Antiquated Structural Systems Series
Part 9a – Open Web Steel Joists
By D. Matthew Stuart, P.E., S.E., F. ASCE, SECB

For this series of articles, “antiquated” has been defined as meaning outmoded or discarded for reasons of age. In reality, however, most of the systems that have been discussed are no longer in use simply because they have been replaced by more innovative or more economical methods of construction.

This article, however, deals with a method of construction that is still very much in use today. Nevertheless, the historic, original construction practices described in this article may still be encountered in existing structures. Therefore, the primary purpose of this series of articles will be fulfilled: to compile and disseminate a resource of information to enable structural engineers to share their knowledge of existing structural systems that may no longer be in use, but are capable of being adapted or reanalyzed for safe reuse in the marketplace of today and the future.

Open Web Steel Joists

History

The author would first like to thank the Steel Joist Institute (SJI) for providing much of the material that was used in the development of this article. In fact, a brief history of open web joists is provided in the Catalog of Standard Specifications and Load Tables for Steel Joists and Joist Girders, published by SJI. A brief summary of this history is as follows:

1923 The first Warren type, open web truss/joist is manufactured using continuous round bars for the top and bottom chords, with a continuous bent round bar used for the web members.
1928 First standard specifications adopted after the formation of SJI. This initial type of open web steel joists was later identified as the SJ-Series.
1929 First load table published.
1953 Introduction of the longspan or L-Series joists for spans up to 96 feet with depths of up to 48 inches, which were jointly approved by AISC.
1959 Introduction of the S-Series joists, which replaced the SJ-Series joists. The allowable tensile strength was increased from 18 ksi to 20 ksi, and joist depths and spans were increased to 24 inches and 48 feet, respectively.
1961 Introduction of the J-Series joists, which replaced the S-Series joists. The allowable tensile strength was increased from 20 ksi to 22 ksi. Introduction of the LA-Series joists to replace the L-Series joists, which included an allowable tensile strength increase from 20 ksi to 22 ksi. Introduction of the H-Series joists, which provided an allowable tensile strength of 30 ksi.
1962 Introduction of the LH-Series joists, which provided yield strengths between 36 ksi and 50 ksi.
1965 Development of a single specification for the J- and H-Series joists by SJI and AISC.
1966 Introduction of the LJ-Series joists, which replaced the LA-Series joist. In addition, a single specification was developed for the LJ- and LH-Series joists.
1970 Introduction of the DLH- and DLJ-Series joists, which included depths up to 72 inches and spans up to 144 feet.
1978 Introduction of Joist Girders, including standard specifications and weight tables.
1986 Introduction of the K-Series joists, which replaced the H-Series joists.
1994 Introduction of the KCS joists, which provided a constant moment and shear capacity envelope across the entire length of the member.

SJI also recently published 80 Years of Open Web Steel Joist Construction. This publication includes a complete chronological listing of the standard specifications and load tables for all of the steel joists, and weight tables for the Joist Girders, previously made available by SJI over the time period from 1928 to 2008. This manual can be an invaluable tool for an engineer involved in the analysis of existing buildings constructed with open web steel joists.

In addition, there were also a number of joists produced by manufacturers that were either never members of SJI or joined it later. Some of these manufacturers include: Ashland Steel Joists (manufactured by Ashland Steel Products Co., Inc.—Ashland City, Tennessee); Vescom Structural Systems, Inc.—Westbury, New York; Ridgeway Joists (manufactured by Continental Steel Ltd.—Coquitlam, British Columbia); Northwest Joist Limited (a Division of Brittain Steel Limited—New Westminster, British Columbia); Cadmus Long Span and Joist Corporation (affiliated with Alexandria Iron Works, Inc.—Alexandria, Virginia); T-Chord Longspan Joists (manufactured by the Haven Busch Company—Grandville and Grand Rapids, Michigan); and the Macomber Steel Company—Canton, Ohio. Table 1 (please see online version; article end note provides web address) provides a summary description of the joists produced by these manufacturers.

In addition, some manufacturers, prior to becoming SJI members, produced products other than the historical standard SJI joist series. Some of these manufacturers include: Truscon Steel Company—Youngstown, Ohio; Macmar and Kalmantruss joists (manufactured by Kalman Steel Corporation, a Subsidiary of Bethlehem Steel Company—Bethlehem, Pennsylvania); and Gabriel Steel Company—Detroit, Michigan. Table 2 (please see online version; article end note provides web address) provides a summary description of the joists produced by these manufacturers. In addition to the information provided in Table 2, it should be noted that Bethlehem Steel Company also produced cold formed joists with hat channel sections for the chord members, and Gabriel Steel Company also produced unique V-shaped top chord and single round bar bottom chord members.

