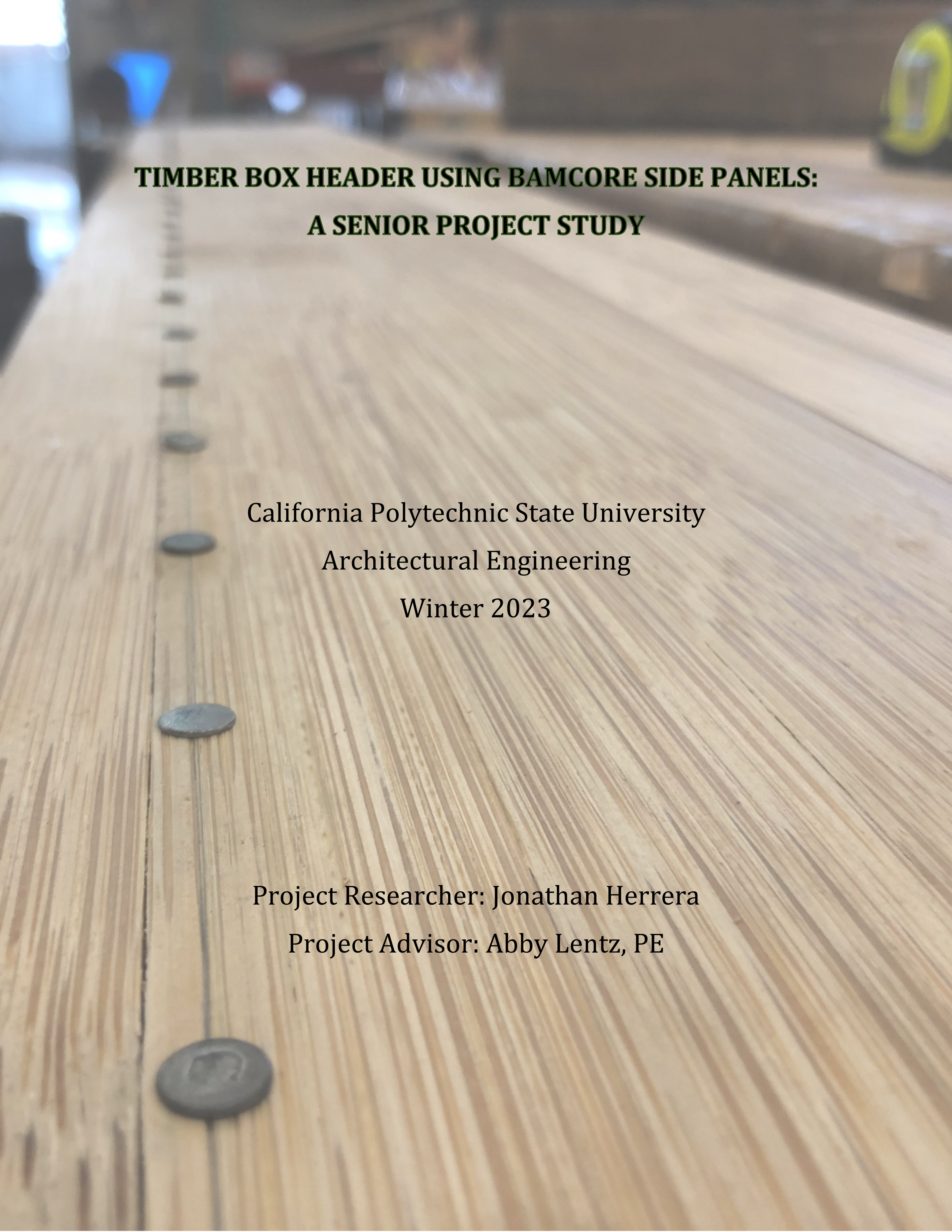


# TIMBER BOX HEADER USING BAMCORE SIDE PANELS: A SENIOR PROJECT STUDY

California Polytechnic State University
Architectural Engineering

Winter 2023

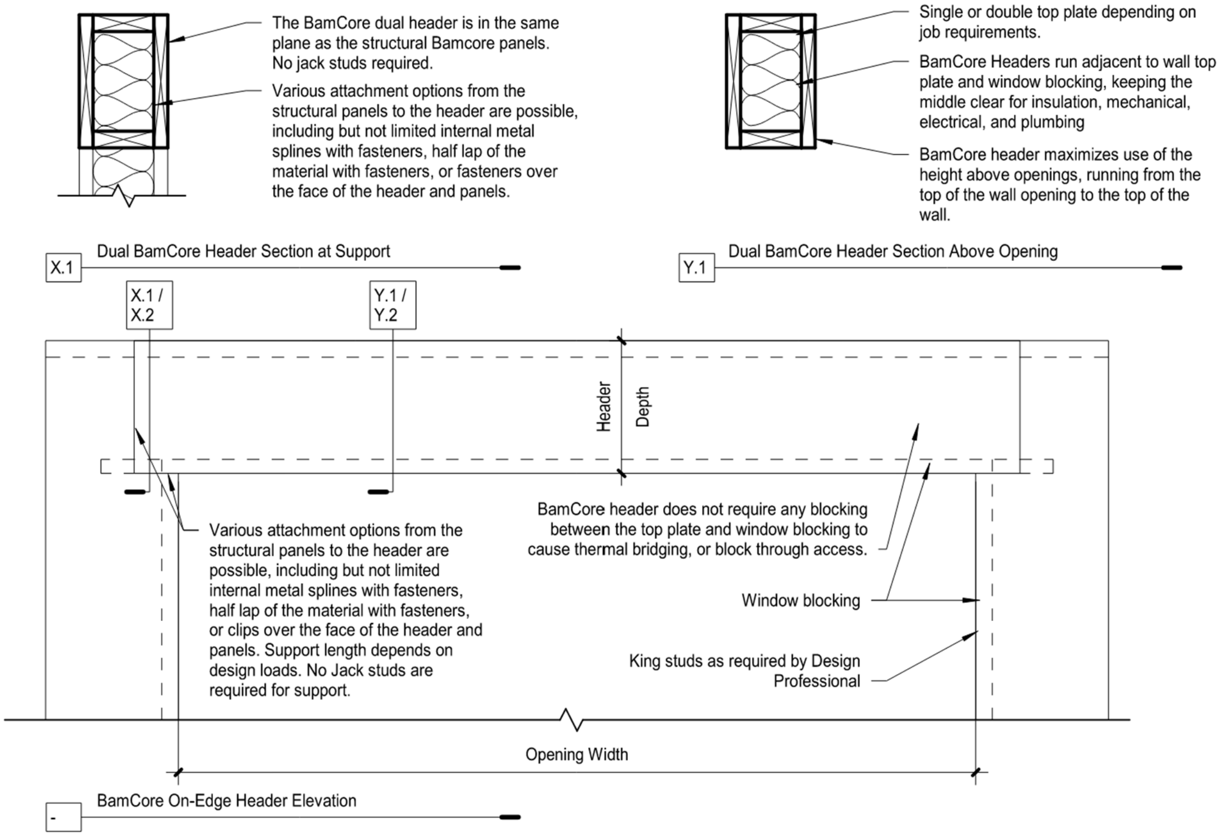
Project Researcher: Jonathan Herrera
Project Advisor: Abby Lentz, PE

# Abstract

The purpose of this study was to begin development of a composite box header that was able to span long openings with minimal deflection. The headers in study were comprised of BamCore side panels, nailed top and bottom each face to a 2x6 top plate, and a header of multiple specified sizes. The 2x6 top plate and headers ranging from a 6x6 to a 6x12 were made up of Douglas Fir-Larch, No.1. Analysis was performed assuming 10d common nailing at top and bottom of the BamCore side panels. Initial analysis of a composite box header was performed and analyzed as a transformed section. Testing ensued after findings from the initial analysis. Testing was performed by fabricating two (2) designed box headers at half scale. The headers that were tested were both analyzed as a 16" deep header with a 6x6 "bottom flange" and 2x6 top plate. At half scale, these headers were 8" deep, with headers and top plates ripped to half scale. The only difference between the two headers tested was that one header had a stiffener placed within the box at midspan—to mimic the splice of the BamCore Panels—and one header did not. The results from testing were compared to the initial analysis to find discrepancies and similarities between analysis and empirical results. This report contains findings from analysis and testing of these materials and sections in order to further develop long-span headers that are used in BamCore panel construction as a use of stronger and sustainable materials.

# Introduction

The development of a timber box header using BamCore side panels began with the initial precedent of BamCore's "Dual BamCore Header". The purpose and advantage of the Dual BamCore Header is the same as the timber box headers in study: to span over a wall opening, while *maximizing* the header depth from the top of the window or door opening to the top of the wall. The BamCore On-Edge Header detail is shown below:




14 BamCore On-Edge Headers
1" = 1'-0"

BamCore has developed span tables for The Dual BamCore Header, which consists of an overall header depth and span corresponding to a maximum uniform load in pounds per linear foot:

BamCore G3 On Edge Header Uniform Load (PLF) Table, **L/240** Deflection Criteria

| Header Depth (in) | 6 | | 8 | | 10 | | 12 | | 14 | | 16 | | 20 | | 24 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Span (ft) | Uniform Load (PLF) | Bearing Length (in) | Uniform Load (PLF) | Bearing Length (in) | Uniform Load (PLF) | Bearing Length (in) | Uniform Load (PLF) | Bearing Length (in) | Uniform Load (PLF) | Bearing Length (in) | Uniform Load (PLF) | Bearing Length (in) | Uniform Load (PLF) | Bearing Length (in) | Uniform Load (PLF) | Bearing Length (in) |
| 3 | 3095 b | 1 3/4 | 4127 b | 2 1/2 | 5159 b | 3 1/4 | 6191 b | 4 | 7223 b | 4 3/4 | 8255 b | 5 1/2 | 10319 b | 7 1/2 | 12383 b | 9 1/2 |
| 4 | 1683 | 1 1/4 | 3094 b | 2 1/2 | 3868 b | 3 | 4641 b | 3 3/4 | 5415 b | 4 1/2 | 6188 b | 5 1/4 | 7736 b | 6 3/4 | 9283 b | 8 1/2 |
| 5 | 941 | 1 | 1976 | 2 | 3093 b | 3 | 3711 b | 3 3/4 | 4330 b | 4 1/4 | 4948 b | 5 | 6186 b | 6 1/2 | 7423 b | 8 |
| 6 | 572 | 3/4 | 1242 | 1 1/2 | 2170 a | 2 1/2 | 3065 a | 3 1/2 | 3606 b | 4 1/4 | 4122 b | 5 | 5152 b | 6 1/4 | 6183 b | 7 3/4 |
| 7 | 371 | 1/2 | 824 | 1 1/4 | 1483 | 2 | 2249 a | 3 | 3012 a | 4 | 3531 b | 4 3/4 | 4414 b | 6 1/4 | 5297 b | 7 1/2 |
| 8 | 252 | 1/2 | 571 | 1 | 1046 | 1 1/2 | 1678 | 2 1/2 | 2304 a | 3 1/2 | 2966 a | 4 1/2 | 3861 b | 6 | 4633 b | 7 1/2 |
| 9 | 179 | 1/2 | 410 | 3/4 | 761 | 1 1/4 | 1239 | 2 | 1818 a | 3 | 2341 a | 4 | 3430 b | 6 | 4116 b | 7 1/4 |
| 9.75 | 141 | 1/4 | 326 | 3/4 | 611 | 1 1/4 | 1002 | 1 3/4 | 1500 | 2 3/4 | 1993 a | 3 3/4 | 3042 a | 5 3/4 | 3798 b | 7 1/4 |

1. [a] means controlled by Bending Strength, [b] means controlled by Shear Strength, no superscript is controlled by deflection.

2. Values include 4% bending strength increase for repetitive members.

3. Values are for 2 members with equal loading. 2.5 inches of width total

However, the span tables only go up to 9.75' spans, as the longest BamCore panels available span 10' in length. A minimum bearing length is also included, because for these shorter spans below 10', the bearing length from panel to panel must meet the requirement, but for spans over 10' of the timber box headers in study, the ends will be bearing on posts or end studs that provide wholly adequate support. Therefore, bearing length was not included in the research of the timber box header.

The typical overall depths of the headers in study were 12", 16", and 24". The range of timber header sizes, or "bottom flange" of the timber box headers, were 6x6, 6x8, 6x10, and 6x12. The calculated spans of the timber box headers were 10', 12', 14', 16', 18', and 20'.

The governing factor in the design of the long span timber box headers was deemed to be the deflection criteria. This is because in BamCore panel building systems, one of the most common locations of long span wall openings are for multi-panel sliding glass doors, like ones shown below:

If the deflection is too large for the headers above the muli-panel sliding glass doors, the doors become highly dysfunctional and can become jammed. These doors must have a tight deflection limit to operate properly, otherwise the tracks of these doors do not allow adequate sliding and movement. Therefore, the deflection limit in the design of the timber box headers was set to L/800 in analysis, which ranges from 0.15” for the 10’ span to 0.30” for the 20’ span. Clearly, this is a very limiting deflection criteria for headers spanning this long, which is precisely why the development of timber box headers was initiated in this study.

# Precedent Research

Precedent research regarding similar areas of study were used to initiate research on timber box headers and their performance.

In "Strength of Plywood Web Box Beam" (Chu et al.), an approach following the laws of mechanics of materials offered insight into transformed sections acting compositely as a box beam. This study also offered insight into how side panels of a non-timber material affect the behavior of a beam. This study focused on strength with given design values tested against a given uniform load, whereas the study contained herein involves finding a maximum uniform load under a limiting deflection criteria.

