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Z.W. Zhu*, T. Qin, X.W. Chen
Preface

These proceedings contain the papers presented at the TENTH INTERNATIONAL CONFERENCE ON ADVANCES IN STEEL STRUCTURES (ICASS 2020) held in Chengdu, China, from 21 to 23 August 2022. The international conference series on Advances in Steel Structures was initiated in 1996 under the support of The Hong Kong Polytechnic University, which remains very active in fostering its continuation—joined a few years later by the Hong Kong Institute of Steel Construction.

These proceedings bring together most recent findings in numerical, theoretical and experimental research, as well as its practical implementation in design practice in the areas of Assembled Structure, Bridge, Cold-formed Steel, Composite, Connections, Corrosion, Fracture & Collapse, Design & Analysis, Direct Analysis, Fatigue, Fire, High-Strength Steel, Impact and Protection, Intelligent Construction, New Material, Seismic Resistance, Stability, Stainless Steel, Structure Systems, Testing & Monitoring. The papers presented in these proceedings come from a wide range of countries/regions and will be a great reference source.

Specially, the subject matter has been categorized under the broad heading of:

**Volume I:** Keynotes Lectures, Assembled Structure, Bridge, Cold-Formed, Composite, Connections, Corrosion, Fracture & Collapse, Design & Analysis, Direct Analysis, Fatigue


Each of the papers was subjected to stringent review by a panel of experts in the respective area. This peer review began with an assessment of the submitted abstracts and following this, authors were invited to submit their full manuscripts. Each manuscript was then carefully reviewed by relevant experts, and their recommendations on accepting, rejecting or modifying the submissions were strictly adhered to, before inclusion in the conference proceedings.
STUDY ON LOCAL BEARING CAPACITY OF COMPOSITE I-GIRDER WITH CONCRETE-FILLED TUBULAR FLANGE AND CORRUGATED WEB

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Abstract: Experimental tests on three composite straight girders and three composite curved girders are carried out to study the local bearing capacity of new composite I-girders with concrete-filled tubular flange and corrugated web (IG-CFTF-CW). The failure modes and the load carrying capacity of the new composite girders under local compressive load are studied. Experimental results show that one of the new composite straight girders failed in web buckling and the other two failed in web yielding. All the three new composite curved girders failed in elastic buckling in the web. The concrete-filled tubular flange (CFTF) can effectively increase the effective bearing length of corrugated web (CW) and the lateral stiffness and the local bearing capacity of the composite girders.

Keywords: Composite curved girder; Composite straight girder; Concrete-filled tubular flange; Corrugated web; Local bearing capacity

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1 INTRODUCTION

Compared with traditional I-girders and I-girders with corrugated web (IG-CW), IG-CFTF-CW have good flexural performance [1,2,3], shear performance [4,5,6], local bearing performance [7], stability [1,8] and fatigue performance [9,10]. However, there are few studies on the local compressive performance of curved I-girder with concrete-filled tubular flange and corrugated web (CIG-CFTF-CW) [11]. This paper investigates the local compressive bearing capacity of the new composite girders, including composite straight girders and composite curved girders, by using experimental method.

2 EXPERIMENTAL TEST

2.1 Specimens design

Six specimens with a span of 1680mm are designed. Geometries of the specimens are shown in Fig. 1. SP1 and SP3 are new composite straight girders, while SP2 and SP4 are new composite curved girders. These four specimens are composed of top CFTF, CW and flat bottom flange. SP5 is a traditional straight IG-CW, and SP6 is a traditional curved I-girder with corrugated webs (CIG-CW). These two specimens are composed of flat top and bottom flanges and CW. Section dimensions and material properties are shown in Table 1 and 2, respectively. $f_y, w$ and $f_y, tube$ in Table 1 are the yield strengths of the web material and of the steel tube material, respectively. The grouting material is high strength cement, and the measured compressive strength is 62.7MPa.
Table 1: Geometric dimensions and material properties of specimens