Additional manufacturers not included in Tables 1 and 2 include: Berger Steel Company (double V-shaped chord members); Armco Steel (cold formed hat channel chord members); Raychord Corporation (cold formed hat channel and U-shaped chord members); Republic Steel (cold formed hat channel chord members); and USS AmBridge (cold formed U-shaped chord members).
Resource Material

80 Years of Open Web Steel Joist Construction; A Compilation of Specifications and Load Tables Since 1928; Steel Joist Institute; Myrtle Beach, South Carolina (2009).

Catalog of Standard Specifications, Load Tables and Weight Tables for Steel Joists and Joist Girders; 42nd Edition; Steel Joist Institute; Myrtle Beach, South Carolina (2007).

Miscellaneous Steel Joist and Joist Girder Specifications and Load Tables; SJI Archives; Steel Joist Institute, Technology, Engineering, and Education Center; Myrtle Beach, South Carolina

Another Resource

Robert Higgins, P.E., maintains a website that provides civil and structural engineering information in the following categories:

- Out-of-print material that may be useful when working on existing facilities.
- Older, usually conservative methods for solving technical problems.
- Public domain documents that have limited availability.

In summary, this is content that is difficult to find anywhere else. To access it, visit www.SlideRuleEra.net.

Watch for Part 9b in an upcoming issue.