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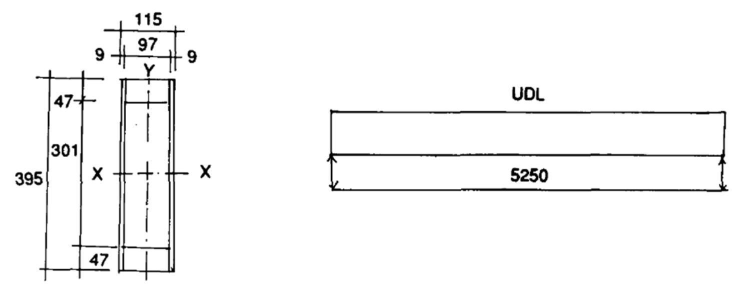
**Appendix**

**(I) Design calculation for 5.4 *m* box beam**




*Given*

| | | |
|---|---|---|
| Effective design span | = | 5.25 *m* |
| Spacing of beams | = | 2.5 *m* |

*Loading*

| | | |
|---|---|---|
| Dead load (DL) | = | 0.5 $kNm^{-2}$ including self weight of beam |
| Live load (LL) | = | 0.5 $kNm^{-2}$ |
| Total | = | 1.0 $kNm^{-2}$ |

*Timber flanges*

Strength group B, dry, standard grade

The following permissible stresses are the grade stresses (except tension stresses) taken from Engku (1980) and increased for medium term loading where applicable.

| | | | | |
|---|---|---|---|---|
| Bending (f) | = | 12.4 × 1.25 | = | 15.5 $Nmm^2$ |
| Tension (t) | = | 7.4 × 1.25 | = | 9.2 $Nmm^2$ (based on 0.6 × bending and not from Engku (1980) |

| | | | | |
|---|---|---|---|---|
| Compression parallel ($c_{//}$) | = | 10.0 × 1.25 | = | 12.5 $Nmm^2$ |
| Compression perpendicular ($c_{\perp}$) | = | 1.24 × 1.25 | = | 1.55 $Nmm^{-2}$ (based on basic stress with no wane) |

In “Design and Fabrication of All-Plywood Beams” (APA), total load based on allowable web and flange bending stress gave direction to finding maximum allowable load in analysis. However, the analysis was performed as a symmetric cross-section, with the neutral axis located at half of the total header depth. In the analysis of the timber box headers in this study, however, the neutral axis was never located at exactly the midpoint of the header depth, due to the varying timber header size and overall header depth.

Design and Fabrication of All-Plywood Beams | 20

**Modulus of Elasticity in Pure Bending (E)**

From PDS Table 3, the Modulus of Elasticity for plywood having face plies of Group 1 species is 1,800,000 psi. This value may be increased 10% to obtain E in pure bending when shear deflection is considered separately.

$E = 1{,}800{,}000 \times 1.10 = 1{,}980{,}000$ psi

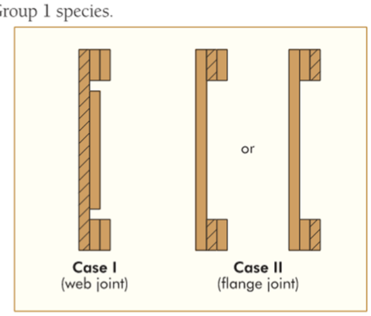
**Shear Modulus (G)**

From PDS Table 3, $G = 90{,}000$ psi for plywood having face plies of Group 1 species.

### A2. Determine Total Load Based on Allowable Web and Flange Bending Stress

#### *A2.1 Net Moment of Inertia ($I_n$)*

For this design example, the following beam cross-sections are possible at web or flange joint locations:




A visual comparison of the three possible cross-sections reveals that the *minimum* section for bending stress calculations occurs at a web joint (Case 1).

$$I_{ws\,(\text{web splice plate})} = \frac{\Sigma t_b\, h_s^3}{12} = \frac{0.289 \times 15.875^3}{12} = 96 \text{ in.}^4$$

$$I_{f\,(\text{flanges})} = \frac{\Sigma t_b\,[h_w^3 - (h_w - 2d)^3]}{12} = \frac{2 \times 0.289\,(23.875^3 - 16.375^3)}{12} = 444 \text{ in.}^4$$

$$I_n = I_{ws} + I_f = 96 + 444 = 540 \text{ in.}^4$$

#### *A2.2 Calculate Total Load Based on Allowable Web and Flange Bending Stress ($w_b$)*

$$w_b = \frac{8\, F_b\, I_n}{12c\, L^2} = \frac{8 \times 3800 \times 540}{12 \times \frac{23.875}{2} \times 24^2} = 199 \text{ lb/ft}$$

### A3. Determine Total Load Based on Allowable Web Shear Stress

#### *A3.1 Total Moment of Inertia ($I_t$)*

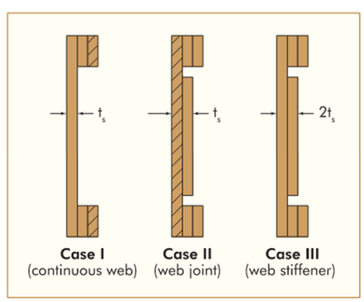
$$I_{w\,(\text{web})} = \Sigma t_b\, h_w^3 = \frac{0.289 \times 23.875^3}{12} = 328 \text{ in.}^4$$

$I_{f\,(\text{flanges})} = 444$ in.$^4$ (from A2.1)

$$I_t = I_w + I_f = 328 + 444 = 772 \text{ in.}^4$$

#### *A3.2 Effective Total Web Shear Thickness ($t_s$)*

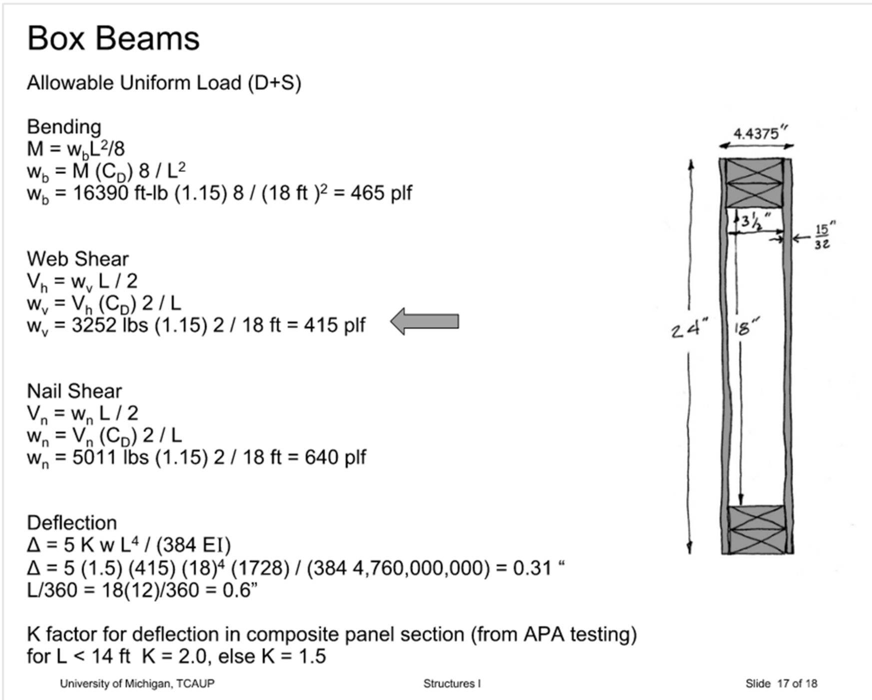
For this design example, the effective web thickness ($t_s$) for shear calculations is shown on the following cross-sections which may occur along the beam:

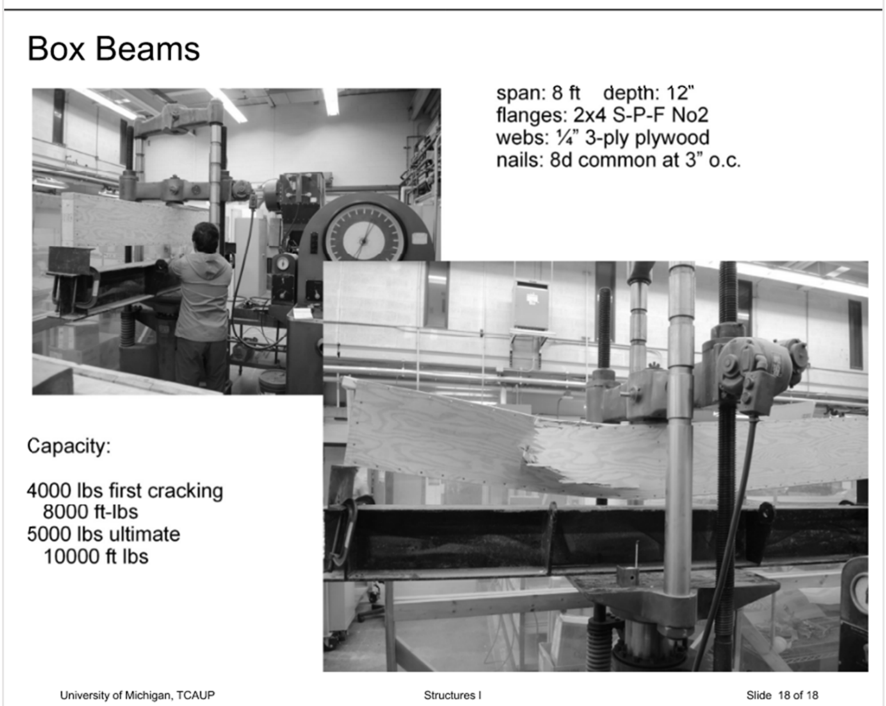



A visual comparison of the three possible cross sections reveals that the minimum thickness for horizontal shear calculations occurs at either a continuous (unreinforced) web (Case I), or at a web joint (Case II). If the beam is detailed so that web joints are kept out of high-shear areas, then the controlling location will be in the unreinforced web, at the edge of the bear-

Form No. H815F ■ © 2008 APA – The Engineered Wood Association ■ www.apawood.org

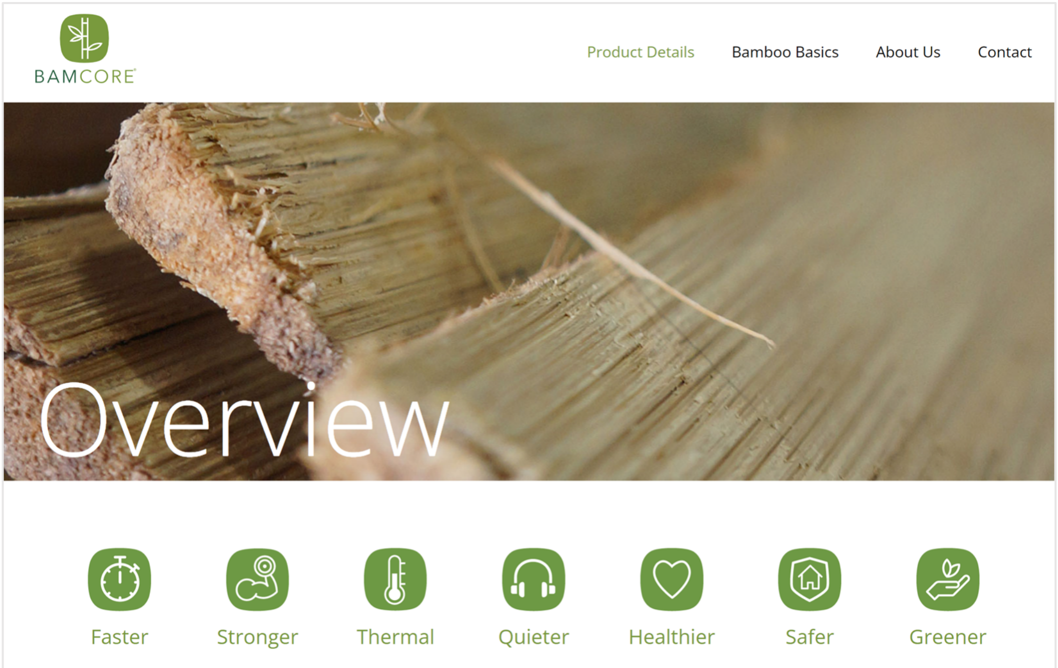
Lastly, an empirical study on box beams by the University of Michigan offered insight into testing procedure to be performed on a transformed section. The beam tested was a plywood box beam with a span of 8', 12" overall depth, 2x4 top and bottom flanges, and 8d common nails at 3" on center, a similar set up to the testing performed during the study of this report.



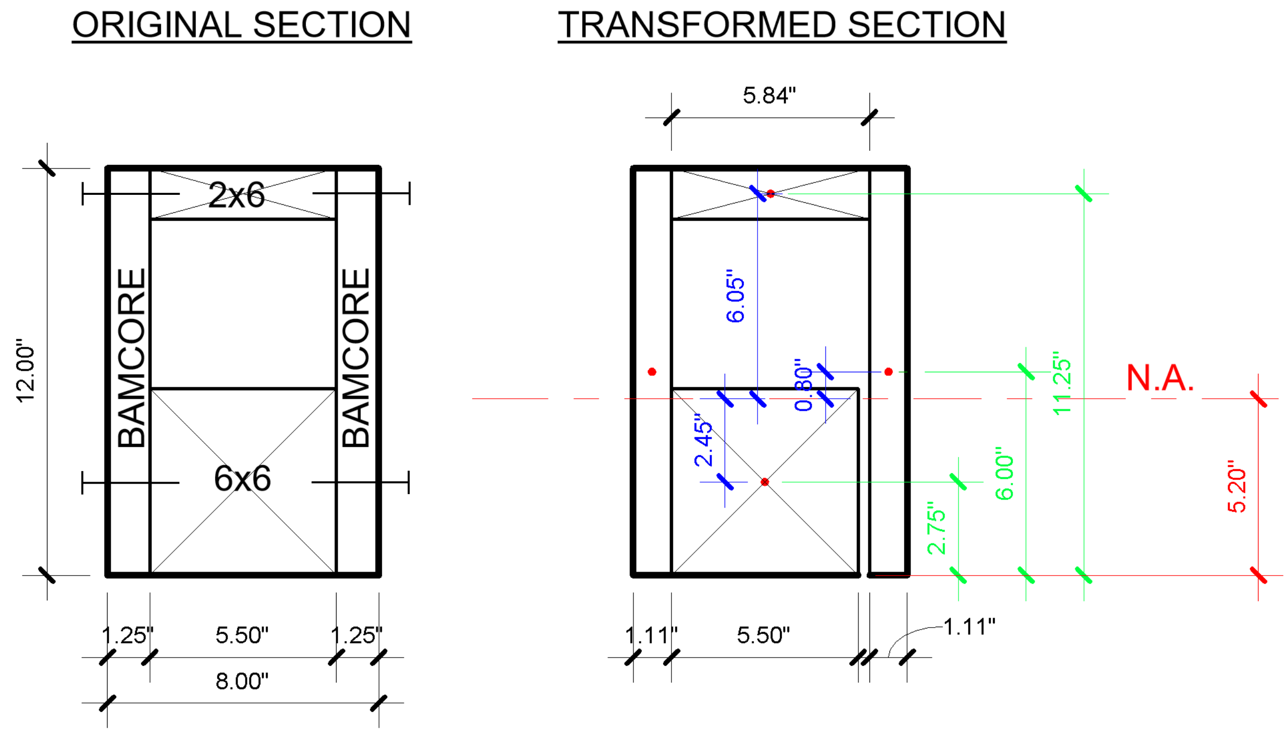
## BamCore

As aforementioned, the panels in the timber box beams are BamCore panels. BamCore panels are heavily engineered hybrid structural panels comprised of a mixture of wood and bamboo.