<table>
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<tr>
<th>Specimen</th>
<th>Corrugation type</th>
<th>( L ) (mm)</th>
<th>( H ) (mm)</th>
<th>( b_t ) (mm)</th>
<th>( h_a ) (mm)</th>
<th>( t_a ) (mm)</th>
<th>( h_w ) (mm)</th>
<th>( t_w ) (mm)</th>
<th>( t_t ) (mm)</th>
<th>( L/R ) (Rad)</th>
<th>( f_{y,w} ) (MPa)</th>
<th>( f_{y,\text{tube}} ) (MPa)</th>
</tr>
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<tbody>
<tr>
<td>SP1</td>
<td>1</td>
<td>1680</td>
<td>666</td>
<td>120</td>
<td>60</td>
<td>3</td>
<td>600</td>
<td>1.9</td>
<td>6</td>
<td>0</td>
<td>323</td>
<td>372</td>
</tr>
<tr>
<td>SP2</td>
<td>1</td>
<td>1680</td>
<td>666</td>
<td>120</td>
<td>60</td>
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<td>600</td>
<td>1.9</td>
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<td>0.3</td>
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<td>SP3</td>
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<td>1680</td>
<td>666</td>
<td>120</td>
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<td>SP4</td>
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<td>SP5</td>
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Table 2: Geometric dimensions of corrugated web

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<th>Corrugation type</th>
<th>( b ) (mm)</th>
<th>( d ) (mm)</th>
<th>( h_t ) (mm)</th>
<th>( q ) (mm)</th>
<th>( \theta ) (°)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>70</td>
<td>50</td>
<td>50</td>
<td>240</td>
<td>45</td>
</tr>
<tr>
<td>2</td>
<td>120</td>
<td>90</td>
<td>50</td>
<td>420</td>
<td>29</td>
</tr>
</tbody>
</table>

2.2 Test setup

The MTS hydraulic servo loading system are used to apply the concentrate load. As shown in Fig. 2, the lateral displacements of the specimens at the two ends are restricted by using two U-shaped supports. The longitudinal displacement of the specimen at the mid-height is constrained at one end by four short bars welded on the two columns of the U-shaped support. A steel block is installed between the MTS actuator and the top flange of the girder (the loading length is \( C=120\text{mm} \)).

Fig. 2: Test setup
3 TEST RESULT ANALYSES

3.1 Failure mode

For the six specimens, the failure modes are all local compressive failure of the corrugated web in the region below the corrugated web/top RGTF connection, as shown in Fig. 3. The length of the failure region in the web of the four new composite girders (i.e., SP1, SP2, SP3 and SP4) are much larger than that of the two traditional composite girders (i.e., SP5 and SP6). This indicates that the CFTF can increase the effective bearing length in the web whether for the straight girders or for the curved girders.

![Fig. 3: Failure modes of specimens](image)

3.2 Strain analysis

The strain development at some critical positions on the specimens is monitored from strain gauges. Fig. 4 and Fig. 5 show the compressive strain distribution along the web length of SP1 and SP2 under different loading levels. It is found that the strains at same location in side A and in side B are found in Figs. 4(a)~4(b) to be approximately same in elastic stage, which indicates that web buckling does not occur in SP1 before failure. In Figs. 5(a)~5(b), the compressive strain at location 4 in side A (same location 11 in side B) is smaller than the corresponding strain at location 11 with same load, which indicates that flexural deformation occurs in location 4 (location 11) at elastic stage, and web buckling occurs in this location. Using this method of analysis, the failure mode of all the specimen can be determined. As listed in Table 3, SP1 and SP5 failed in web yielding while the other four specimen failed in web elastic buckling. Therefore, the initial curvature and the waveform shape have influence on the failure mode of the composite girders.

![Fig. 4: Compressive strain distribution and development in the web of SP1](image)
Three strain rosettes are placed uniformly along the web height at the 1/4 span for each specimen, and the load-shear strain curves can be obtained, as shown in Fig. 6. From the curves, it is found that shear failure occurs only in the web of SP2, while no shear failure occurs in the other specimens. For the curved girder SP2, the shear stress increases rapidly due to large out-of-plane flexural and torsional deformation after the load exceeds 225kN. For the straight girder SP1, there is only shear stress in the web and shear failure does not occur. Therefore, it can be concluded that initial curvature has influence on the shear resistance of the web.

