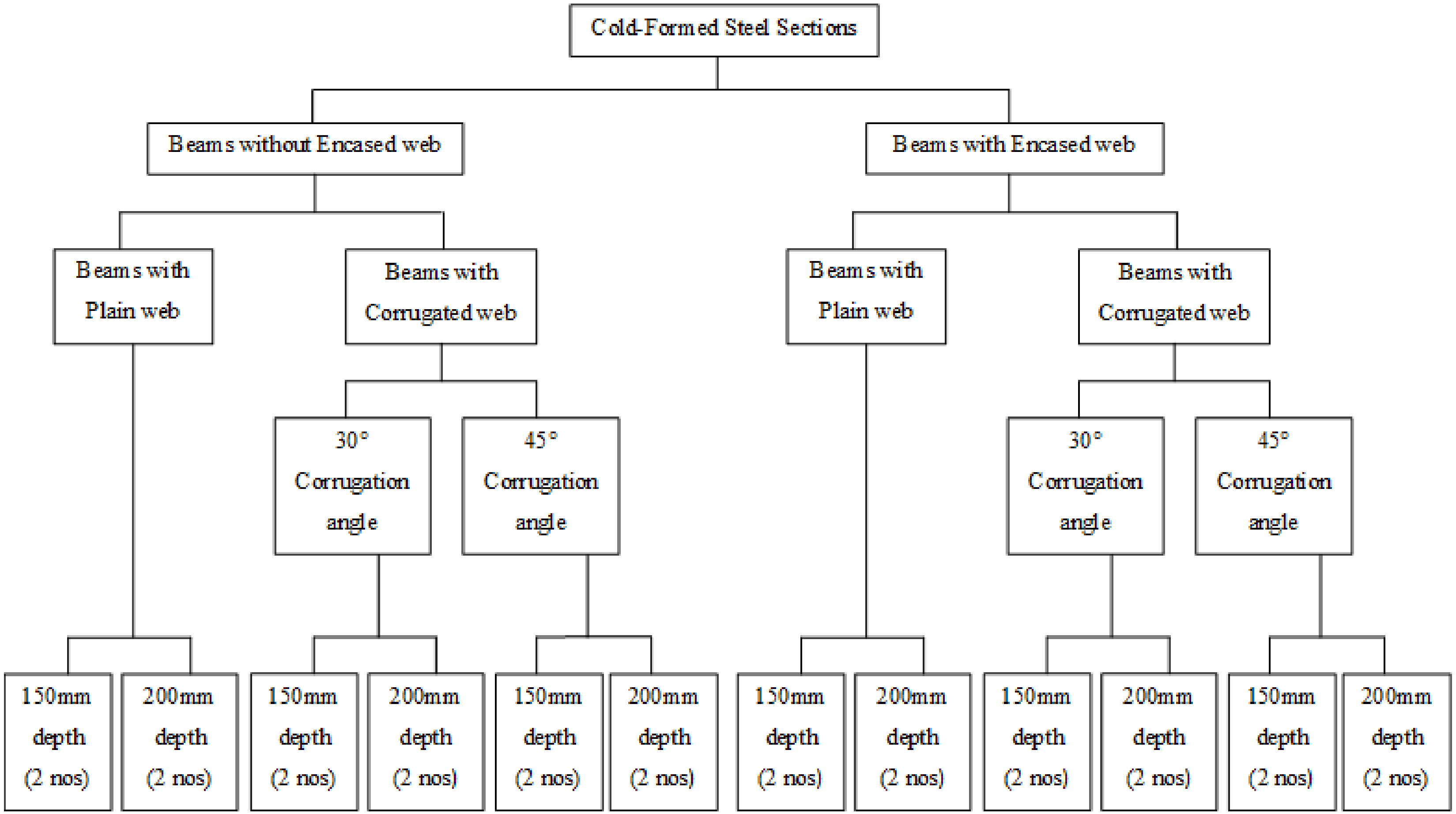


Figure 3.3 Details of Experiments Conducted

Table 3.6 Details of the Specimens

Sl. No	Description	No. of Beams	Beam ID	Dimensions			
				Length (mm)	Width(mm)	Depth (mm)	Thickness't'
1-8	**Group A** Beams with Plain Web	2	NPWB 0^0, 150-1 NPWB 0^0, 150-2	2000	100	150	2.5
		2	NPWB 0^0, 200-1 NPWB 0^0, 200-2			200	
		2	EPWB 0^0, 150-1 EPWB 0^0, 150-2			150	
		2	EPWB 0^0, 200-1 EPWB 0^0, 200-2			200	
1-8	**Group B** Beams with 30^0 Corrugated Web	2	NCWB 30^0, 150-1 NCWB 30^0, 150-2	2000	100	150	2.5
		2	NCWB 30^0, 200-1 NCWB 30^0, 200-2			200	
		2	ECWB 30^0, 150-1 ECWB 30^0, 150-2			150	
		2	ECWB 30^0, 200-1 ECWB 30^0, 200-2			200	
1-8	**Group C** Beams with 45^0 Corrugated Web	2	NCWB 45^0, 150-1 NCWB 45^0, 150-2	2000	100	150	2.5
		2	NCWB 45^0, 200-1 NCWB 45^0, 200-2			200	
		2	ECWB 45^0, 150-1 ECWB 45^0, 150-2			150	
		2	ECWB 45^0, 200-1 ECWB 45^0, 200-2			200	

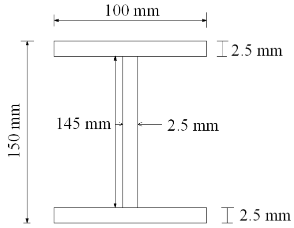
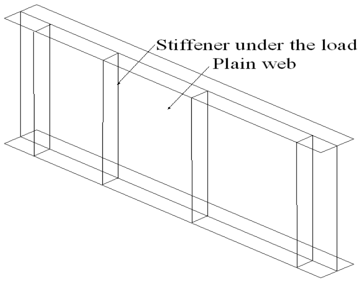
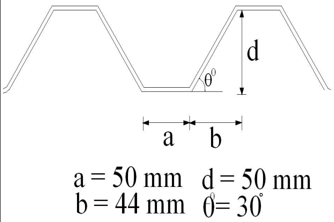
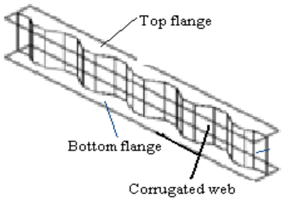
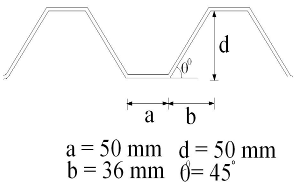
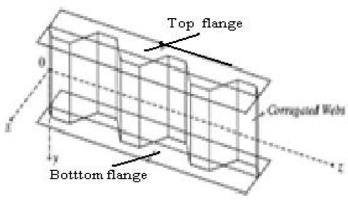
		
Cross section of the beam	**Longitudinal View**	**Fabricated specimen with plain web**
(a) Beam with plain web		
		