This material is advertised as stronger, more insular, safer, and more environmentally friendly than traditionally used timber in construction. The BamCore sided timber box headers would be used in conjunction with the BamCore Prime Wall, a hollow wall made up of two parallel runs, outside and inside, that are filled with blown-in insulation. Without studs, there are no thermal bridges that displace insulation and negatively impact the thermal performance of the wall assembly. The BamCore Prime Wall is shown to be 51% stronger in vertical load bearing strength than conventional 2x6 framing, and 14% stronger than even conventional 2x8 framing. The raw material is purchased from sustainably harvested suppliers, and even in the process of manufacturing, there is no chemicals, water, heat, or stream used to mill, prepare, and manufacture the bamboo into panels. In contrast to other bamboo based construction products that start with high amounts of embodied energy because they start with small strips of squared and planed bamboo, BamCore preserves the full length of the bamboo based panel without cutting it into small strips that must all be glued together with adhesive. The adhesive BamCore is carefully selected to ensure minimum embodied carbon, and used to splice the full length panels at staggered locations on the panel with a finger joint. The material properties of BamCore provided in the technical evaluation report, TER 1507-03, were considered in the development and testing of the timber box header.

## Analysis




The objective of this study was to begin development of a composite box header that was able to span long openings with minimal deflection, and to develop span tables with a tight L/800 deflection limit. The following analysis was performed to obtain maximum uniform load values, and an expanded calculation follows. For different header sizes, span lengths, and overall depths, the same process was carried out in a spreadsheet.

### Elasticity

$E_{Header} = 1{,}600{,}000\ psi$

$E_{BamCore} = 1{,}420{,}000\ psi$

$E_{2x6} = 1{,}700{,}000\ psi$

### Transformation to $E_{Header}$

$$\frac{EBamCore}{EHeader} = 0.89$$

$$\frac{E2x6}{EHeader} = 1.06$$

**Neutral Axis**

$$N.A. = \frac{\Sigma yA}{\Sigma A} = 5.2 \quad (d = |5.2 - y|)$$

**Moment of Inertia**

$$I = \Sigma I_{parts} + \Sigma Ad^2 = 397.4 + 519.5 = 917\ in^4$$

**Demand vs. Capacity**

$$F'_b = .99(1200\ psi) = 1200\ psi$$

$$F'_t = 825\ psi$$

$$F'_c = .57(1500\ psi) = 852\ psi$$

**6x6:**

$$M_{allow} = \frac{F'_t I}{y} = 145485\ \#in = 12123\ \#ft$$

$$w_{allow} = \frac{8M_{allow}}{L^2} = 1349\ plf$$

**SECTION BENDING:**

$$M_{allow} = \frac{F'_b I}{y} = 150246\ \#in = 12520\ \#ft$$

$$w_{allow} = \frac{8M_{allow}}{L^2} = 1001\ plf$$

**2x6:**

$$M_{allow} = \frac{F'_c I}{y} = 145485\ \#in = 12123\ \#ft$$

$$w_{allow} = \frac{8M_{allow}}{L^2} = 1349\ plf$$

**L/800 DEFLECTION LIMIT:**

$$w_{allow} = \frac{384E_{Header}I(L/800)}{5L^4} = 81.5\ plf$$

**MAX WEB SHEAR:**

Horizontal Shear of BamCore = $F_v = 465\ psi$

$t = 1.11"\ (transformed)$

$F_v t_v = 516\ \#/in$

$V_h = \frac{(F_v t_v) I (N_{webs})}{Q_t}$

**Statical Moment of Area:**

Area of Flange & Web Above N.A.

$Q_{top} = Q_{bottom} = Q$

$Q_{2x6} = 1.5"x5.84"(h -.75" - y) = 1.5"x5.84"(12" -.75" - 5.2") = 53\ in^3$

$Q_{BamCore} = 2x1.11(h - y)(\frac{h-y}{2}) = 2x1.11(12 - 5.2)(\frac{12-5.2}{2}) = 51.3\ in^3$

$Q = 53 + 51.3 = 104.3\ in^3$

$V_h = 9076\ \#$

$V = \frac{w_{allow} L}{2}$

$w = \frac{2V}{L} = 1815\ plf$

**MAX NAIL SHEAR:**

For analysis, use 10d nails; $t_s = 1\ \frac{1}{4}"$; $G = .50$

$Z = 118\ \#$

$q = \frac{2\ nails(118\ \#/nail)}{6"} = 39\ \#/in = 472\ \#/ft$

$q = \frac{VQ}{I}$

$39\ \#/in = \frac{V(104.3\ in^3)}{917\ in^4} \rightarrow V = 342.9\ \#$

$w = \frac{2V}{L} = 68.6\ plf \rightarrow try\ @\ 4"\ o.c.$

$q = \frac{2\ nails(118\ \#/nail)}{4"} = 59\ \#/in \rightarrow 518.7\ \#$

$w = \frac{2V}{L} = 104\ plf \geq 81.5\ plf$ ✓

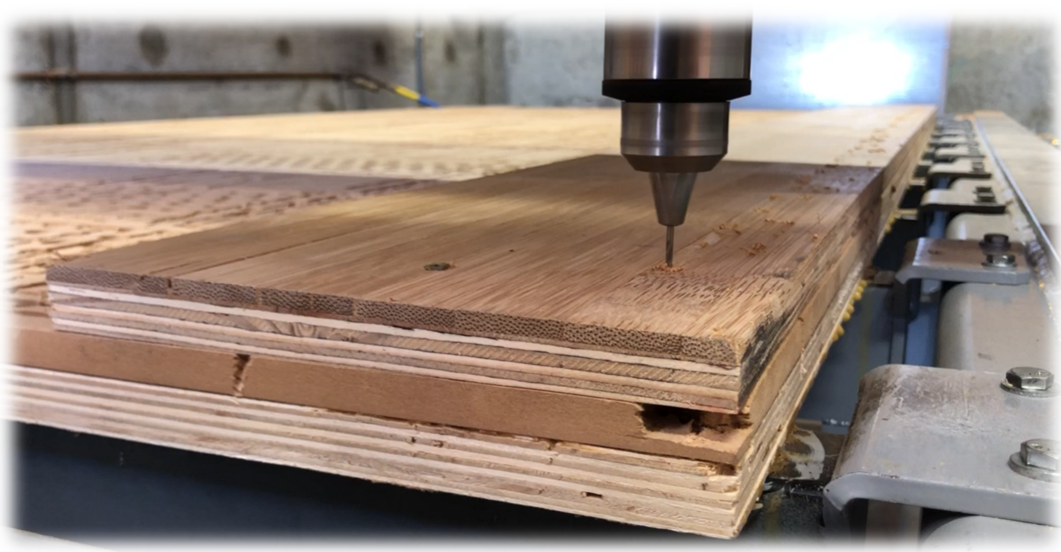
# Fabrication

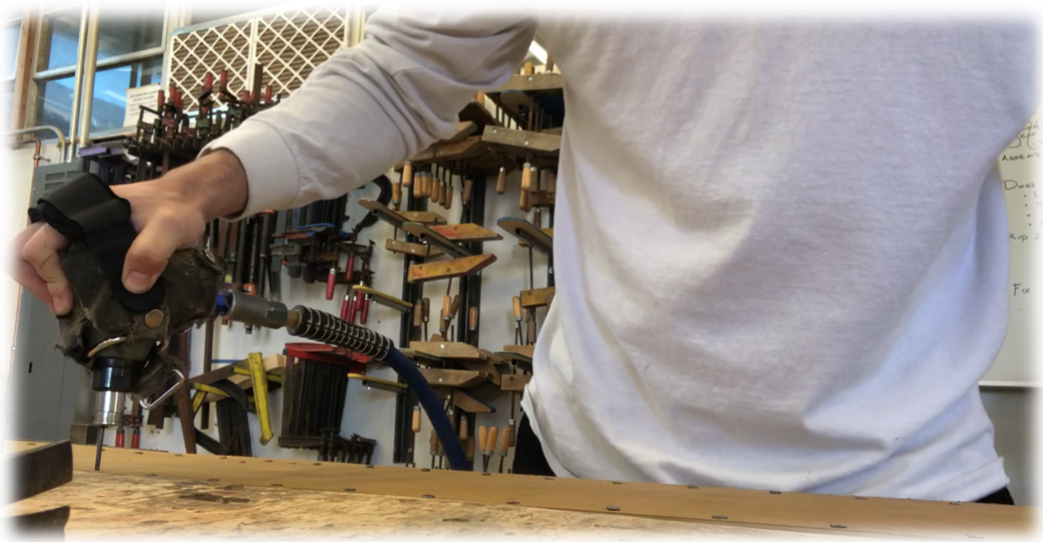
Two specimens were tested under the Riehle Testing Machine in the High Bay at Cal Poly San Luis Obispo. Both specimens were timber box headers with BamCore side panels. The dimensions were to mimic a full scale timber box header that would be:

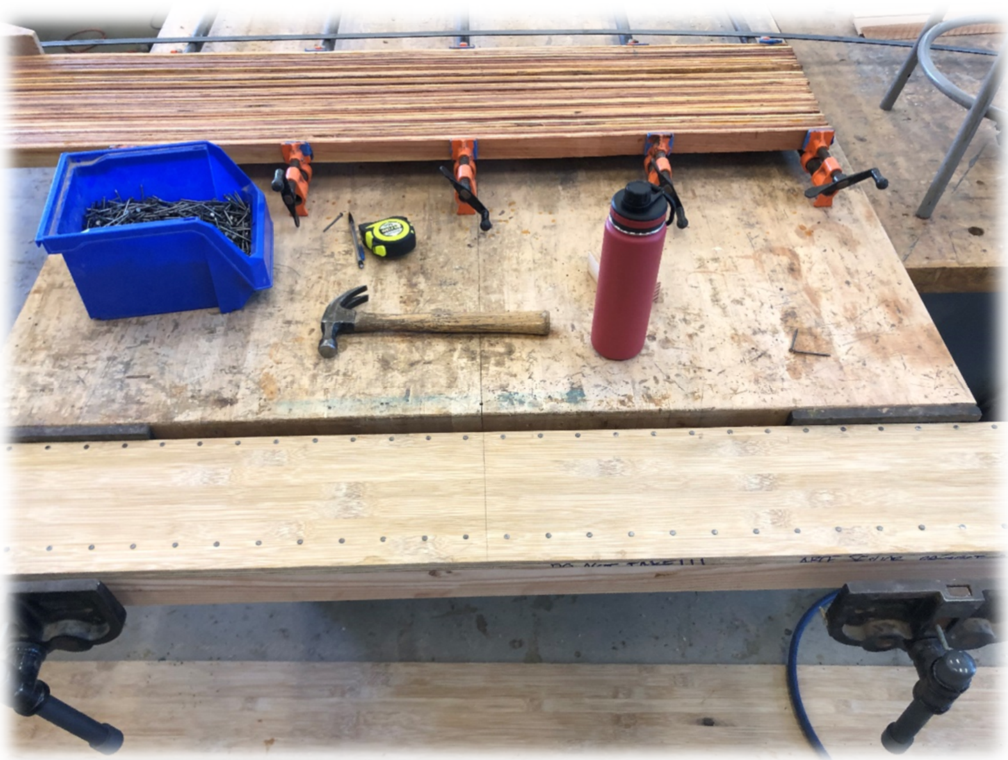
- 16' in length,
- 16" in depth,
- possess a 6x6 bottom flange,
- a 2x6 top plate, and
- two (2) panels on each side of 1 ¼" thickness, as shown in the figure below:

In order to accommodate these proportions, both specimens needed to be fabricated at half scale. BamCore donated some of its material to this study, which was given as two panels, 8' in length, 8" in depth, and 1¼" in thickness. In order to construct two half scale specimens, each member of the overall section had to be appropriately proportioned. Each panel's thickness was cut in half down to $^5/_8$".

The 2x6 was fabricated as 1x3 (truly dimensioned ¾" x 2 ¾"), and the 6x6 was fabricated as a 3x3 (truly dimensioned 2 ¾" x 2 ¾"). Nailing was a particular area of interest, since BamCore's typical details call out custom nailing of .131" diameter nails x 3 ¼" long at 6" on center. For analysis, 10d common nails were used, with a .148" shank diameter 3" long. The shear capacity of these nails is 118 #/nail per NDS, and at 6" on center, the shear flow maximum uniform load would not always be sufficient enough to be greater than the L/800 deflection limit. So the analysis deemed 10d nails at 4" on center appropriate. At half scale, a nail size with half the shear capacity was needed. 6d common nails were found to have shear capacity of 64 #/nail per NDS (nearly half the value of  118 #/2 = 59 #). Since 4" on center was deemed appropriate at full scale, 2" on center was the nail spacing necessary for fabrication. The following photos show part of the fabrication process, with resawed material, pre-drilling holes with the CNC Router, nailing with palm nailer, and final product (predrilling and palm nailing only occurred due to university policy of no nail guns, otherwise nail gun would be used):