Table 1 online version web address: www.STRUCTUREmag.org/archives/2009-6/table-1.pdf
Table 2 online version web address: www.STRUCTUREmag.org/archives/2009-6/table-2.pdf
<table>
<thead>
<tr>
<th>System</th>
<th>Figure</th>
<th>Description</th>
<th>Yield Strength</th>
<th>Depth (inches)</th>
<th>Span (feet)</th>
<th>Chords</th>
<th>Webs</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ashland</td>
<td>1</td>
<td>HS-Series Joists</td>
<td>50 ksi</td>
<td>8 to 24</td>
<td>8 to 48</td>
<td>Double angles</td>
<td>Round bars</td>
<td></td>
</tr>
<tr>
<td></td>
<td>N/A</td>
<td>LS-Series Joists</td>
<td>50 ksi</td>
<td>Unknown</td>
<td>64 maximum</td>
<td>Unknown</td>
<td>Unknown</td>
<td></td>
</tr>
<tr>
<td>Cadmus</td>
<td>5</td>
<td>1952 Structural T Longspan &amp; Standard Joists</td>
<td>See Note 6</td>
<td>10± to 54</td>
<td>12'-6&quot; to 108</td>
<td>Split T</td>
<td>Angles</td>
<td>6, 7</td>
</tr>
<tr>
<td>Haven Busch</td>
<td>6</td>
<td>1952 to 1962 T-Chord Longspan Joists</td>
<td>See Note 9</td>
<td>18 to 88</td>
<td>25 to 175</td>
<td>Split T</td>
<td>Angles</td>
<td>8, 9</td>
</tr>
<tr>
<td>Macomber</td>
<td>7</td>
<td>Purlin or Steel Joist</td>
<td>Unknown</td>
<td>8 to 16</td>
<td>10 to 26</td>
<td>See Note 10</td>
<td>Round bars</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>8</td>
<td>Massillon Steel Joist</td>
<td>Unknown</td>
<td>8 to 16</td>
<td>4 to 31</td>
<td>Round bars</td>
<td>Round bars</td>
<td></td>
</tr>
<tr>
<td></td>
<td>9</td>
<td>Canton Steel Joist</td>
<td>Unknown</td>
<td>8 to 16</td>
<td>Unknown</td>
<td>Double angles</td>
<td>Round bars</td>
<td></td>
</tr>
<tr>
<td></td>
<td>10</td>
<td>Buffalo Steel Joist</td>
<td>Unknown</td>
<td>8 to 16</td>
<td>Unknown</td>
<td>See Note 11</td>
<td>Round bars</td>
<td>11</td>
</tr>
<tr>
<td></td>
<td>N/A</td>
<td>Special Joists</td>
<td>Unknown</td>
<td>12 to 20</td>
<td>8 to 40</td>
<td>Unknown</td>
<td>Unknown</td>
<td></td>
</tr>
<tr>
<td></td>
<td>11</td>
<td>Residence Joist</td>
<td>Unknown</td>
<td>6 to 10</td>
<td>6 to 20</td>
<td>See Note 12</td>
<td>Round bars</td>
<td>12</td>
</tr>
<tr>
<td></td>
<td>12</td>
<td>Standard Longspan Joist</td>
<td>See Note 14</td>
<td>18 to 40</td>
<td>24 to 72</td>
<td>Double angles</td>
<td>Angles &amp; bars</td>
<td>13, 14</td>
</tr>
<tr>
<td></td>
<td>N/A</td>
<td>Intermediate Longspan</td>
<td>See Note 14</td>
<td>18.4 to 22</td>
<td>20 to 44</td>
<td>See Note 10</td>
<td>Round bars</td>
<td>10, 14</td>
</tr>
<tr>
<td></td>
<td>13</td>
<td>1955 New Yorker</td>
<td>Unknown</td>
<td>8 to 24</td>
<td>7 to 48</td>
<td>V shaped plates</td>
<td>Round bars</td>
<td></td>
</tr>
<tr>
<td></td>
<td>14</td>
<td>V or Double V Bar Joist</td>
<td>Unknown</td>
<td>8 to 22</td>
<td>4 to 44</td>
<td>V shaped plates</td>
<td>Round bars</td>
<td></td>
</tr>
<tr>
<td></td>
<td>N/A</td>
<td>V-Girders</td>
<td>Unknown</td>
<td>18 to 48</td>
<td>13 to 96</td>
<td>V shaped plates</td>
<td>Round bars</td>
<td></td>
</tr>
<tr>
<td></td>
<td>15</td>
<td>V-Purlin</td>
<td>Unknown</td>
<td>8 to 60</td>
<td>8 to 120</td>
<td>V shaped plates</td>
<td>See Note 15</td>
<td>15</td>
</tr>
<tr>
<td></td>
<td>16</td>
<td>Allspan</td>
<td>Unknown</td>
<td>8 to 76</td>
<td>8 to 152</td>
<td>V &amp; Double V shaped plates</td>
<td>See Note 15</td>
<td>15</td>
</tr>
<tr>
<td></td>
<td>N/A</td>
<td>V-Lok Purlin</td>
<td>Unknown</td>
<td>8 to 36</td>
<td>8 to 72</td>
<td>V &amp; Double V shaped plates</td>
<td>Round bars or round pipes</td>
<td>16, 17</td>
</tr>
<tr>
<td></td>
<td>17</td>
<td>V-Lok Girder</td>
<td>Unknown</td>
<td>12 to 40</td>
<td>15 to 50</td>
<td>See Note 18</td>
<td>Round bars or Angles</td>
<td>16, 18</td>
</tr>
<tr>
<td></td>
<td>18</td>
<td>V-Beam</td>
<td>Unknown</td>
<td>8 to 28</td>
<td>8 to 56</td>
<td>See note 19</td>
<td>Round bars</td>
<td>19</td>
</tr>
<tr>
<td>Northwest</td>
<td>4</td>
<td>Series 1, 2, 3 &amp; 4 Joists</td>
<td>See Note 5</td>
<td>12 to 72</td>
<td>12 to 80</td>
<td>V shaped plates</td>
<td>Square bars &amp; round pipes</td>
<td>4, 5</td>
</tr>
<tr>
<td>Ridgeway</td>
<td>3</td>
<td>Open Web Joists</td>
<td>See Note 3</td>
<td>12± to 47±</td>
<td>16± to 59±</td>
<td>V shaped plates</td>
<td>Square bars &amp; round pipes</td>
<td>3</td>
</tr>
<tr>
<td>Vescom</td>
<td>2</td>
<td>Composite Floor Joists</td>
<td>36 &amp; 50 ksi</td>
<td>8 to 40</td>
<td>20 to 48</td>
<td>Double angles</td>
<td>Round bars</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>N/A</td>
<td>Composite Truss Girders</td>
<td>36 &amp; 50 ksi</td>
<td>16 to 40</td>
<td>20 to 50</td>
<td>Double angles</td>
<td>Angles</td>
<td>2</td>
</tr>
</tbody>
</table>
Notes:
1. Top chord included deformed, extended vertical leg of one angle for composite action with surrounding concrete slab.
2. Top chord included deformed, extended vertical plate in addition to double angles for composite action with surrounding concrete slab.
3. Web allowable stress: 36 ksi (bars) & 50 ksi (pipes); Chord allowable stress: 54 ksi.
4. Joist designs over 80 feet spans were available upon request.
5. Web allowable stress: 33 & 44 ksi (bars), 50 ksi (pipes); Chord allowable stress: 55 ksi.
6. Allowable compressive stress for top chord or web members = 15 ksi. Allowable combined compressive stress at top chord panel points and allowable tensile stress = 18 ksi.
7. Chord tees cut from standard wide flange or junior beams.
8. Available as parallel chord, single or double sloped top chord or hipped end configurations.
10. Double angle top chord; Round bars bottom chord.
11. Inverted double angle top chord; Round bars bottom chord.
12. Single steel angle and wood nailer top chord; Round bars bottom.
13. Available as parallel chord or single or double sloped top chord.
14. Allowable combined direct and bending stress in top chords = 20 ksi.
15. Sizes #2 - #9: Round bars; Sizes #10 up through #22: Angles.
16. Included proprietary stud and slot end bearing connection – See Figure 17.
17. Round bars, round pipes or angles.
18. V & double V shaped plates or double angles.
### Table 2: Unique Open Web Joists (Load Tables may be available from SJI)

