Flexural Behaviour of Concrete Encased Cold Formed Steel Channel Section

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Abstract— The use of Cold-Formed Steel (CFS) structures has become increasingly popular in different fields of building technology. The reasons behind the growing popularity of these products include their ease of fabrication, high strength/weight ratio and suitability for a wide range of applications. These advantages can result in more cost-effective designs, as compared with hot-rolled steel, especially in short-span applications. In this project work attempt has been made to use Cold formed steel section as replacement to conventional steel reinforcement bar. Reinforced concrete beam and concrete beam encased with lipped CFS channel sections with open and closed configuration are incorporated for study. Experimental testing is done to study the flexural behaviour of specimen by using two-point loading. Results showed increased load carrying capacity for CFS encased beam. Concrete encasing prevented local buckling of CFS sections improving flexural bending capacity of section.

Key words: Cold-Formed Steel, lipped channel section, concrete encased beam, flexural capacity

I. INTRODUCTION

A. General

Composite construction refers to making use of more than one material to construct any member of a building. Composite construction aims to make each material perform the function it is best at, or to strengthen a given cross section of a weaker material. Concrete and steel are the two most widely used composite construction material. These two materials complete one another and results in following properties: (a) Concrete is efficient in compression and steel in tension, (b) Concrete encasement restrain steel against buckling, (c) Concrete provides protection against corrosion and fire, (d) Steel bring ductility into the structure. However, use of Cold-Formed Steel is gaining rapid popularity in recent past as an alternative construction material to steel.

B. Cold Formed Steel

Cold-formed steel structures are steel structural products that are made by bending flat sheets of steel at ambient temperature into shapes which will support more than the flat sheets themselves. However, in recent years, higher strength materials and a wider range of structural applications have caused a significant growth in cold-formed steel relative to the traditional heavier hot-rolled steel structural members.

Cold forming has the effect of increasing the yield strength of steel, the increase being the consequence of cold working well into the strain-hardening range. These increases are predominant in zones where the metal is bent by folding. The effect of cold working is thus to enhance the mean yield stress by 15% - 30%. For purposes of design, the yield stress may be regarded as having been enhanced by a minimum of 15%.

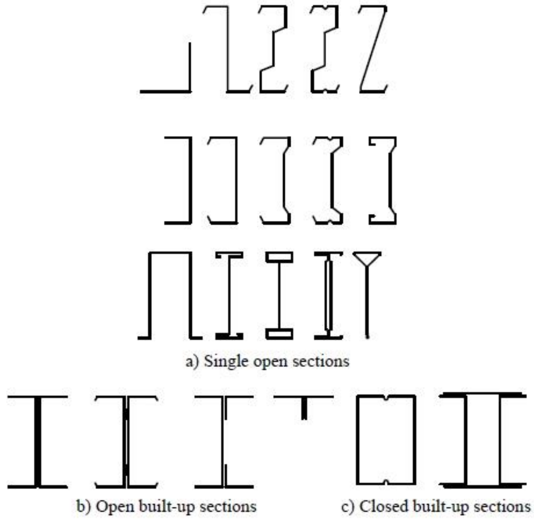


Fig. 1.1: Various types of Cold-Formed Sections

Advantages of Cold-Formed Steel as compared with hot rolled steel counterpart are

- Cross sectional shapes are formed to close tolerances and these can be consistently repeated for as long as required.
- Cold rolling can be employed to produce almost any desired shape to any desired length.
- Pre-galvanised or pre-coated metals can be formed, so that high resistance to corrosion, besides an attractive surface finish, can be achieved.
- All conventional jointing methods, (i.e. riveting, bolting, welding and adhesives) can be employed.
- High strength to weight ratio is achieved in cold-rolled products.
- They are usually light making it easy to transport and erect.

II. NEED FOR STUDY

Cold formed steel posses many advantages over hot-rolled steel as mention in earlier section. Beams form the horizontal elements of a building in transferring vertical loads and are conventionally constructed as reinforced concrete (RC) beam. Reinforcing steel bars used in forming reinforced concrete beam do not possess any load carrying capacity on its own. Whereas hot rolled structural steel section which has good load carrying capacity can be encased with concrete to form a beam element, but due to high load carrying capacity steel section concrete will not take up load and concrete will fail before the steel section.