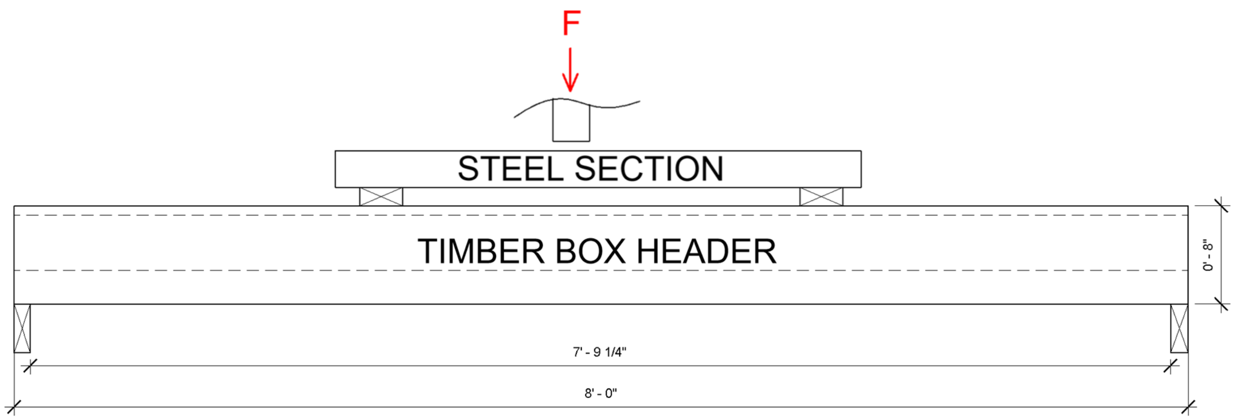


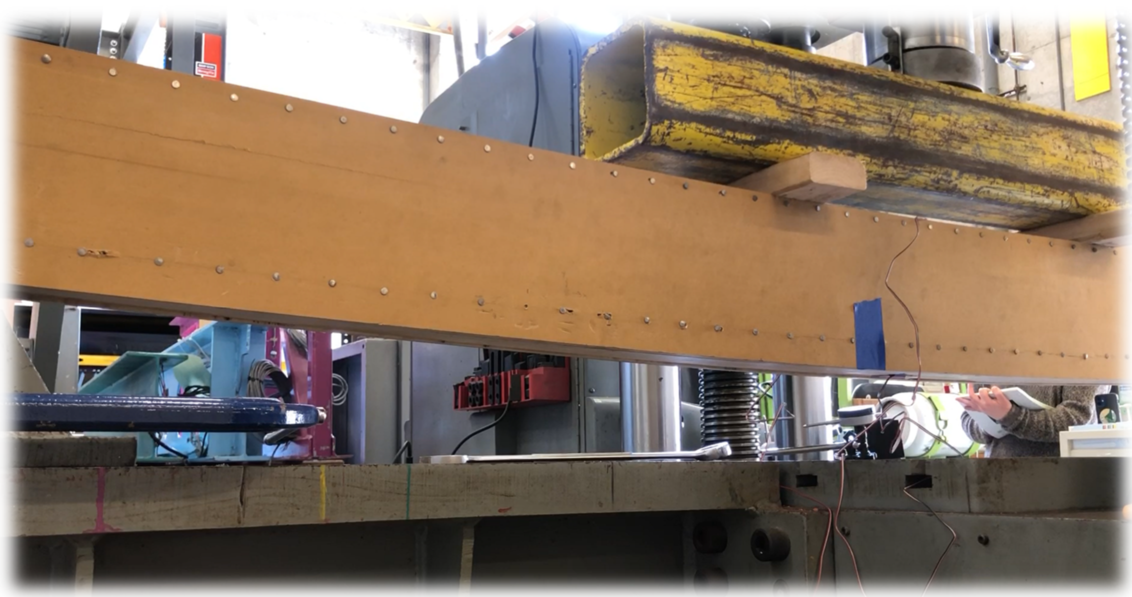


TIMBER BOX HEADER USING BAMCORE SIDE PANELS

# Testing

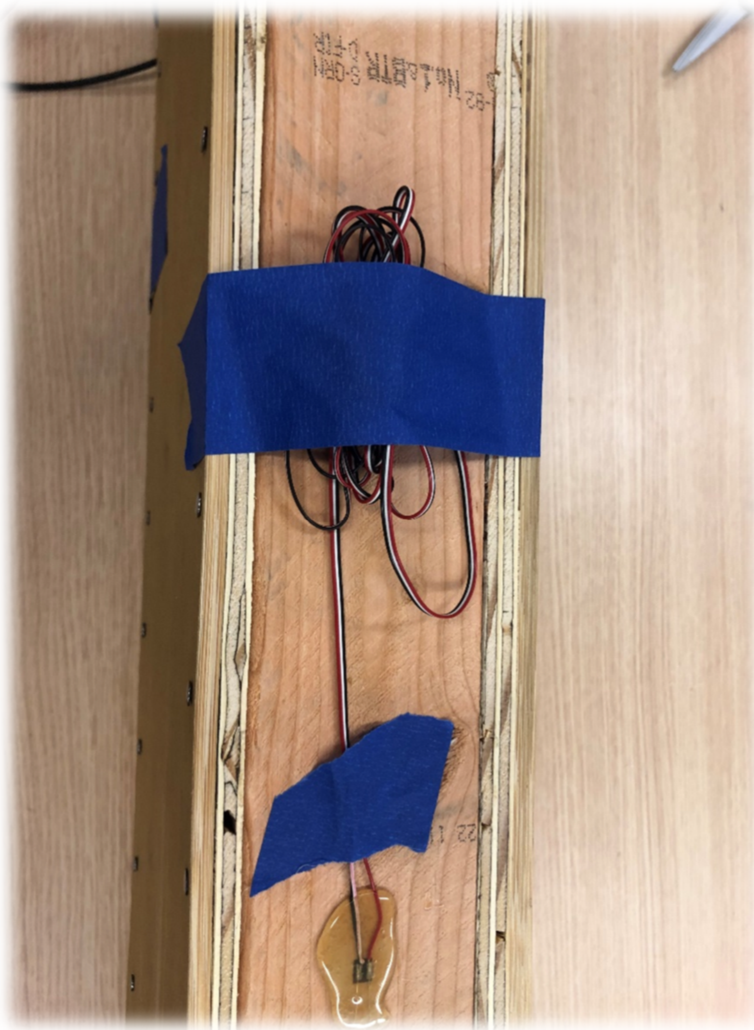
Each of the two specimens were placed in the Riehle Testing Machine, supported by two wood blocks on each end. The machine applied a point load to the header with its piston head, which contacted a steel section laying on top of the specimen. The steel section laid on top of the specimen atop wood blocks at each end, to limit deformation of the steel pressing into the timber header directly. The purpose of the steel section between the piston head and the timber header was to more accurately mimic a uniform load across the header and a constant maximum moment over the middle span, as opposed to a direct point load applied at the midspan.



Data was collected directly from the Riehle machine and recorded, as the dial on the machine registered load being applied in pounds, and additionally displayed the total "deflection" (distance traveled, in inches, by the piston head after being zeroed out at first contact with the steel section).

Supplemental data was collected by attaching strain gages to the top plate, one side panel, and the bottom flange. The strain gages were placed to measure the elongation or shrinkage of the material it was applied to, and use the strain to obtain the stresses at the different locations of the header.

The strain gages recorded strain by tracking electrical currents running through the gage out to exposed wires, then attaching the exposed wires to a solder pad. Then external wires were also attached to the solder pad on one end, and attached to a desktop on the other end to record strain on the screen. The strain gage on the top plate was placed on its top in hopes to capture shrinkage in compression, and the strain gage on the bottom flange was placed on its bottom in hopes to capture elongation. Traditionally, strain gages are not applied to wood or bamboo, since the materials are very fibrous compared to steel, the material that strain gages are normally applied to. Additionally, the electric current running through the gage had the potential to heat up the spot of application very quickly in comparison to steel, and wood reacts much more dramatically to the direct application of heat than steel at this scale. The potential for the strain gages not recording the correct strain was known prior to testing, and after analysis was deemed only supplemental data. The fabrication, set up, and testing for both specimens were exactly the same, with the exception of one specimen having a stiffener inside the header at midspan in order to mimic a splice of the BamCore panels along a span larger than 10’.

# Results and Comparison

Upon the completion of fabrication, testing, and data collection, the empirical results were compared with the analytical results to note discrepancies. The first area of comparison was the L/800 deflection limit. During initial analysis, it was found to be that a timber box header spanning 16', with a 6x6, and 16" overall depth could support a uniform load of 43 plf before deflecting L/800 = .24". The half scale model, a timber box header spanning 8', with a 3x3, and 8" overall depth, was found to support a uniform load of 50 plf in Specimen 1, and 54 plf in Specimen 2. Ideally, the objective was to see if these values would align, because although the half scale specimens possessed a smaller section size, they simultaneously spanned a shorter distance. This would mean a 14% difference between expected value and actual value for Specimen 1, and a 20% difference between expected value and actual value for Specimen 2.

The specimens were also tested to fracture, as a means to observe design stress values compared to test stress values. Strain values were recorded using the strain gages, but during comparison, it was found that the "test stress values" would be off my multiple factors from design stress values, which is an indication that the strain gages likely did not record strain on the timber box header accurately.

However, the maximum allowable uniform loads for tension, compression, and bending were all found during analysis using design stress values, and the point load from the tests was converted to a uniform load, and compared to the maximum allowable uniform loads from analysis. Both specimens seemed to have elements of multiple failure modes. What was evident after both tests was a failure of a combination of bending of the section and tension in the BamCore panel.

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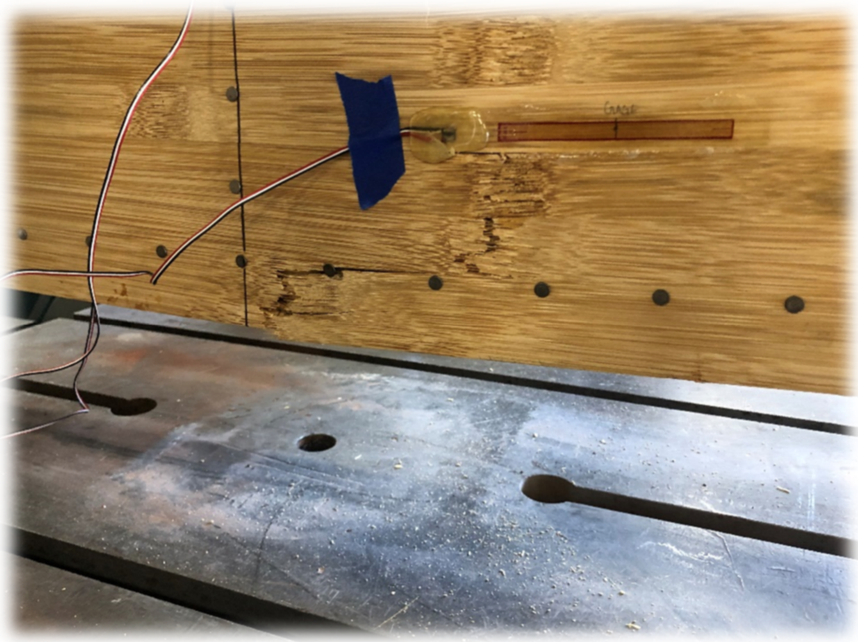
There also seemed to be a failure plane in the BamCore panels along the nail lines, visibly "ripping" the wood along the 6d nails at 2" on center.

Many of the tension failure cracks in the BamCore panels occurred at the finger joints of the panels, where different strips of BamCore would be joined together.



When comparing the maximum load on Specimen 1 to maximum bending load, the test applied 873 plf compared to 934 plf maximum bending load—a 6.9% difference. When comparing the maximum load on Specimen 2 to maximum bending load, the test applied 700 plf compared to 934 plf maximum bending load—a 33% difference.

The development of timber box headers using BamCore side panels was a study that aimed to bring about new insight as to how BamCore and timber interact together when supporting a uniform load. The findings in this report have led to an initial span table, as shown below, along with maximum loads for different failure modes. BamCore panels provide an efficient use of material in a given cross section by providing more strength than typical plywood, and sustainability in practice and development.

# Appendix & Spreadsheet Calculations

## MOMENT OF INERTIA AND N.A. SPREADSHEET FOR 6X6:

**SET DATA**

| Moduluses of Elasticity | psi |
|---|---|
| $E_{Headers}$ | 1600000 |
| $E_{Bamcore}$ | 1420000 |
| $E_{2x6}$ | 1700000 |

| Transformation to $E_{Heade}$ | n |
|---|---|
| Ebamcore/Eheader= | 0.89 |
| E2x6/Eheader= | 1.06 |

| Header Depths (in) |
|---|
| 12 |
| 16 |
| 24 |

**12" TOTAL DEPTH**

| Part Dimensions | $b_{Original}$ | $b_{Transformed}$ | h | Area | I |
|---|---|---|---|---|---|
| 6x6 | 5.5 | 5.5 | 5.5 | 30.25 | 76.26 |
| (2) Bamcore Panels | 2.5 | 2.22 | 12 | 26.63 | 319.50 |
| 2x6 | 5.5 | 5.84 | 1.5 | 8.77 | 1.64 |
| | | | **Σ(A)=** | 65.64 | 397.40 |

| Centroid | in |
|---|---|
| $y_{Header}$= | 2.75 |
| $y_{Bamcore}$ = | 6 |
| $y_{2x6}$ = | 11.25 |

*distance from datum at y=0 (bottom of header) to centroid of individual part*

| Σ(y*A)= | 341.55 |
|---|---|
| **N.A.** | **5.20** |

*N.A. = Σ(y*A)/ΣA*
**in from bottom**

| $d_{Header}$= | 2.45 |
|---|---|
| $d_{Bamcore}$ = | 0.80 |
| $d_{2x6}$ = | 6.05 |