Cross section of the web	**Longitudinal View**	**Fabricated specimen with corrugated web**
(b) Beam with 30^0corrugated web		
		
Cross section of the web	**Longitudinal View**	**Fabricated specimen with corrugated web**
(c) Beam with 45^0corrugated web		

Figure 3.4 Cross Sectional and Longitudinal View of the Beam Specimens

3.4 FABRICATION OF THE SPECIMENS

3.4.1 Beams without Concrete Encased Web

The cold-formed steel plates of size 2.4 m x 1.2 m of 2.5 mm thickness were cut by means of cutting machine to make flanges and webs of desired dimensions. Figure 3.5(a) shows the webs being cut to the desired depth and width and corrugations having fold angle of 30^0 and 45^0 were provided by using press break machine. Figure 3.5(b) shows the web plate with corrugation. The corrugated web was welded to the flange by means of arc welding and stiffeners were provided at the loading and support points to avoid bearing failures as shown in Figure 3.5(c). Figure 3.5(d) shows the view of the corrugated web welded with the bottom flange. The fabricated specimens with plain web, 30^0corrugation web and 45^0corrugation web are shown in Figure 3.6.

(a) Folding of Web Plate by Press-Break

(b) Web plate with Corrugation

Figure 3.5 (Continued)

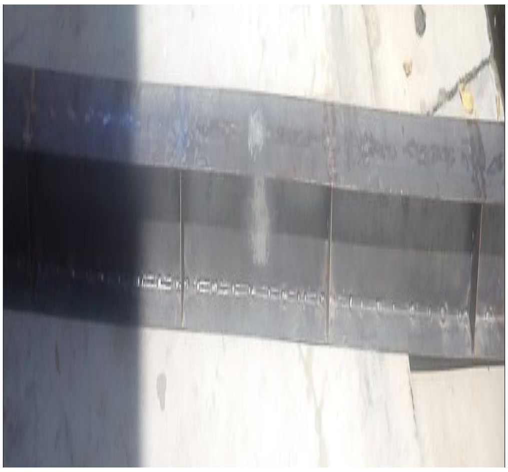
(c) Welding of the Corrugated Web with the Flange