<table>
<thead>
<tr>
<th>System</th>
<th>Figure</th>
<th>Description</th>
<th>Yield Strength</th>
<th>Depth (inches)</th>
<th>Span (feet)</th>
<th>Chords</th>
<th>Webs</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bethlehem</td>
<td>24</td>
<td>KalmanTruss Joists</td>
<td>See Note 8</td>
<td>8 to 16</td>
<td>4 to 32</td>
<td>T shape</td>
<td>Rectangular</td>
<td>7, 8, 9</td>
</tr>
<tr>
<td></td>
<td>25</td>
<td>MacMar Joists</td>
<td>See Note 10</td>
<td>8 to 16</td>
<td>4 to 32</td>
<td>Angles</td>
<td>Round bars</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>26</td>
<td>BLJ Series</td>
<td>See Note 11</td>
<td>52 to 60</td>
<td>89 to 120</td>
<td>Structural Tee</td>
<td>Angles</td>
<td>11</td>
</tr>
<tr>
<td></td>
<td>26</td>
<td>BLH Series</td>
<td>See Note 12</td>
<td>52 to 60</td>
<td>89 to 120</td>
<td>Structural Tee</td>
<td>Angles</td>
<td>12</td>
</tr>
<tr>
<td></td>
<td>27</td>
<td>Standard Open Web Joist</td>
<td>See Note 13</td>
<td>8 to 16</td>
<td>4 to 32</td>
<td>Angles</td>
<td>Round bars</td>
<td>13</td>
</tr>
<tr>
<td></td>
<td>28</td>
<td>Longspan Open Web Joist</td>
<td>See Note 14</td>
<td>18 to 32</td>
<td>25 to 64</td>
<td>Angles</td>
<td>Round bars</td>
<td>14</td>
</tr>
<tr>
<td></td>
<td>29</td>
<td>BJ Series</td>
<td>See Note 15</td>
<td>24 to 60</td>
<td></td>
<td></td>
<td>Round bars</td>
<td>11, 15</td>
</tr>
<tr>
<td></td>
<td>29</td>
<td>BH Series</td>
<td>See Note 15</td>
<td>24 to 60</td>
<td></td>
<td></td>
<td>Round bars</td>
<td>12, 15</td>
</tr>
<tr>
<td>Gabriel</td>
<td>30</td>
<td>Long Span Joist</td>
<td></td>
<td>18 to 32</td>
<td>24 to 64</td>
<td></td>
<td></td>
<td>Round bars</td>
</tr>
<tr>
<td>Truscon</td>
<td>19 &amp; 20</td>
<td>O-T (Open Truss) Joists</td>
<td>See Note 1</td>
<td>8 to 20</td>
<td>7 to 40</td>
<td>“Tee” &amp; M shaped plate</td>
<td></td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>21</td>
<td>Series AS Joists</td>
<td>See Note 2</td>
<td>8 to 24</td>
<td>7 to 48</td>
<td>U shaped</td>
<td>Round bars</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>21</td>
<td>Series BB Joists</td>
<td>See Note 3</td>
<td>8 to 24</td>
<td>7 to 48</td>
<td>U shaped</td>
<td>Round bars</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>22 &amp; 23</td>
<td>Clerespan Joists</td>
<td>See Note 6</td>
<td>18 to 32</td>
<td>26 to 64</td>
<td>“Tee” &amp; angles</td>
<td>Angles &amp; bars</td>
<td>4, 5, 6</td>
</tr>
</tbody>
</table>