*distance from centroid of individual part to section N.A.*

| $Ad^2$ | $in^4$ |
|---|---|
| Bamcore | 16.90 |
| Header | 182.07 |
| 2x6 | 320.49 |
| Total | 519.46 |

| Moment of Inertia | $in^4$ |
|---|---|
| Σ (I parts) | 397.40 |
| Σ ($Ad^2$) | 519.46 |
| **Moment of Inertia** | **917** |

| c= | 6.80 |
|---|---|

*largest distance between extreme fiber and neutral axis*

| Section Modulus (S | **134.9** |
|---|---|

$in^3$

**16" TOTAL DEPTH**

| Part Dimensions | $b_{Original}$ | $b_{Transformed}$ | h | Area | I |
|---|---|---|---|---|---|
| 6x6 | 5.5 | 5.5 | 5.5 | 30.25 | 76.26 |
| (2) Bamcore Panels | 2.5 | 2.22 | 16 | 35.50 | 757.33 |
| 2x6 | 5.5 | 5.84 | 1.5 | 8.77 | 1.64 |
| | | | **Σ(A)=** | 74.52 | 835.23 |

| Centroid | in |
|---|---|
| $y_{Header}$= | 2.75 |
| $y_{Bamcore}$ = | 8 |
| $y_{2x6}$ = | 15.25 |

| Σ(y*A)= | 500.86 |
|---|---|
| **N.A.** | **6.72** |

**in**

| $d_{Header}$= | 3.97 |
|---|---|
| $d_{Bamcore}$ = | 1.28 |
| $d_{2x6}$ = | 8.53 |

| $Ad^2$ | $in^4$ |
|---|---|
| Bamcore | 58.02 |
| Header | 477.15 |
| 2x6 | 637.56 |
| Total | 1172.73 |

| Moment of Inertia | $in^4$ |
|---|---|
| Σ (I parts) | 835.23 |
| Σ ($Ad^2$) | 1172.73 |
| **Moment of Inertia** | **2008** |

| c= | 9.28 |
|---|---|

| Section Modulus (S | **216.4** |
|---|---|

$in^3$

**24" TOTAL DEPTH**

| Part Dimensions | $b_{Original}$ | $b_{Transformed}$ | h | Area | I |
|---|---|---|---|---|---|
| 6x6 | 5.5 | 5.5 | 5.5 | 30.25 | 76.26 |
| (2) Bamcore Panels | 2.5 | 2.22 | 24 | 53.25 | 2556.00 |
| 2x6 | 5.5 | 5.84 | 1.5 | 8.77 | 1.64 |
| | | | **Σ(A)=** | 92.27 | 2633.90 |

| Centroid | in |
|---|---|
| $y_{Header}$= | 2.75 |
| $y_{Bamcore}$ = | 12 |
| $y_{2x6}$ = | 23.25 |

| Σ(y*A)= | 925.99 |
|---|---|
| **N.A.** | **10.04** |

**in**

| $d_{Header}$= | 7.29 |
|---|---|
| $d_{Bamcore}$ = | 1.96 |
| $d_{2x6}$ = | 13.21 |

| $Ad^2$ | $in^4$ |
|---|---|
| Bamcore | 205.38 |
| Header | 1605.90 |
| 2x6 | 1530.54 |
| Total | 3341.81 |

| Moment of Inertia | $in^4$ |
|---|---|
| Σ (I parts) | 2633.90 |
| Σ ($Ad^2$) | 3341.81 |
| **Moment of Inertia** | **5976** |

| c= | 13.96 |
|---|---|

| Section Modulus (S | **427.9** |
|---|---|

$in^3$

# MOMENT OF INERTIA AND N.A. SPREADSHEET FOR 6X8:

**SET DATA**

| Moduluses of Elasticity | psi |
|---|---|
| $E_{Headers}$ | 1600000 |
| $E_{Bamcore}$ | 1420000 |
| $E_{2x6}$ | 1700000 |

| Transformation to $E_{Heade}$ | n |
|---|---|
| Ebamcore/Eheader= | 0.89 |
| E2x6/Eheader= | 1.06 |

| Header Depths (in) |
|---|
| 12 |
| 16 |
| 24 |

**12" TOTAL DEPTH**

| Part Dimensions | $b_{Original}$ | $b_{Transformed}$ | h | Area | I |
|---|---|---|---|---|---|
| 6x8 | 5.5 | 5.5 | 7.5 | 41.25 | 193.36 |
| (2) Bamcore Panels | 2.5 | 2.22 | 12 | 26.63 | 319.50 |
| 2x6 | 5.5 | 5.84 | 1.5 | 8.77 | 1.64 |
| | | | Σ(A)= | 76.64 | 514.50 |

| Centroid | in |
|---|---|
| $y_{Header}$= | 3.75 |
| $y_{Bamcore}$ = | 6 |
| $y_{2x6}$ = | 11.25 |

*distance from datum at y=0 (bottom of header) to centroid of individual part*

| Σ(y*A)= | 413.05 |
|---|---|
| **N.A.** | **5.39** |

*N.A. = Σ(y*A)/ΣA* **in from bottom**

| $d_{Header}$= | 1.64 |
|---|---|
| $d_{Bamcore}$ = | 0.61 |
| $d_{2x6}$ = | 5.86 |

*distance from centroid of individual part to section N.A.*

| $Ad^2$ | in$^4$ |
|---|---|
| Bamcore | 9.93 |
| Header | 110.87 |
| 2x6 | 301.06 |
| Total | 421.86 |

| Moment of Inertia | in$^4$ |
|---|---|
| Σ (I parts) | 514.50 |
| Σ ($Ad^2$) | 421.86 |
| **Moment of Inertia** | **936** |

| c= | 6.61 |
|---|---|

*largest distance between extreme fiber and neutral axis*

| Section Modulus (S | **141.6** |
|---|---|

in$^3$

**16" TOTAL DEPTH**

| Part Dimensions | $b_{Original}$ | $b_{Transformed}$ | h | Area | I |
|---|---|---|---|---|---|
| 6x8 | 5.5 | 5.5 | 7.5 | 41.25 | 193.36 |
| (2) Bamcore Panels | 2.5 | 2.22 | 16 | 35.50 | 757.33 |
| 2x6 | 5.5 | 5.84 | 1.5 | 8.77 | 1.64 |
| | | | Σ(A)= | 85.52 | 952.34 |

| Centroid | in |
|---|---|
| $y_{Header}$= | 3.75 |
| $y_{Bamcore}$ = | 8 |
| $y_{2x6}$ = | 15.25 |

| Σ(y*A)= | 572.36 |
|---|---|
| **N.A.** | **6.69** |

**in**

| $d_{Header}$= | 2.94 |
|---|---|
| $d_{Bamcore}$ = | 1.31 |
| $d_{2x6}$ = | 8.56 |

| $Ad^2$ | in$^4$ |
|---|---|
| Bamcore | 60.64 |
| Header | 357.30 |
| 2x6 | 641.83 |
| Total | 1059.76 |

| Moment of Inertia | in$^4$ |
|---|---|
| Σ (I parts) | 952.34 |
| Σ ($Ad^2$) | 1059.76 |
| **Moment of Inertia** | **2012** |

| c= | 9.31 |
|---|---|

| Section Modulus (S | **216.2** |
|---|---|

in$^3$

**24" TOTAL DEPTH**

| Part Dimensions | $b_{Original}$ | $b_{Transformed}$ | h | Area | I |
|---|---|---|---|---|---|
| 6x8 | 5.5 | 5.5 | 7.5 | 41.25 | 193.36 |
| (2) Bamcore Panels | 2.5 | 2.22 | 24 | 53.25 | 2556.00 |
| 2x6 | 5.5 | 5.84 | 1.5 | 8.77 | 1.64 |
| | | | Σ(A)= | 103.27 | 2751.00 |

| Centroid | in |
|---|---|
| $y_{Header}$= | 3.75 |
| $y_{Bamcore}$ = | 12 |
| $y_{2x6}$ = | 23.25 |

| Σ(y*A)= | 997.49 |
|---|---|
| **N.A.** | **9.66** |

**in**

| $d_{Header}$= | 5.91 |
|---|---|
| $d_{Bamcore}$ = | 2.34 |
| $d_{2x6}$ = | 13.59 |

| $Ad^2$ | in$^4$ |
|---|---|
| Bamcore | 291.71 |
| Header | 1440.51 |
| 2x6 | 1619.04 |
| Total | 3351.27 |

| Moment of Inertia | in$^4$ |
|---|---|
| Σ (I parts) | 2751.00 |
| Σ ($Ad^2$) | 3351.27 |
| **Moment of Inertia** | **6102** |

| c= | 14.34 |
|---|---|

| Section Modulus (S | **425.5** |
|---|---|

in$^3$

# MOMENT OF INERTIA AND N.A. SPREADSHEET FOR 6X10:

**SET DATA**

| Moduluses of Elasticity | psi |
|---|---|
| $E_{Headers}$ | 1600000 |
| $E_{Bamcore}$ | 1420000 |
| $E_{2x6}$ | 1700000 |

| Transformation to $E_{Heade}$ | n |
|---|---|
| Ebamcore/Eheader= | 0.89 |
| E2x6/Eheader= | 1.06 |

| Header Depths (in) |
|---|
| 12 |
| 16 |
| 24 |

**12" TOTAL DEPTH**

| Part Dimensions | $b_{Original}$ | $b_{Transformed}$ | h | Area | I |
|---|---|---|---|---|---|
| 6x10 | 5.5 | 5.5 | 9.5 | 52.25 | 392.96 |
| (2) Bamcore Panels | 2.5 | 2.22 | 12 | 26.63 | 319.50 |
| 2x6 | 5.5 | 5.84 | 1.5 | 8.77 | 1.64 |
| | | | **Σ(A)=** | 87.64 | 714.11 |

| Centroid | in |
|---|---|
| $y_{Header}$= | 4.75 |
| $y_{Bamcore}$ = | 6 |
| $y_{2x6}$ = | 11.25 |

*distance from datum at y=0 (bottom of header) to centroid of individual part*

| Σ(y*A)= | 506.55 |
|---|---|
| **N.A.** | **5.78** |

*N.A. = Σ(y*A)/ΣA*

**in from bottom**

| $d_{Header}$= | 1.03 |
|---|---|
| $d_{Bamcore}$ = | 0.22 |
| $d_{2x6}$ = | 5.47 |

*distance from centroid of individual part to section N.A.*

| $Ad^2$ | $in^4$ |
|---|---|
| Bamcore | 1.29 |
| Header | 55.42 |
| 2x6 | 262.29 |
| Total | 319.00 |

| Moment of Inertia | $in^4$ |
|---|---|
| Σ (I parts) | 714.11 |
| Σ ($Ad^2$) | 319.00 |
| **Moment of Inertia** | **1033** |

| c= | 6.22 |
|---|---|

*largest distance between extreme fiber and neutral axis*

| Section Modulus (S | **166.1** |
|---|---|

$in^3$

**16" TOTAL DEPTH**

| Part Dimensions | $b_{Original}$ | $b_{Transformed}$ | h | Area | I |
|---|---|---|---|---|---|
| 6x10 | 5.5 | 5.5 | 9.5 | 52.25 | 392.96 |
| (2) Bamcore Panels | 2.5 | 2.22 | 16 | 35.50 | 757.33 |
| 2x6 | 5.5 | 5.84 | 1.5 | 8.77 | 1.64 |
| | | | **Σ(A)=** | 96.52 | 1151.94 |

| Centroid | in |
|---|---|
| $y_{Header}$= | 4.75 |
| $y_{Bamcore}$ = | 8 |
| $y_{2x6}$ = | 15.25 |

| Σ(y*A)= | 665.86 |
|---|---|
| **N.A.** | **6.90** |

**in**

| $d_{Header}$= | 2.15 |
|---|---|
| $d_{Bamcore}$ = | 1.10 |
| $d_{2x6}$ = | 8.35 |

| $Ad^2$ | $in^4$ |
|---|---|
| Bamcore | 43.03 |
| Header | 241.31 |
| 2x6 | 611.30 |
| Total | 895.64 |

| Moment of Inertia | $in^4$ |
|---|---|
| Σ (I parts) | 1151.94 |
| Σ ($Ad^2$) | 895.64 |
| **Moment of Inertia** | **2048** |

| c= | 9.10 |
|---|---|

| Section Modulus (S | **225.0** |
|---|---|

$in^3$

**24" TOTAL DEPTH**

| Part Dimensions | $b_{Original}$ | $b_{Transformed}$ | h | Area | I |
|---|---|---|---|---|---|
| 6x10 | 5.5 | 5.5 | 9.5 | 52.25 | 392.96 |
| (2) Bamcore Panels | 2.5 | 2.22 | 24 | 53.25 | 2556.00 |
| 2x6 | 5.5 | 5.84 | 1.5 | 8.77 | 1.64 |
| | | | **Σ(A)=** | 114.27 | 2950.61 |

| Centroid | in |
|---|---|
| $y_{Header}$= | 4.75 |
| $y_{Bamcore}$ = | 12 |
| $y_{2x6}$ = | 23.25 |

| Σ(y*A)= | 1090.99 |
|---|---|
| **N.A.** | **9.55** |

**in**

| $d_{Header}$= | 4.80 |
|---|---|
| $d_{Bamcore}$ = | 2.45 |
| $d_{2x6}$ = | 13.70 |

| $Ad^2$ | $in^4$ |
|---|---|
| Bamcore | 320.20 |
| Header | 1202.75 |
| 2x6 | 1645.74 |
| Total | 3168.69 |

| Moment of Inertia | $in^4$ |
|---|---|
| Σ (I parts) | 2950.61 |
| Σ ($Ad^2$) | 3168.69 |
| **Moment of Inertia** | **6119** |

| c= | 14.45 |
|---|---|

| Section Modulus (S | **423.4** |
|---|---|

$in^3$

# MOMENT OF INERTIA AND N.A. SPREADSHEET FOR 6X12:

**SET DATA**

| Moduluses of Elasticity | psi |
|---|---|
| $E_{Headers}$ | 1600000 |
| $E_{Bamcore}$ | 1420000 |
| $E_{2x6}$ | 1700000 |

| Transformation to $E_{Heade}$ | n |
|---|---|
| Ebamcore/Eheader= | 0.89 |
| E2x6/Eheader= | 1.06 |

| Header Depths (in) |
|---|
| 12 |
| 16 |
| 24 |

**12" TOTAL DEPTH**

| Part Dimensions | $b_{Original}$ | $b_{Transformed}$ | h | Area | I |
|---|---|---|---|---|---|
| 6x12 | 5.5 | 5.5 | 11.5 | 63.25 | 697.07 |
| (2) Bamcore Panels | 2.5 | 2.22 | 12 | 26.63 | 319.50 |
| 2x6 | 5.5 | 5.84 | 1.5 | 8.77 | 1.64 |
| | | | Σ(A)= | 98.64 | 1018.21 |

| Centroid | in |
|---|---|
| $y_{Header}$= | 5.75 |
| $y_{Bamcore}$ = | 6 |
| $y_{2x6}$ = | 11.25 |

*distance from datum at y=0 (bottom of header) to centroid of individual part*

| | |
|---|---|
| Σ(y*A)= | 622.05 |
| **N.A.** | **6.31** |

*N.A. = Σ(y*A)/ΣA*
**in from bottom**

| | |
|---|---|
| $d_{Header}$= | 0.56 |
| $d_{Bamcore}$ = | 0.31 |
| $d_{2x6}$ = | 4.94 |