(d) View of the Corrugated Web Welded with the Bottom Flange

Figure 3.5 Fabrication of the Specimens

(a) Fabricated Specimens with Plain Web, 30^0 and 45^0 Corrugated Web Beam

Figure 3.6 (Continued)



(b) Beams with Plain Web

(c) Beams with 45^0 Corrugated Web

Figure 3.6 Fabricated Specimens

3.4.2 Beams with Concrete Encased Web

The concrete was placed in the web in two to three layers; each layer was vibrated with a needle vibrator. The top of the beams were floated off smoothly with a straight edge. The specimens were cured by providing wet gunny bags for 28 days and air dried for 1 day before testing. Figure 3.7 shows the specimens before concreting the web. The concreting was done on one face and left to set for one day and the same procedure was followed for the other face also. Figure 3.8 shows the specimens with concrete encased web.

Figure 3.7 Specimens Before Concreting the Web

Figure 3.8 Specimens with Concrete Encased Web

3.5 TEST SET-UP

The testing was carried out in a loading frame of 400 kN capacity. All the specimens were tested for flexural strength under two point loading. The specimens were arranged with simply supported conditions having an effective span of 1.7 m. Loads were applied at one-third distance from the supports at a uniform rate of 2 kN/min till the ultimate failure of the specimens occurred. Linear Variable Displacement Transducers (LVDTs) were used for measuring deflections at five locations, one at mid span, two directly below the loading points and two near the end supports as shown in the Figure 3.9. Strain gauges and LVDTs were connected to a data logger from which the readings were captured by a computer at every load intervals until failure of the beam occurred. The experimental set-up for the test specimens are shown in Figure 3.10.

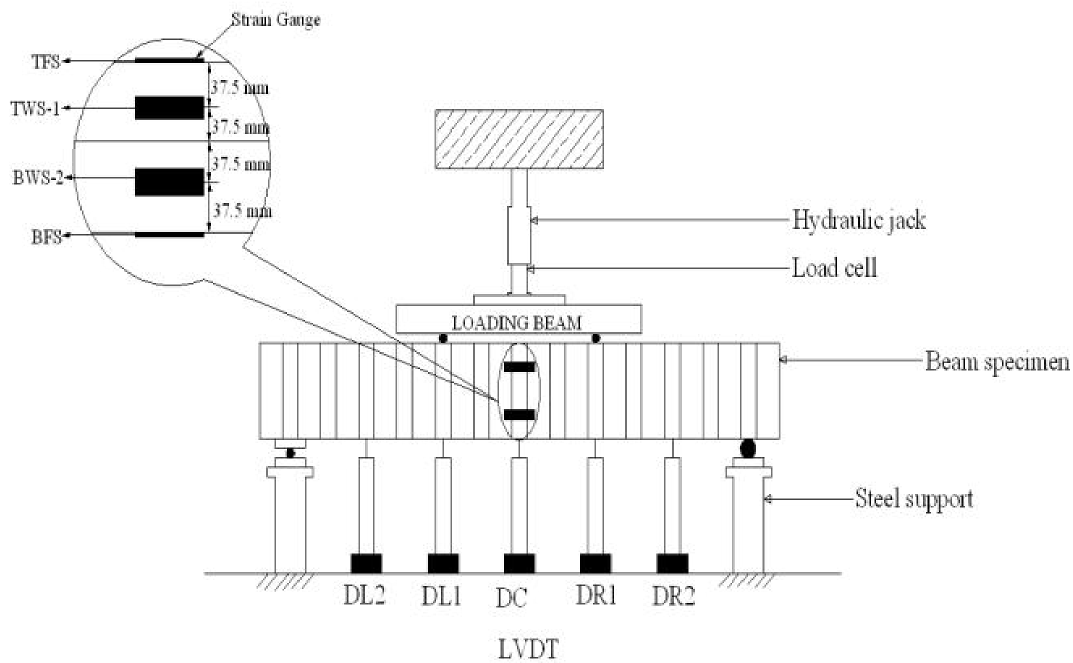


Figure 3.9 Schematic Diagram of Experimental Set-up

Figure 3.10 Experimental Set-up for the test Specimens

3.6 SUMMARY

The details of the experiments carried out on the performance of beams with plain web, trapezoidally corrugated web, concrete encased plain web and concrete encased trapezoidally corrugated web are presented in this chapter. The experimental investigation includes fabrication of the specimens, casting of the test specimens, test set-up, loading and testing procedure.