Cold formed steel sections, formed by cold rolling process have enhanced yield strength compared with hot rolled steel. CFS being thin material, sections formed with CFS takes less load when compared with hot rolled steel section and can act in harmony with concrete. Study on using CFS section in place of conventional reinforcement will enlighten us to the behaviour exhibited by such composite beam.

III. Materials and Methods

A. Materials and Specimen

Four CFS encased beam specimen were considered in this study. All the beams had final dimension 100×150×1200. Each beam is made of encasing CFS lipped channel section. Cold-formed steel sheet of thickness 1.5mm with yield strength of 260N/mm^2 were cut into necessary size using shear cutting machine. The sheets were then folded to required cross section using press break machine. Each lipped channel section had dimension 100×50×15×1.5×1100. Channel sections are connected by Grade 4.6 10mm headed bolts of 70mm length on center of channel section in web along the length of beam. Each beam is connected using 8nos of bolts with part length of bolt protruding on either side of CFS section. Among four beam specimen, two beams were made by placing lipped channel section with back-to-back arrangement forming open section (I-section) and two beams with face-to-face arrangement forming closed section (Box section) and encasing the section with concrete. Typical cross sectional details of beam specimen are shown in Fig 3.1.

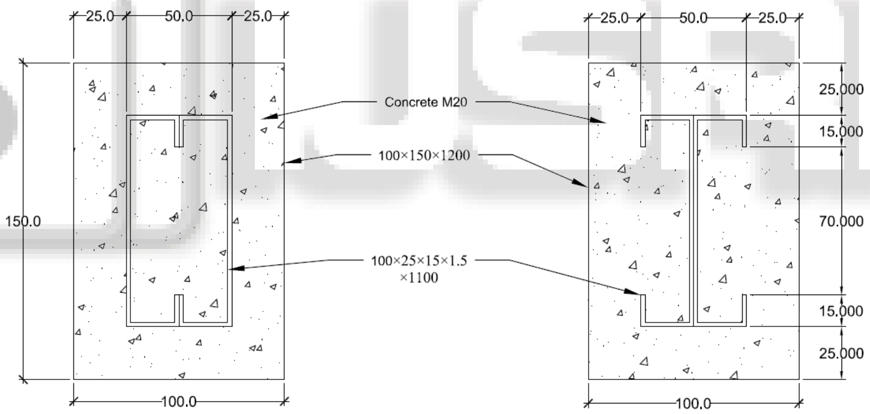
Concrete of grade M20 was used for casting beam specimen. Mix proportion 1:1.5:3 for concrete mix with w/c of 0.45 was adopted. Cement of grade OPC53 and coarse aggregate of crushed gravel aggregate with maximum size of 12.5mm were used. Locally available river sand were used as finer aggregate.

Beam with encased open sections were named I-1 and I-2 and beam with encased closed section were named B-1 and B-2. Concrete cubes casted during the time of casting of beams were tested for their compression strength using compressive testing machine. Concrete cubes resulted average compression strength of 22.2N/mm^2.

B. Test Procedure and Instrumentation

The beams were white washed at the surfaces before testing. Using permanent marker the locations of the supports, Linear Variable Differential Transformer (LVDT) points to measure deflections were marked. A self-straining frame of 50-ton capacity fixed over strong floor was used for testing. The beams were simply supported with an effective span of 1000 mm c/c. Two point loads were applied transversely at one third distances from each support using a spreader beam (a rolled steel I-joist). Two rollers were placed over loading section on beam and spreader beam was mounted on top of rollers placed over the beam.

LVDTs were used to measure the deflection of the beams. One LVDT was kept at the mid span of the beam and other two were kept under the loading points. Loading was applied by means of 20 ton hydraulic loading jack. The behavior of the beams was keenly observed from the beginning till the collapse. The appearance of the first crack, the development and propagation of cracks due to the increase of load were also recorded. The test set up is shown in Fig 3.2.