Normal strains of the bottom plate flange at 1/4 span and at mid-span for the specimens are obtained. From load-normal strain curves of all the specimens, it is found that the bottom flanges of all the specimens are in elastic states except position 48 in the bottom flange of SP2. Due to the complex stress state of coupled in-plane bending, out-of-plane bending and torsional...
deformation, the strain in position 48 in SP2 exceeds the yield strength when the load exceeds 200kN, as shown in Fig. 7.

Normal strains of the top CFTF at the side close to the curvature center (the number is in red font in Fig. 8) and at the side away from the curvature center (the number is in blue font in Fig. 8) are obtained. It is found that for the top CFTFs of the two new composite curved girders (SP2 and SP4), the side close to the curvature center is in compression while the side away from the curvature center is in tension, which is produced due to from the out-of-plane bending and torsion of the specimens.

3.3 Load-displacement curves analysis

The load-vertical displacement curves of the 6 specimens are shown in Fig. 9. The vertical displacement is measured from the LVDTs placed on the top flanges at mid-span. From the load-displacement curves, the ultimate loads of specimens are obtained and listed in Table 3. The four new composite girders have much higher load carrying capacity compared to the two conventional flat plate flange girders.

The load-lateral displacement curves of the three composite curved girders are shown in Fig. 10. The lateral displacement is measured from the LVDTs placed horizontally on the two sides of the top flanges at mid-span. It is found from Fig. 10 that the lateral stiffnesses of the two new composite curved girders are much larger than that of the conventional flat plate flange curved girders.

![Fig. 9: Load-vertical displacement curves of specimens](image1)

![Fig. 10: Load-lateral displacement curves of the three curved girders](image2)

Table 3: Comparison of load carrying capacity and web failure modes between specimens

<table>
<thead>
<tr>
<th>Specimens</th>
<th>SP1</th>
<th>SP2</th>
<th>SP3</th>
<th>SP4</th>
<th>SP5</th>
<th>SP6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ultimate bearing capacity (kN)</td>
<td>278</td>
<td>235</td>
<td>206</td>
<td>201</td>
<td>106</td>
<td>118</td>
</tr>
<tr>
<td>Web failure modes</td>
<td>Web yielding</td>
<td>Web elastic buckling</td>
<td>Web shear yield</td>
<td>Web elastic buckling</td>
<td>Web bottom flange yielding</td>
<td>Web elastic buckling</td>
</tr>
</tbody>
</table>

4 CONCLUSIONS

(1) CFTF increases the effective bearing length of the corrugated web. Therefore, CFTF increases greatly the local bearing capacity of the new composite girders with CW. For the three composite curved girders, the lateral stiffnesses of SP2 and SP4 are much larger than that of SP6. That is because the CFTF has larger torsional stiffness than flat plate flange.
(2) For the new composite curved girder specimen SP2, the web firstly failed in local bearing zone at load of 160kN, then the bottom flange began to yield at load of about 200kN, which followed by the shear failure of the web at the ultimate load of 235kN. This phenomenon indicates that if appropriate waveform is selected, the girder will not lose its bearing capacity immediately even if the local bearing failure occurs in the web.

(3) The web waveform shape and initial curvature have significant affection on the failure mode of the new composite girders. The composite straight girders with waveform 1 (i.e., SP1 and SP5) failed in web yielding while other four girders failed in web elastic buckling.

(4) The effect of initial curvature on the local bearing capacity can be ignored if the initial curvature is smaller than the engineering limit. Although SP3 is a straight girder while SP4 is a curved girder with the initial curvature of 0.3, but they almost have the same carrying capacity.

REFERENCES


These proceedings contain the papers at the TENTH INTERNATIONAL CONFERENCE ON ADVANCES IN STEEL STRUCTURES (ICASS 2020) held in Chengdu, China, from 21 to 23 August 2022. The international conference series on Advances in Steel Structures was initiated in 1996 under the support of The Hong Kong Polytechnic University, which remains very active in fostering its continuation - joined a few years later by the Hong Kong Institute of Steel Construction.

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