Chapter III
Test Specimens and Testing Procedure

3.1 Introduction

To investigate the results of the procedures used in Chapter II for determining critical unbraced lengths, tests were conducted on two specimens. The objective of the testing was to simulate the loading conditions that a castellated beam would experience through the handling and construction stage of its life. During this stage the beam is unstable due to the absence of the continuous bracing of a floor assembly that will later be placed on top of it. The tests were conducted at the Virginia Tech Department of Civil and Environmental Engineering Structures and Materials Research Laboratory. SMI Steel Products fabricated and provided the test specimens, which are commercially available sections.

3.2 Test Set-up and Procedure

Each specimen was placed into the test set-up using the laboratory crane, in the same manner it would be raised into place in the field. The castellated beam was then bolted to two columns that were previously bolted to a reaction floor beam, as shown in Figure 3.1. The castellated beam was connected to the columns using web-to-column flange double angle connections. The connection details are shown in Figure 3.2. The web-to-column flange connection shown is a typical connection used in buildings utilizing castellated beams. The long leg of a L5 x 3-½ x 12 angle was bolted to the web of the castellated beam. On this leg,
slotted holes were cut to increase the number of times the test specimens could be tested by allowing leeway for bolthole placement in the web of the castellated beam. The connection angle details are shown in Figure 3.3.

Figure 3.1 Full Test Set-up
CASTELLATED BEAM
L5" x 3½" x 3½" WITH (2) 3/8" DIAMETER BOLTS EACH LEG
SUPPORT COLUMN BOLTED TO REACTION FLOOR
CASTELLATED BEAM

(a)

(b)

Figure 3.2 Web to Column Flange Double Angle Connection Detail
Catch bracing was located at the quarter points and at mid span of the castellated beam. The catch bracing was connected to the reaction floor and allowed the castellated beam to deflect, but not allow excessive deflections that would result in permanent deformation of the specimen. The catch bracing at the quarter points was secured with the face of the catch bracing 1 in. from the edge.
of the flange of the castellated beam. The mid-span bracing was installed with the face of the catch bracing 10 in. from the edge of the castellated beam. This greater distance of the mid-span catch bracing was in place to catch the beam only if the quarter point catch bracing failed. Once the beam deflected the 1 in., it was assumed that the beam would continue to deflect and buckle. The catch bracing was fabricated from C6x8.2 and L3x3x¼ sections. See Figures 3.4, 3.5, and 3.6 for the catch bracing details.

Figure 3.4 Catch Bracing Detail (Elevation View)
Once the web-to-column flange connections were secured, the crane was released. At this moment the beam was observed under self-weight loading. The effects of the initial imperfection of the beam could be observed at this stage. Next a loading plate, as seen in Figure 3.7, was clamped to the top flange of the castellated beam at mid span. The centerline of the loading plate was placed directly over the web of the test beam. Plates, weighing 10 lb each, were then placed on the loading plate until the beam buckled or 300 lb was reached. The
application of a maximum 300 lb point load at mid-span was used to simulate the weight of an ironworker who would need to disconnect the crane from the castellated beam. The lateral deflection was observed as the 10 lb weights were added. The susceptibility of the castellated beam to sway laterally was also observed.

![Figure 3.7 Loading Plate](image)

The loading continued until failure occurred; characterization of failure for this testing is described in Section 3.3. Once failure occurred, the length of the
beam and the load that was applied were recorded and the load and loading plate were removed.

The loading procedure was then repeated with 1½ in. and 2 in. eccentricities as illustrated in Figure 3.8. This was done to observe the susceptibility of the castellated section to sway laterally due to an off center load.

![Figure 3.8 Load Application Descriptions](image)

**Figure 3.8 Load Application Descriptions**

After the third load application, the crane was reconnected to the castellated beam and one web-to-column connection was removed. The beam was then shortened using a plasma torch to cut a segment of the beam off. The
plasma torch was then used to burn two bolt holes in the web of the castellated beam to allow the web-to-column flange connection to be reattached. The support column was moved into its new location and reattached to the reaction floor. Next the castellated beam was reattached to the column. Lastly, the catch bracing was repositioned for the new beam length and the three loadings applied. This process was continued until a total of 300 lb could be applied without buckling as defined in section 3.3. Once this occurred, the length of the beam was considered less than critical.

### 3.3 Determination of Critical Length

When dealing with stability, issues the need for careful observation while the testing is being performed is critical. The smallest change and reaction of the test specimen needs to be observed. The testing procedure requires unique requirements to define failure not present in other testing. Not only does the castellated beam need to support load, but also the beam needs to be evaluated for stiffness and constructability. The steps to describe a stable castellated beam need to be considered.

