WEB CRIPLING BEHAVIOUR OF LITESTEEL BEAM

T. Manju* and H. Silpha
School of Civil Engineering, SASTRA University, Thanjavur 613401, India

Received: 14 October 2016; Accepted: 2 January 2017

ABSTRACT

LiteSteel Beam (LSB) was introduced in order to meet the growing demand of light structural elements that are easier to carry and install. They are in a way different from normal CFS sections in terms of their hollow flange which increases its load carrying capacity, the absence of free edges in LSB which minimizes local buckling failure, higher bending moment carrying capacity as the materials are distributed away from the neutral axis and greater bending stiffness. The LSB sections considered, consisted of two rectangular hollow flanges and a thin web in between, joined by welding. The basis of this study involved fabricating three sections 1.2 mm thick and depth varied as 300 mm, 250 mm, 200 mm as a representative of using it as purlin and in few cases as a secondary beam in small steel-framed houses. The Web crippling behaviour of these sections was studied by finding the sectional properties of the specimens using Cornell university finite strip method (CUFSM), followed by an experimental study which consisted of i) material characterization through tensile coupon tests ii) test on specimens to obtain maximum load carrying capacities and desired buckling modes. Further, using Finite element analysis software (ABAQUS) a model was generated to reproduce the results.

Keywords: LiteSteel beam; finite strip method; web crippling; finite element analysis.

1. INTRODUCTION

Cold-formed steel (CFS) sections are made up of thin steel sheets having a minimum thickness. These thin steel sheets are cold rolled i.e. they are manufactured without the application of heat, which makes its production easier. The geometry of these sections is unique, such that it resists greater bending moment, as the section walls are thinner and thereby, increasing the moment of inertia. These sections are lightweight, easy to carry, transport and install. Also, it can be provided with any type of connections such as bolted, welded and riveted. Their application includes using it as a structural member in the form of studs and purls to carry loads. Further, it plays a major role in resisting in-plane and out-
of-plane loads along the surface of roof, wall and floor panels. In addition to these, it also can be used as pre-fabricated assemblies in roof trusses.

Litesteel beams (LSB) are similar to cold-formed steel sections in the manufacturing process but, differs in profile as it has two hollow rectangular flanges connected by a thin web in between. In addition to cold-forming, it also involves electric welding at the web-flange junction. The uniqueness in LSB section lies in the hollow flange which is most capable of resisting higher bending moments; this is due to the fact that materials are distributed far away from the neutral axis. The absence of local buckling mode of failure as there are no free edges. Further, these sections resist twisting or torsion. LSB sections considered in this study consisted of two rectangular hollow flanges and a thin web in between joined by welding. In the present study, an attempt is made to understand the Web crippling behaviour of LSB sections through experiments and numerical analysis. As a part of the experimental investigation, the material properties are found through tensile coupon test, the maximum load carrying capacity of the sections are found and the corresponding modes of failure are obtained on applying two point loading conditions. Further, a numerical model was generated to compare with the results obtained experimentally.

2. SPECIMENT PROPERTIES

LSB I-sections were considered in this study. The dimensions of the sections were selected in such a way that it can be used as a secondary beam. A single sheet of 1.2 mm thick was used for making both rectangular hollow flange and a thin web. These were then fabricated as sections, by welding the flange and the web portion. The overall depth of the sections is varied as 300 mm, 250 mm, 200 mm for the purpose of the study. This sort of specifications is done, with a view to reducing local buckling mode of failure. The cross and longitudinal view of the specimen considered for this study is as shown in Fig. 1 and the details of dimensions are depicted in Table 1.

Figure 1. (a) Cross-sectional view of specimen (b) Longitudinal view
### Table 1: Dimensions of specimens considered (in mm)

<table>
<thead>
<tr>
<th>Specimen no.</th>
<th>d</th>
<th>h</th>
<th>t</th>
<th>b</th>
<th>l</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>300</td>
<td>25</td>
<td>1.2</td>
<td>150</td>
<td>1200</td>
</tr>
<tr>
<td>2</td>
<td>250</td>
<td>25</td>
<td>1.2</td>
<td>150</td>
<td>1200</td>
</tr>
<tr>
<td>3</td>
<td>200</td>
<td>25</td>
<td>1.2</td>
<td>150</td>
<td>1200</td>
</tr>
</tbody>
</table>

### 3. FINITE STRIP METHOD

FSM is one such technique which involves a semi-analytical and semi-numerical method of analysis of rectangular plates and plane stress problems. This method is less efficient than Finite element method (FEM) in some situations. In spite of these, it becomes useful in the design and analysis of bridges, tall structures as well as in the analysis of steel beams. One such package which uses FSM is Cornell University Finite Strip Method (CUFSM), which is used in the determination of sectional properties as depicted in Table 2 and also proves essential in predicting the buckling modes of thin-walled cold-formed steel members as shown in Fig. 2.