*distance from centroid of individual part to section N.A.*

| $Ad^2$ | $in^4$ |
|---|---|
| Bamcore | 2.50 |
| Header | 19.57 |
| 2x6 | 214.24 |
| Total | 236.31 |

| Moment of Inertia | $in^4$ |
|---|---|
| Σ (I parts) | 1018.21 |
| Σ ($Ad^2$) | 236.31 |
| **Moment of Inertia** | **1255** |

| | |
|---|---|
| c= | 6.31 |

*largest distance between extreme fiber and neutral axis*

| | |
|---|---|
| Section Modulus (S | **198.9** |

$in^3$

**16" TOTAL DEPTH**

| Part Dimensions | $b_{Original}$ | $b_{Transformed}$ | h | Area | I |
|---|---|---|---|---|---|
| 6x12 | 5.5 | 5.5 | 11.5 | 63.25 | 697.07 |
| (2) Bamcore Panels | 2.5 | 2.22 | 16 | 35.50 | 757.33 |
| 2x6 | 5.5 | 5.84 | 1.5 | 8.77 | 1.64 |
| | | | Σ(A)= | 107.52 | 1456.04 |

| Centroid | in |
|---|---|
| $y_{Header}$= | 5.75 |
| $y_{Bamcore}$ = | 8 |
| $y_{2x6}$ = | 15.25 |

| | |
|---|---|
| Σ(y*A)= | 781.36 |
| **N.A.** | **7.27** |

**in**

| | |
|---|---|
| $d_{Header}$= | 1.52 |
| $d_{Bamcore}$ = | 0.73 |
| $d_{2x6}$ = | 7.98 |

| $Ad^2$ | $in^4$ |
|---|---|
| Bamcore | 19.05 |
| Header | 145.64 |
| 2x6 | 558.56 |
| Total | 723.25 |

| Moment of Inertia | $in^4$ |
|---|---|
| Σ (I parts) | 1456.04 |
| Σ ($Ad^2$) | 723.25 |
| **Moment of Inertia** | **2179** |

| | |
|---|---|
| c= | 8.73 |

| | |
|---|---|
| Section Modulus (S | **249.6** |

$in^3$

**24" TOTAL DEPTH**

| Part Dimensions | $b_{Original}$ | $b_{Transformed}$ | h | Area | I |
|---|---|---|---|---|---|
| 6x12 | 5.5 | 5.5 | 11.5 | 63.25 | 697.07 |
| (2) Bamcore Panels | 2.5 | 2.22 | 24 | 53.25 | 2556.00 |
| 2x6 | 5.5 | 5.84 | 1.5 | 8.77 | 1.64 |
| | | | Σ(A)= | 125.27 | 3254.71 |

| Centroid | in |
|---|---|
| $y_{Header}$= | 5.75 |
| $y_{Bamcore}$ = | 12 |
| $y_{2x6}$ = | 23.25 |

| | |
|---|---|
| Σ(y*A)= | 1206.49 |
| **N.A.** | **9.63** |

**in**

| | |
|---|---|
| $d_{Header}$= | 3.88 |
| $d_{Bamcore}$ = | 2.37 |
| $d_{2x6}$ = | 13.62 |

| $Ad^2$ | $in^4$ |
|---|---|
| Bamcore | 298.74 |
| Header | 952.90 |
| 2x6 | 1625.72 |
| Total | 2877.35 |

| Moment of Inertia | $in^4$ |
|---|---|
| Σ (I parts) | 3254.71 |
| Σ ($Ad^2$) | 2877.35 |
| **Moment of Inertia** | **6132** |

| | |
|---|---|
| c= | 14.37 |

| | |
|---|---|
| Section Modulus (S | **426.8** |

$in^3$

# Inertia Summary Table

| Header Section | Total Depth (in) | Moment of Inertia (in$^4$) | N.A. from bottom (in) | Q (in3) |
|---|---|---|---|---|
| 6x6 | 12 | 917 | 5.20 | 104.2 |
| | 16 | 2008 | 6.72 | 148.5 |
| | 24 | 5976 | 10.04 | 269.3 |
| 6x8 | 12 | 936 | 5.39 | 101.5 |
| | 16 | 2012 | 6.69 | 149.1 |
| | 24 | 6102 | 9.66 | 281.1 |
| 6x10 | 12 | 1033 | 5.78 | 95.9 |
| | 16 | 2048 | 6.90 | 144.9 |
| | 24 | 6119 | 9.55 | 284.7 |
| 6x12 | 12 | 1255 | 6.31 | 89.0 |
| | 16 | 2179 | 7.27 | 137.6 |
| | 24 | 6132 | 9.63 | 282.0 |

# Cp Sample Calculation

| | | | | | |
|---|---|---|---|---|---|
| Strong Axis | $l_1$ = | 14 | ft | 168 | inches |
| Stability Factor | $K_E$ = | 1.0 | | | *[Table G1, A* Appendix G |
| | c = | 0.8 | | | *[Sect. 3.7.1]* |

**Section Properties and Allowable Stresses:** Douglas Fir - Larch

Properties:

| | | | | | |
|---|---|---|---|---|---|
| E = | 1.70E+06 | psi | A = | 11.58 | $in^2$ |
| Emin = | 6.20E+05 | psi | $F_c$ = | 1,500 | psi |

Adjustment Factors:

| | | | |
|---|---|---|---|
| $C_D$ = | 1 | Load Duration Factor | *[Table 2.3.2 ]* |
| $C_M$ = | 1 | Wet Service Factor | |
| $C_t$ = | 1 | Temperature Factor | |
| $C_F$ = | 1.00 | Size Factor | |
| $C_i$ = | 1 | Incising Factor | |
| $C_T$ = | 1 | Buckling Stiffness Factor | |

**Determine Allowable Stress:**

Maximum Slenderness Ratio:

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Strong Axis: | $l_{1e}$ = | 168 | $d_1$ = | 7.72 | | $r^*_1$ = | 474 |
| Weak Axis: | $l_{2e}$ = | 0 | $d_2$ = | 1.5 | | $r^*_2$ = | 0 |
| $r^*_{MAX}$ = | 474 | | A = | 11.58 | $in^2$ | | |

Ratio of Critical Stress to Maximum Stress: $in^2$

| | | | | | | |
|---|---|---|---|---|---|---|
| $F_{CE}$ = | 1,076 | psi | *[Sect. 3.7.1]* | E'min = | 620,000 | psi |
| $F^*_c$ = | 1,500 | psi | *[Sect. 3.7.1]* | le/d= | 22 | |

Column Stability Factor:

$C_p$ = 0.57 *[EQ 3.7-1]*

Allowable Stress:

$F'^*_c$ = 852 psi

# Maximum Uniform Loads Tables

| | | | TENSION | | COMPRESSION | | BENDING | | DEFLECTION | SHEAR | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Header | Depth (in) | Mallow (#-ft) | wallow (plf) | Mallow (#-ft) | wallow (plf) | Mallow (#-ft) | wallow (plf) | wallow (plf) | V (#) | wallow (plf) | MAX PLF | L/480 | L/360 | L/240 |
| 10' SPAN | 6x6 | 12 | 12114 | 969 | 16862 | 1349 | 17621 | 1410 | 81.5 | 9076 | 1815 | 81 | 136 | 181 | 272 |
| | | 16 | 20538 | 1643 | 27051 | 2164 | 29873 | 2390 | 178.5 | 13954 | 2791 | 178 | 297 | 397 | 595 |
| | | 24 | 40935 | 3275 | 53493 | 4279 | 59542 | 4763 | 531.2 | 22898 | 4580 | 531 | 885 | 1180 | 1771 |
| | 6x8 | 12 | 11945 | 956 | 17706 | 1416 | 17374 | 1390 | 83.2 | 9522 | 1904 | 83 | 139 | 185 | 277 |
| | | 16 | 20668 | 1653 | 27024 | 2162 | 30062 | 2405 | 178.9 | 13927 | 2785 | 178 | 298 | 397 | 596 |
| | | 24 | 43432 | 3475 | 53191 | 4255 | 63174 | 5054 | 542.4 | 22400 | 4480 | 542 | 904 | 1205 | 1808 |
| | 6x10 | 12 | 10054 | 804 | 20761 | 1661 | 20108 | 1609 | 91.8 | 11115 | 2223 | 91 | 153 | 204 | 306 |
| | | 16 | 16695 | 1336 | 28123 | 2250 | 33389 | 2671 | 182.0 | 14584 | 2917 | 182 | 303 | 404 | 607 |
| | | 24 | 36051 | 2884 | 52927 | 4234 | 72102 | 5768 | 543.9 | 22181 | 4436 | 543 | 907 | 1209 | 1813 |
| | 6x12 | 12 | 11190 | 895 | 27541 | 2203 | 22380 | 1790 | 111.5 | 14553 | 2911 | 111 | 186 | 248 | 372 |
| | | 16 | 16868 | 1349 | 31195 | 2496 | 33735 | 2699 | 193.7 | 16345 | 3269 | 193 | 323 | 430 | 646 |
| | | 24 | 35813 | 2865 | 53346 | 4268 | 71626 | 5730 | 545.1 | 22438 | 4488 | 545 | 908 | 1211 | 1817 |

| | | | TENSION | | COMPRESSION | | BENDING | | DEFLECTION | SHEAR | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Header | Depth (in) | Mallow (#-ft) | wallow (plf) | Mallow (#-ft) | wallow (plf) | Mallow (#-ft) | wallow (plf) | wallow (plf) | V (#) | wallow (plf) | MAX PLF | | | |
| 12' SPAN | 6x6 | 12 | 12114 | 673 | 16862 | 937 | 17621 | 979 | 47.2 | 9076 | 1513 | 47 | 79 | 105 | 157 |
| | | 16 | 20538 | 1141 | 27051 | 1503 | 29873 | 1660 | 103.3 | 13954 | 2326 | 103 | 172 | 230 | 344 |
| | | 24 | 40935 | 2274 | 53493 | 2972 | 59542 | 3308 | 307.4 | 22898 | 3816 | 307 | 512 | 683 | 1025 |
| | 6x8 | 12 | 11945 | 664 | 17706 | 984 | 17374 | 965 | 48.2 | 9522 | 1587 | 48 | 80 | 107 | 161 |
| | | 16 | 20668 | 1148 | 27024 | 1501 | 30062 | 1670 | 103.5 | 13927 | 2321 | 103 | 173 | 230 | 345 |
| | | 24 | 43432 | 2413 | 53191 | 2955 | 63174 | 3510 | 313.9 | 22400 | 3733 | 313 | 523 | 698 | 1046 |
| | 6x10 | 12 | 10054 | 559 | 20761 | 1153 | 20108 | 1117 | 53.1 | 11115 | 1852 | 53 | 89 | 118 | 177 |
| | | 16 | 16695 | 927 | 28123 | 1562 | 33389 | 1855 | 105.3 | 14584 | 2431 | 105 | 176 | 234 | 351 |
| | | 24 | 36051 | 2003 | 52927 | 2940 | 72102 | 4006 | 314.8 | 22181 | 3697 | 314 | 525 | 700 | 1049 |
| | 6x12 | 12 | 11190 | 622 | 27541 | 1530 | 22380 | 1243 | 64.5 | 14553 | 2425 | 64 | 108 | 143 | 215 |
| | | 16 | 16868 | 937 | 31195 | 1733 | 33735 | 1874 | 112.1 | 16345 | 2724 | 112 | 187 | 249 | 374 |
| | | 24 | 35813 | 1990 | 53346 | 2964 | 71626 | 3979 | 315.4 | 22438 | 3740 | 315 | 526 | 701 | 1051 |

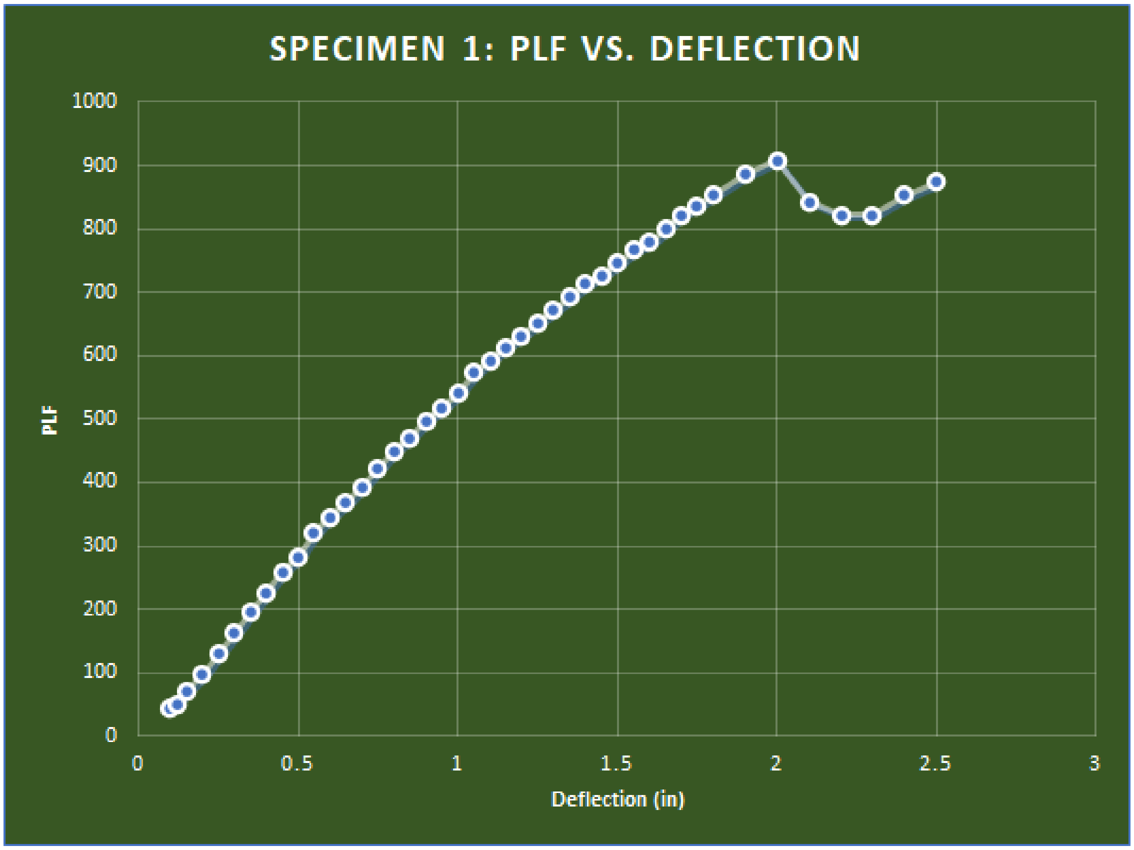
| | | | TENSION | | COMPRESSION | | BENDING | | DEFLECTION | SHEAR | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Header | Depth (in) | Mallow (#-ft) | wallow (plf) | Mallow (#-ft) | wallow (plf) | Mallow (#-ft) | wallow (plf) | wallow (plf) | V (#) | wallow (plf) | MAX PLF | | | |
| 14' SPAN | 6x6 | 12 | 12114 | 494 | 16862 | 688 | 17621 | 719 | 29.7 | 9076 | 1297 | 29 | 50 | 66 | 99 |
| | | 16 | 20538 | 838 | 27051 | 1104 | 29873 | 1219 | 65.0 | 13954 | 1993 | 65 | 108 | 145 | 217 |
| | | 24 | 40935 | 1671 | 53493 | 2183 | 59542 | 2430 | 193.6 | 22898 | 3271 | 193 | 323 | 430 | 645 |
| | 6x8 | 12 | 11945 | 488 | 17706 | 723 | 17374 | 709 | 30.3 | 9522 | 1360 | 30 | 51 | 67 | 101 |
| | | 16 | 20668 | 844 | 27024 | 1103 | 30062 | 1227 | 65.2 | 13927 | 1990 | 65 | 109 | 145 | 217 |
| | | 24 | 43432 | 1773 | 53191 | 2171 | 63174 | 2579 | 197.7 | 22400 | 3200 | 197 | 329 | 439 | 659 |
| | 6x10 | 12 | 10054 | 410 | 20761 | 847 | 20108 | 821 | 33.5 | 11115 | 1588 | 33 | 56 | 74 | 112 |
| | | 16 | 16695 | 681 | 28123 | 1148 | 33389 | 1363 | 66.3 | 14584 | 2083 | 66 | 111 | 147 | 221 |
| | | 24 | 36051 | 1471 | 52927 | 2160 | 72102 | 2943 | 198.2 | 22181 | 3169 | 198 | 330 | 441 | 661 |
| | 6x12 | 12 | 11190 | 457 | 27541 | 1124 | 22380 | 913 | 40.6 | 14553 | 2079 | 40 | 68 | 90 | 135 |
| | | 16 | 16868 | 688 | 31195 | 1273 | 33735 | 1377 | 70.6 | 16345 | 2335 | 70 | 118 | 157 | 235 |
| | | 24 | 35813 | 1462 | 53346 | 2177 | 71626 | 2923 | 198.6 | 22438 | 3205 | 198 | 331 | 441 | 662 |