The first stability requirement is that the castellated beam must support load. For this testing, the castellated beam must support the weight of an erector, 300lb. During loading, if the top flange of the castellated beam touched the quarter point catch bracing, loading was stopped and this was considered buckling. This requirement limits the lateral and torsional displacements. The critical loading is defined as the load that caused the top flange to touch the catch
bracing. When this occurred, the length of the beam was defined as beyond the critical unbraced length.

The second stability requirement deals with the constructability of a structure utilizing castellated beams. The castellated beam needs to be stable enough to allow an ironworker to walk out to the midspan of the beam and release the beam from the grasp of the crane, then return to the supporting column. During the initial tests on each specimen, the beam was observed to be laterally unstable. Specifically, the beam would sway tremendously and continue swaying if a small force was applied laterally to the top flange of the castellated beam. As an aside, a laboratory technician tried to walk from one support column to the midspan. It was observed that if the beam was stabilized and the technician stood still on the beam, then when the beam was released the beam would remain still. However, once the technician shifted weight from one foot to another in order to take a step, the beam started swaying uncontrollably. This occurrence justified the categorizing of failure without the formation of a buckle. The beam’s lateral stiffness would drastically improve once the unbraced length was less than critical. The improvement was very noticeable and allowed the technician to walk the beam more comfortably.

If during loading any of these requirements were not met, the beam length was considered beyond critical. The beam was shortened and the testing procedure continued until all requirements were met regarding stability. Since the failure of the specimen is subjective, the critical unbraced length from the testing is an approximate value.
3.4 Test Specimens and Results

3.4.1 CB24x26 Specimen

The delivered length of the CB24x26 section was 54 ft. The CB24x26 specimen was tested at lengths of 48 ft 4 in., 44 ft 10 in., 41 ft 4 in., and 37 ft 6 in. as shown in Figure 3.9. At these lengths the termination of the castellated beam coincided with the allowable placement of the support column on the reaction floor and provided for adequate placement of the web-to-column flange connection.

![Figure 3.9 CB24x26 Test Lengths](image)

From the testing, it was determined that the critical unbraced length for the CB24x26 specimen is approximately 37 ft 6 in. At this length the castellated beam satisfied the requirements of this study to be considered stable and was able to support a 300 lb concentrated load at midspan with no eccentricity. Table 3.1 is a summary of the test results for this specimen. For lengths longer than the critical length, the load that caused failure is also presented in Table 3.1. The test data is in Appendix B.
Table 3.1 Summary of CB24x26 Test Data

<table>
<thead>
<tr>
<th>Eccentricity</th>
<th>Test Length</th>
<th>Concentrated Load (lb)</th>
</tr>
</thead>
<tbody>
<tr>
<td>e = 0</td>
<td>48.3ft</td>
<td>170</td>
</tr>
<tr>
<td></td>
<td>44.8ft</td>
<td>220</td>
</tr>
<tr>
<td></td>
<td>41.3ft</td>
<td>260</td>
</tr>
<tr>
<td></td>
<td>37.5ft</td>
<td>300</td>
</tr>
<tr>
<td>e = 1 1/2&quot;</td>
<td>100</td>
<td>150</td>
</tr>
<tr>
<td></td>
<td>190</td>
<td>260</td>
</tr>
<tr>
<td>e = 2&quot;</td>
<td>80</td>
<td>120</td>
</tr>
<tr>
<td></td>
<td>150</td>
<td>200</td>
</tr>
</tbody>
</table>

3.4.2 CB27x40 Specimen

The delivered length of the CB27x40 section was 59 ft. The CB27x40 specimen was tested at lengths of 51 ft 9 in., 47 ft 3 in., 44 ft 6 in., and 42 ft 6 in. as shown in Figure 3.10. At these lengths the termination of the castellated beam coincided with the allowable placement of the support column on the reaction floor and provided for adequate placement of the web-to-column flange connection.

![Figure 3.10 CB27x40 Test Lengths](image)

From the testing, it was determined that the critical unbraced length for the CB27x40 specimen is approximately 42 ft 6 in. At this length the castellated beam satisfied the requirements of this study to be considered stable and was able to support a 300 lb concentrated load at midspan with no eccentricity. Table 3.2
is a summary of the test results for this specimen. For lengths longer than the critical length, the load that caused failure is also presented in Table 3.2. The test data is in Appendix D.

Table 3.2 Summary of CB27x40 Test Data

<table>
<thead>
<tr>
<th>Eccentricity</th>
<th>Test Length</th>
<th>Concentrated Load (lb)</th>
</tr>
</thead>
<tbody>
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<td></td>
<td>51.8ft</td>
<td>47.3ft</td>
</tr>
<tr>
<td>e = 0</td>
<td>self wt.</td>
<td>120</td>
</tr>
<tr>
<td>e = 1 1/2&quot;</td>
<td>self wt.</td>
<td>60</td>
</tr>
<tr>
<td>e = 2&quot;</td>
<td>self wt.</td>
<td>40</td>
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