**Notes:**
1. Web allowable stress: 19,000 psi - 100(l/r); Chord allowable stress: 16,000 psi.
2. Cold formed chord allowable tension: 25 ksi; Hot rolled web members allowable compression: 17,000 psi - 100(l/r).
3. Cold formed chord allowable tension: 28.5 ksi; Hot rolled web members allowable compression: 19,000 psi - 100(l/r).
4. Available as parallel chord, single or double sloped top chord configurations.
5. Chord angles were some times arranged toe to toe for channel configuration.
7. Manufactured by punching web opening in blanks such that chords and webs do not have to be welded together.
9. Also marked as Kalman Joist.
10. Allowable tensile stress: 18 ksi.
15. Double angle top chord; Round bars bottom chord.
ELEVATION AND DETAILS

\[
\text{TOP CHORD LENGTH (TC) = MS + 1'3" or MS \pm (E_a + E_c)}
\]
\[
\text{MIN SPAN (MS) \times NO. TOP CHORD PANELS (N) \times P = 2.5L}
\]
\[
\text{BOTTOM CHORD LENGTH (BC) = R + 6" OR = TC - (C_a + C_c)}
\]

*E = 7\frac{1}{2}" unless E_a and E_c specified. (NOTE: 2 E = 1'3")

*"F" Fillers having same diameter as web bar are spaced in top chord panels between quarter span points.

GROSS SECTIONS AND DETAILS

WEB SECTION

JOIST ON STEEL BEARING - FIELD WELDED

END BEARING SECTION

ALL WELDED CONSTRUCTION
**Figure 7**

**Macomber Steel Purlin**

- Double angle top chord.
- The bearing plate is one-quarter inch thick and is sufficiently wide to provide proper bearing.
- Purlins furnished with one or both ends standard joist design without extra cost.

**Figure 8**

**Massillon Steel Joist**

- The end plates are all one-quarter inch thick.
- Solid steel arc welded connections provide for greater stresses than the members they unite.
- The cantilever end provides flexibility of span and increases salvage value.
- The ceiling extension is an accessory item used to complete the ceiling line to walls.

**Manufactured by**

Macomber Incorporated
Canton, Ohio.
Figure 11

Figure 12

Macomber "Longspan" Joists are made for the purpose of supporting very lightweight loads in long open floor and roof construction. In each particular they are designed to function in the manner to which the purchaser has a right to expect. Developed and marketed by the originator of the open web steel joist - the details are such as to give the maximum of strength, lateral rigidity, economy and erection efficiency.

Macomber building materials are distributed through a national organization of Local Dealers. These men - experts and individuals - many of whom have handled Macomber products for ten to thirty years - are experienced in the demands of independent builders, contractors and their respective Salesmen. Of their own accord they will examine the value in this product. They will utilize a definite valuable line in the Macomber chain of economical, efficient merchandising.

End Section BB

Figure 12
Figure 13

Figure 14

Figure 15

The 2½" end depth is standard in the No. 1 Series, but 4" and 5" deep ends can be furnished. All panel points in this series are on 2" centers.
Allspan dimensions and properties

The 2 1/4" end depth is standard in this series but 4" and 5" deep ends can be furnished.

ALLSPAN BEARING

<table>
<thead>
<tr>
<th>Size</th>
<th>Bearing Depth</th>
</tr>
</thead>
<tbody>
<tr>
<td>25&quot;</td>
<td>2 3/4&quot;</td>
</tr>
<tr>
<td>32&quot;</td>
<td>3 1/4&quot;</td>
</tr>
<tr>
<td>over 52&quot;</td>
<td>4&quot;</td>
</tr>
</tbody>
</table>

Figure 16

ALLSPAN TOP CHORD SIZES #1 THROUGH #9

Figure 17

THE MACOMBER V-BEAM

Figure 18

MACOMBER V-SECTION TOP CHORD

Figure 19

MACOMBER V-SECTION BOTTOM CHORD

MACOMBER B-SECTION BEARING PLATE

MACOMBER B-SECTION BOTTOM CHORD

NAILING GROOVE

WEB

END BAR
Figure 20

Figure 21

Figure 22

For Clear Spans up to 44 Feet

Figure 23

Figure 24

Figure 25

Figure 26
Figure 27

Figure 28

Figure 29

Figure 30