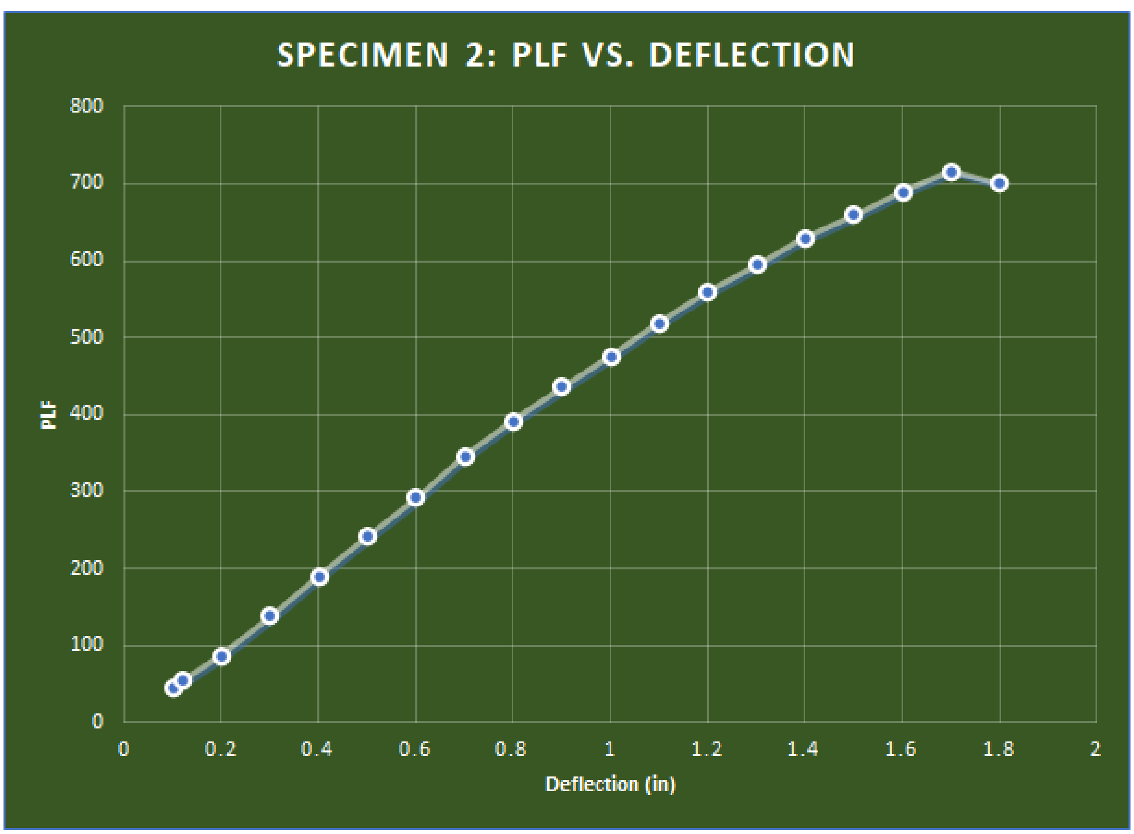
| | | | TENSION | | COMPRESSION | | BENDING | | DEFLECTION | SHEAR | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Header | Depth (in) | Mallow (#-ft) | wallow (plf) | Mallow (#-ft) | wallow (plf) | Mallow (#-ft) | wallow (plf) | wallow (plf) | V (#) | wallow (plf) | MAX PLF | | | |
| 16' SPAN | 6x6 | 12 | 12114 | 379 | 16862 | 527 | 17621 | 551 | 19.9 | 9076 | 1135 | 19 | 33 | 44 | 66 |
| | | 16 | 20538 | 642 | 27051 | 845 | 29873 | 934 | 43.6 | 13954 | 1744 | 43 | 73 | 97 | 145 |
| | | 24 | 40935 | 1279 | 53493 | 1672 | 59542 | 1861 | 129.7 | 22898 | 2862 | 129 | 216 | 288 | 432 |
| | 6x8 | 12 | 11945 | 373 | 17706 | 553 | 17374 | 543 | 20.3 | 9522 | 1190 | 20 | 34 | 45 | 68 |
| | | 16 | 20668 | 646 | 27024 | 845 | 30062 | 939 | 43.7 | 13927 | 1741 | 43 | 73 | 97 | 146 |
| | | 24 | 43432 | 1357 | 53191 | 1662 | 63174 | 1974 | 132.4 | 22400 | 2800 | 132 | 221 | 294 | 441 |
| | 6x10 | 12 | 10054 | 314 | 20761 | 649 | 20108 | 628 | 22.4 | 11115 | 1389 | 22 | 37 | 50 | 75 |
| | | 16 | 16695 | 522 | 28123 | 879 | 33389 | 1043 | 44.4 | 14584 | 1823 | 44 | 74 | 99 | 148 |
| | | 24 | 36051 | 1127 | 52927 | 1654 | 72102 | 2253 | 132.8 | 22181 | 2773 | 132 | 221 | 295 | 443 |
| | 6x12 | 12 | 11190 | 350 | 27541 | 861 | 22380 | 699 | 27.2 | 14553 | 1819 | 27 | 45 | 60 | 91 |
| | | 16 | 16868 | 527 | 31195 | 975 | 33735 | 1054 | 47.3 | 16345 | 2043 | 47 | 79 | 105 | 158 |
| | | 24 | 35813 | 1119 | 53346 | 1667 | 71626 | 2238 | 133.1 | 22438 | 2805 | 133 | 222 | 296 | 444 |

| | | | TENSION | | COMPRESSION | | BENDING | | DEFLECTION | SHEAR | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Header | Depth (in) | Mallow (#-ft) | wallow (plf) | Mallow (#-ft) | wallow (plf) | Mallow (#-ft) | wallow (plf) | wallow (plf) | V (#) | wallow (plf) | MAX PLF | | | |
| 18' SPAN | 6x6 | 12 | 12114 | 299 | 16862 | 416 | 17621 | 435 | 14.0 | 9076 | 1008 | 13 | 23 | 31 | 47 |
| | | 16 | 20538 | 507 | 27051 | 668 | 29873 | 738 | 30.6 | 13954 | 1550 | 30 | 51 | 68 | 102 |
| | | 24 | 40935 | 1011 | 53493 | 1321 | 59542 | 1470 | 91.1 | 22898 | 2544 | 91 | 152 | 202 | 304 |
| | 6x8 | 12 | 11945 | 295 | 17706 | 437 | 17374 | 429 | 14.3 | 9522 | 1058 | 14 | 24 | 32 | 48 |
| | | 16 | 20668 | 510 | 27024 | 667 | 30062 | 742 | 30.7 | 13927 | 1547 | 30 | 51 | 68 | 102 |
| | | 24 | 43432 | 1072 | 53191 | 1313 | 63174 | 1560 | 93.0 | 22400 | 2489 | 93 | 155 | 207 | 310 |
| | 6x10 | 12 | 10054 | 248 | 20761 | 513 | 20108 | 497 | 15.7 | 11115 | 1235 | 15 | 26 | 35 | 52 |
| | | 16 | 16695 | 412 | 28123 | 694 | 33389 | 824 | 31.2 | 14584 | 1620 | 31 | 52 | 69 | 104 |
| | | 24 | 36051 | 890 | 52927 | 1307 | 72102 | 1780 | 93.3 | 22181 | 2465 | 93 | 155 | 207 | 311 |
| | 6x12 | 12 | 11190 | 276 | 27541 | 680 | 22380 | 553 | 19.1 | 14553 | 1617 | 19 | 32 | 42 | 64 |
| | | 16 | 16868 | 416 | 31195 | 770 | 33735 | 833 | 33.2 | 16345 | 1816 | 33 | 55 | 74 | 111 |
| | | 24 | 35813 | 884 | 53346 | 1317 | 71626 | 1769 | 93.5 | 22438 | 2493 | 93 | 156 | 208 | 312 |

| | | | TENSION | | COMPRESSION | | BENDING | | DEFLECTION | SHEAR | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Header | Depth (in) | Mallow (#-ft) | wallow (plf) | Mallow (#-ft) | wallow (plf) | Mallow (#-ft) | wallow (plf) | wallow (plf) | V (#) | wallow (plf) | MAX PLF | | | |
| 20' SPAN | 6x6 | 12 | 12114 | 242 | 16862 | 337 | 17621 | 352 | 10.2 | 9076 | 908 | 10 | 17 | 23 | 34 |
| | | 16 | 20538 | 411 | 27051 | 541 | 29873 | 597 | 22.3 | 13954 | 1395 | 22 | 37 | 50 | 74 |
| | | 24 | 40935 | 819 | 53493 | 1070 | 59542 | 1191 | 66.4 | 22898 | 2290 | 66 | 111 | 148 | 221 |
| | 6x8 | 12 | 11945 | 239 | 17706 | 354 | 17374 | 347 | 10.4 | 9522 | 952 | 10 | 17 | 23 | 35 |
| | | 16 | 20668 | 413 | 27024 | 540 | 30062 | 601 | 22.4 | 13927 | 1393 | 22 | 37 | 50 | 75 |
| | | 24 | 43432 | 869 | 53191 | 1064 | 63174 | 1263 | 67.8 | 22400 | 2240 | 67 | 113 | 151 | 226 |
| | 6x10 | 12 | 10054 | 201 | 20761 | 415 | 20108 | 402 | 11.5 | 11115 | 1111 | 11 | 19 | 26 | 38 |
| | | 16 | 16695 | 334 | 28123 | 562 | 33389 | 668 | 22.8 | 14584 | 1458 | 22 | 38 | 51 | 76 |
| | | 24 | 36051 | 721 | 52927 | 1059 | 72102 | 1442 | 68.0 | 22181 | 2218 | 67 | 113 | 151 | 227 |
| | 6x12 | 12 | 11190 | 224 | 27541 | 551 | 22380 | 448 | 13.9 | 14553 | 1455 | 13 | 23 | 31 | 46 |
| | | 16 | 16868 | 337 | 31195 | 624 | 33735 | 675 | 24.2 | 16345 | 1634 | 24 | 40 | 54 | 81 |
| | | 24 | 35813 | 716 | 53346 | 1067 | 71626 | 1433 | 68.1 | 22438 | 2244 | 68 | 114 | 151 | 227 |

## Test Results: PLF vs. Deflection



# Timber Box Header Span Tables

| | Header | Depth (in) | Uniform Load (PLF) |
|---|---|---|---|
| 10' SPAN | 6x6 | 12 | 81 |
| | | 16 | 178 |
| | | 24 | 531 |
| | 6x8 | 12 | 83 |
| | | 16 | 178 |
| | | 24 | 542 |
| | 6x10 | 12 | 91 |
| | | 16 | 182 |
| | | 24 | 543 |
| | 6x12 | 12 | 111 |
| | | 16 | 193 |
| | | 24 | 545 |

| | Header | Depth (in) | Uniform Load (PLF) |
|---|---|---|---|
| 12' SPAN | 6x6 | 12 | 47 |
| | | 16 | 103 |
| | | 24 | 307 |
| | 6x8 | 12 | 48 |
| | | 16 | 103 |
| | | 24 | 313 |
| | 6x10 | 12 | 53 |
| | | 16 | 105 |
| | | 24 | 314 |
| | 6x12 | 12 | 64 |
| | | 16 | 112 |
| | | 24 | 315 |

| | Header | Depth (in) | Uniform Load (PLF) |
|---|---|---|---|
| 14' SPAN | 6x6 | 12 | 29 |
| | | 16 | 65 |
| | | 24 | 193 |
| | 6x8 | 12 | 30 |
| | | 16 | 65 |
| | | 24 | 197 |
| | 6x10 | 12 | 33 |
| | | 16 | 66 |
| | | 24 | 198 |
| | 6x12 | 12 | 40 |
| | | 16 | 70 |
| | | 24 | 198 |

| | Header | Depth (in) | Uniform Load (PLF) |
|---|---|---|---|
| 16' SPAN | 6x6 | 12 | 19 |
| | | 16 | 43 |
| | | 24 | 129 |
| | 6x8 | 12 | 20 |
| | | 16 | 43 |
| | | 24 | 132 |
| | 6x10 | 12 | 22 |
| | | 16 | 44 |
| | | 24 | 132 |
| | 6x12 | 12 | 27 |
| | | 16 | 47 |
| | | 24 | 133 |

| | Header | Depth (in) | Uniform Load (PLF) |
|---|---|---|---|
| 18' SPAN | 6x6 | 12 | 13 |
| | | 16 | 30 |
| | | 24 | 91 |
| | 6x8 | 12 | 14 |
| | | 16 | 30 |
| | | 24 | 93 |
| | 6x10 | 12 | 15 |
| | | 16 | 31 |
| | | 24 | 93 |
| | 6x12 | 12 | 19 |
| | | 16 | 33 |
| | | 24 | 93 |

| | Header | Depth (in) | Uniform Load (PLF) |
|---|---|---|---|
| 20' SPAN | 6x6 | 12 | 10 |
| | | 16 | 22 |
| | | 24 | 66 |
| | 6x8 | 12 | 10 |
| | | 16 | 22 |
| | | 24 | 67 |
| | 6x10 | 12 | 11 |
| | | 16 | 22 |
| | | 24 | 67 |
| | 6x12 | 12 | 13 |
| | | 16 | 24 |
| | | 24 | 68 |