### Table 2: Sectional properties of specimens

<table>
<thead>
<tr>
<th>Section no.</th>
<th>A (mm$^2$)</th>
<th>$I_{XX}$ (mm$^4$)</th>
<th>$I_{ZZ}$ (mm$^4$)</th>
<th>$X_{cg}$ (mm)</th>
<th>$Z_{cg}$ (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1138.197</td>
<td>1.752x10$^7$</td>
<td>2.017x10$^6$</td>
<td>74.93</td>
<td>149.96</td>
</tr>
<tr>
<td>2</td>
<td>1073.675</td>
<td>1.147x10$^7$</td>
<td>2.009x10$^6$</td>
<td>74.93</td>
<td>124.968</td>
</tr>
<tr>
<td>3</td>
<td>1014.514</td>
<td>6.828x10$^6$</td>
<td>2.016x10$^6$</td>
<td>74.93</td>
<td>99.90</td>
</tr>
</tbody>
</table>
4. EXPERIMENTAL PROGRAMME

Three beam sections are fabricated with varying depth of 300 mm, 250 mm, 200 mm as shown in Fig. 3 and the details of the geometry of specimens were given before in Table 1. The specimens were placed in the testing machine, such a way that two point loading conditions are applied at L/3 spans and also a bearing of 100 mm was given at each end and the supports are placed. At first, a small unit of the load was applied to ensure that the specimen and the supports are in firm contact. Later, the initial value is set to zero and the loading is commenced. The load is transferred through the load cells and the load increments are observed and the corresponding deflections are noted. The schematic diagram of two point loading is shown in Fig. 4.
5. FINITE ELEMENT ANALYSIS

FEA is a numerical approach for solving real-world problems in engineering. It is more suitable for applying different boundary conditions, suitable for a wide variety of material properties, also proves efficient in deriving solutions to complicated geometry. One such package which is used for our study is ABAQUS. It is a software tool which is used for modelling and analysis of components and assemblies. It has wide applications in the field of civil and mechanical engineering.

6. RESULTS AND DISCUSSION

Calibration of the numerical model provided good agreement with the experimental results in terms of maximum load carrying capacity and modes of failure. Table 3 shows the comparison of load carrying capacity obtained in the experimental and numerical study.

<table>
<thead>
<tr>
<th>Section no.</th>
<th>Depth (mm)</th>
<th>Experimental result (kN)</th>
<th>Numerical result (kN)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>300</td>
<td>3.50</td>
<td>4.45</td>
</tr>
<tr>
<td>2</td>
<td>250</td>
<td>4.25</td>
<td>5.37</td>
</tr>
<tr>
<td>3</td>
<td>200</td>
<td>5.35</td>
<td>6.38</td>
</tr>
</tbody>
</table>

It was observed from Table 3 that numerical results are slightly higher than experimental results. Further, the variation of load carrying capacity are nearer to each other and is clearly understood from Fig. 5, which tells us that numerical values are in the same range of experimental results.

![Figure 5. Comparison of maximum loads carrying capacity](image)

Further, there is an increase in load carrying capacity as the depth of section decreases. In addition, as load values increase the corresponding deflection goes on increasing. The load vs displacement curve shown in Fig. 6, shows the variation of the same of the three sections considered. It explains the fact that load increases as the depth of section decreases.
In addition, when the depth of section decreases the beam shows higher resistance to bending and thereby increasing stiffness. Fig. 7 shows the variation of the maximum bending moment of each section and is observed that 1st section can resist higher moment. It decreases as the depth of section decreases.

Further on comparing the failure modes, it was observed that distortional buckling was the prominent mode of failure obtained in both the studies. In section-1 and section-2 considered, there was flange crushing along with distortional buckling. In section-3, flange crushing and distortional buckling along with slight crippling of web nearer to the junction of web and flange occurred. Figs. 8-12 shows the comparison of results obtained experimentally and numerically.
Figure 8. Comparison of distortional buckling obtained in section-1

Figure 9. Comparison of distortional buckling obtained in section-2

Figure 10. Comparison of top view of obtained failure mode
The comparison of obtained failure modes clearly explains that there is no local buckling mode of failure, as it is more prevalent in normal CFS sections; this is due to the fact that LSB has a hollow compression flange where flange crushing took place instead of local buckling. The specimens possess greater resistance to bending of thin web part thereby providing greater stiffness. Distortional buckling is greatly pronounced in these sections. The failure modes obtained through experiments and numerical analysis are more relevant to each other.

7. CONCLUSIONS

This paper reported the results of experimental and numerical study on LSB sections to investigate the web crippling behaviour. Firstly, CUFSM analysis provided sectional properties and also predicted the various buckling modes. Later, an experimental program was conducted on all the three specimens, it was seen that as the depth of specimen
decreases load carrying capacity increases and thereby increasing bending stiffness. Also, the depth of specimen decreases the ability to withstand bending goes on decreasing and the beam becomes stiffer. In addition to these, the specimens reported well distributed distortional buckling with a change in cross-section, followed by flange crushing of the compression flange. Web crippling failure was less significant and it occurred in section-3 nearer to the junction of web and flange. Further, there was no proof of local buckling as there are no free edges, which proved to be the advantage of using LSB. Calibration of a numerical model with FSM proved less effective as it overruled the mode shapes obtained through experiments. The numerical analysis conducted through FEA provided a significantly close relationship to the experimental results in terms of load carrying capacity and modes of failure. The load carrying capacity values obtained through FEA was quite significant and there was an only minor deviation from experimental test results. While comparing the failure mode shapes, the distortional buckling mode of failure and the flange crushing was well reproduced in finite element analysis. But, it failed in depicting the web crippling failure obtained in the experimental study. There were no local buckling waves seen in the numerical study too. Thus, the experimental and numerical results provided a good agreement to each other and it proved the advantage of using LSB sections.

REFERENCES