Closed section — Open section

Fig. 3.1: Typical cross sectional details of beam specimens (all dimensions are in mm)

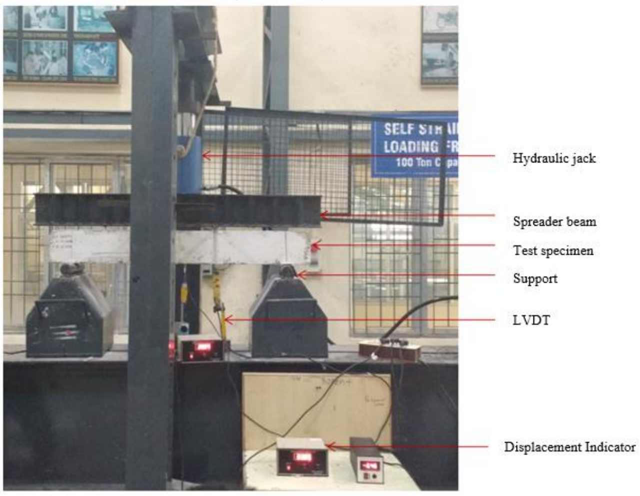


Fig. 3.2: Two-point loading test setup

IV. Results and Discussion

Test observation and failure

In beam specimens with encased CFS lipped channels forming open section, no cracking was observed till 33% of ultimate load. Fine cracking was observed till 60-65% of ultimate load. The cracks were equally spaced and concentrated in the pure bending region. Number of cracks varied from 7 to 9. Cracks were predominantly equally spaced vertical cracks propagating from bottom of beam to top and were concentrated in flexural span of beam which corresponds to span between two point loads. At 85% ultimate load fine horizontal cracks appeared on upper part of beam in between point load, indicating initiation of concrete crushing due to compression. On further loading cracks begins to widen up.

On the other hand in beam specimens with encased CFS lipped channels forming closed section, no cracking was observed till 30% of ultimate load. Fine crack was observed till 70-75% of ultimate load. Number of cracks varied from 10 to 12. Vertical cracks of equal spacing were located in flexural span of beam as observed in previous case. In addition to vertical cracks, diagonal cracks extending from bottom to top of beam from near the support to immediate loading point was observed indicating shear cracks. Increased number for fine cracks in random direction was observed at 90-95% of ultimate load. This indicated that the outer concrete acted as individual concrete layer no longer maintaining bond with encased steel section.

Sl. No.	Beam ID	Load at initial crack	Ultimate load	Ultimate deflection
		(kN)	(kN)	(mm)
1	I 1	24	60	28.83
2	I 2	26	60	28.69
3	B 1	18	62	26.61
4	B 2	20	60	26.45

Table 1: Experimental results

A. Load Deformation Response

In the present work the load vs central deflection as in Fig 4.1 for the tested beams were used to decide the failure type. The flexural failure is identified to take place in beams in which the encased CFS section yields first and consequently the beams exhibit large plastic plateau prior to failure. The flexural failure is characterized by a very large increase in deflection for the same load or a very little increase of load. The load vs corresponding deflection curves were drawn for all the beams and are shown in Fig 5.1. These diagrams give a better picture of the behavior of beams. A linear elastic response can be seen in the load deflection curves for all PCRC beams at the initial loading stage.

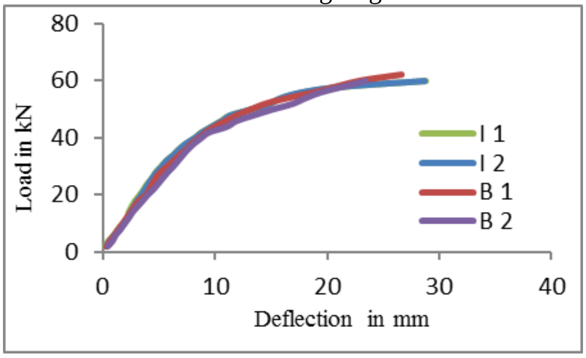


Fig. 4.1: Load–Deflection response of encased beams

V. CONCLUSION

Four specimens were fabricated and tested to investigate the flexural behaviour of CFS section encased concrete beams. The Load-Deflection curves were plotted and the failure mode of each specimen was recorded and studied carefully. Based on the test observations, the following conclusions can be drawn.

- Local buckling which is one of the main drawback of CFS is prevent due to confinement provided by encasing concrete
- Flexural load carrying capacity of CFS encased concrete beam is increased as the effective area of steel acting in bending is increased as local bucking is prevented
- Beams encasing back-to-back arrangement (open section) suffered larger vertical deflection but lesser cracks and only flexural failure.
- Beams encasing face-to-face arrangement showed lesser deflection but flexural and shear cracks were formed at failure
- Beams encasing open section exhibited equally spaced vertical flexural cracks of lesser number
- At ultimate load closed section encased beam undergoes 7 to 9% lesser deflection than open section encased beam

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