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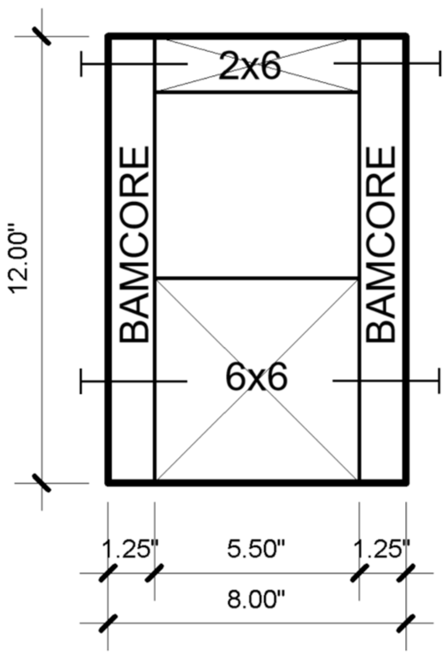
# Timber Box Header Using BamCore Side Panels

A Senior Project Study by Jonathan Herrera
Project Advisor: Abby Lentz, PE
California Polytechnic State University
Winter 2023

# Abstract



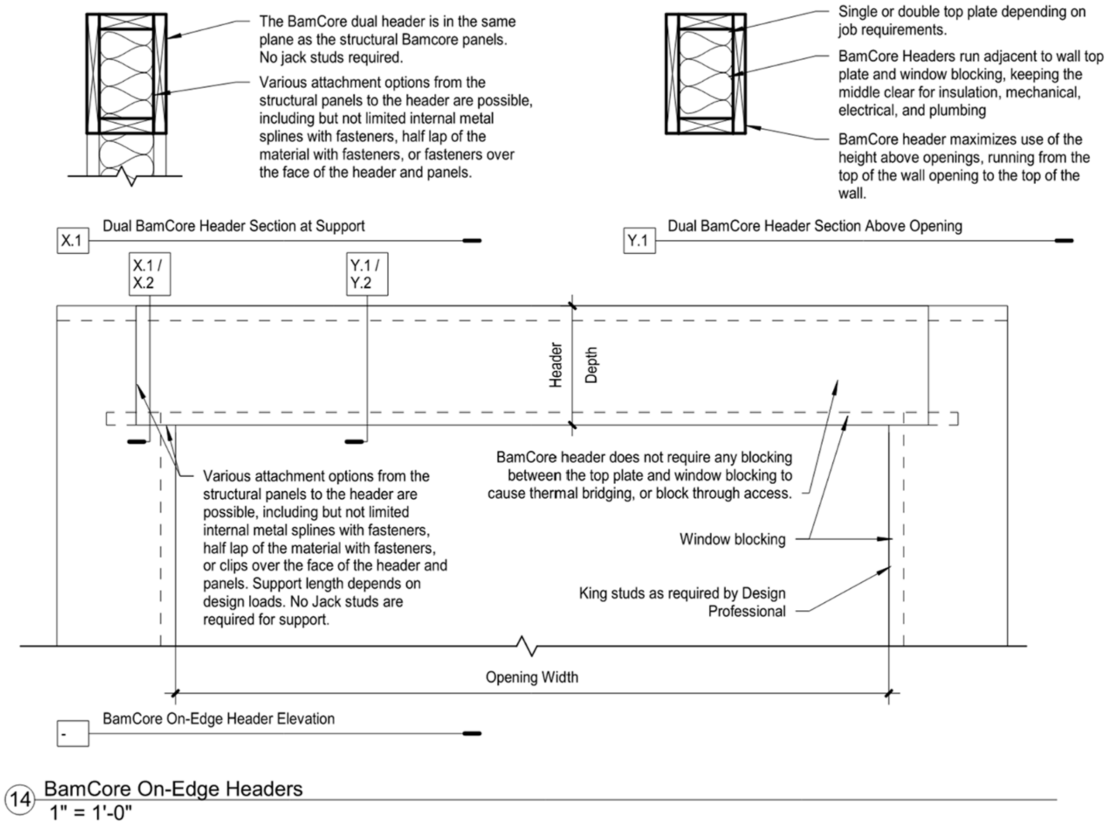

Purpose: begin development of a composite box header that was able to span long openings with minimal deflection, and fabricate at half scale

Box header comprised of:

| | | | | |
|---|---|---|---|---|
| 2x6 Top Plate | (2) 1 ¼" BamCore Side Panels | Bottom Header ranging from 6x6 to 6x12 | Depth ranging from 12" to 24" | Span ranging from 10' to 20' |

# Introduction

- Design: derived from design of "Dual BamCore Header", but currently insufficient for spans longer than 10'



# Current BamCore Span Tables

- Span Tables for Dual BamCore Header, only up to 9.75', no L/800 Deflection Criteria

BamCore G3 On Edge Header Uniform Load (PLF) Table, **L/240** Deflection Criteria

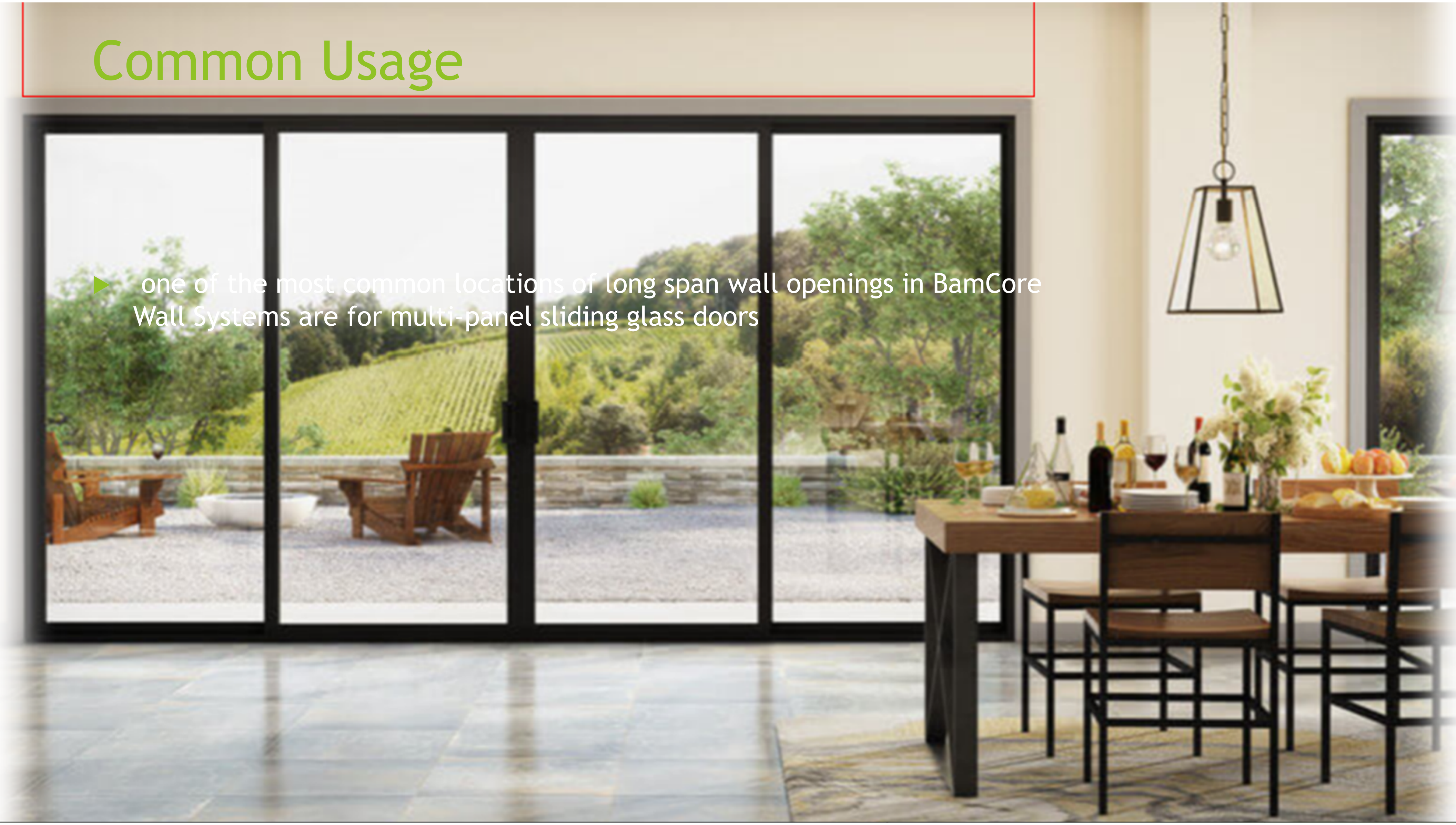
| Header Depth (in) | 6 | | 8 | | 10 | | 12 | | 14 | | 16 | | 20 | | 24 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Span (ft) | Uniform Load (PLF) | Bearing Length (in) | Uniform Load (PLF) | Bearing Length (in) | Uniform Load (PLF) | Bearing Length (in) | Uniform Load (PLF) | Bearing Length (in) | Uniform Load (PLF) | Bearing Length (in) | Uniform Load (PLF) | Bearing Length (in) | Uniform Load (PLF) | Bearing Length (in) | Uniform Load (PLF) | Bearing Length (in) |
| 3 | 3095 b | 1 3/4 | 4127 b | 2 1/2 | 5159 b | 3 1/4 | 6191 b | 4 | 7223 b | 4 3/4 | 8255 b | 5 1/2 | 10319 b | 7 1/2 | 12383 b | 9 1/2 |
| 4 | 1683 | 1 1/4 | 3094 b | 2 1/2 | 3868 b | 3 | 4641 b | 3 3/4 | 5415 b | 4 1/2 | 6188 b | 5 1/4 | 7736 b | 6 3/4 | 9283 b | 8 1/2 |
| 5 | 941 | 1 | 1976 | 2 | 3093 b | 3 | 3711 b | 3 3/4 | 4330 b | 4 1/4 | 4948 b | 5 | 6186 b | 6 1/2 | 7423 b | 8 |
| 6 | 572 | 3/4 | 1242 | 1 1/2 | 2170 a | 2 1/2 | 3065 a | 3 1/2 | 3606 b | 4 1/4 | 4122 b | 5 | 5152 b | 6 1/4 | 6183 b | 7 3/4 |
| 7 | 371 | 1/2 | 824 | 1 1/4 | 1483 | 2 | 2249 a | 3 | 3012 a | 4 | 3531 b | 4 3/4 | 4414 b | 6 1/4 | 5297 b | 7 1/2 |
| 8 | 252 | 1/2 | 571 | 1 | 1046 | 1 1/2 | 1678 | 2 1/2 | 2304 a | 3 1/2 | 2966 a | 4 1/2 | 3861 b | 6 | 4633 b | 7 1/2 |
| 9 | 179 | 1/2 | 410 | 3/4 | 761 | 1 1/4 | 1239 | 2 | 1818 a | 3 | 2341 a | 4 | 3430 b | 6 | 4116 b | 7 1/4 |
| 9.75 | 141 | 1/4 | 326 | 3/4 | 611 | 1 1/4 | 1002 | 1 3/4 | 1500 | 2 3/4 | 1993 a | 3 3/4 | 3042 a | 5 3/4 | 3798 b | 7 1/4 |

1. [a] means controlled by Bending Strength, [b] means controlled by Shear Strength, no superscript is controlled by deflection.

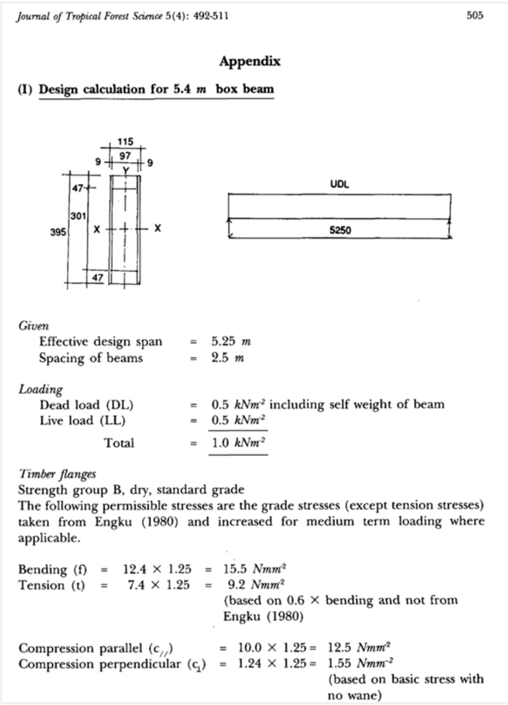
2. Values include 4% bending strength increase for repetitive members.

3. Values are for 2 members with equal loading. 2.5 inches of width total

# Common Usage



- one of the most common locations of long span wall openings in BamCore Wall Systems are for multi-panel sliding glass doors



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**Appendix**

**(I) Design calculation for 5.4 *m* box beam**

115
97
9 9
Y
47
301
395
X X
47
UDL
5250

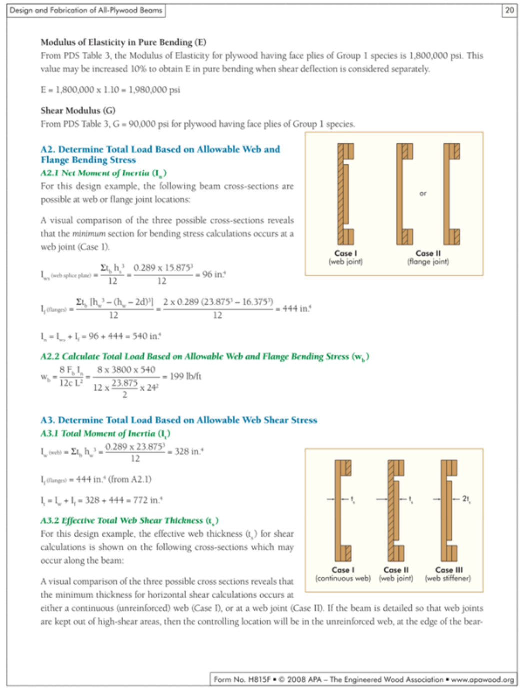
*Given*
Effective design span = 5.25 *m*
Spacing of beams = 2.5 *m*

*Loading*
Dead load (DL) = 0.5 $kNm^2$ including self weight of beam
Live load (LL) = 0.5 $kNm^2$
Total = 1.0 $kNm^2$

*Timber flanges*
Strength group B, dry, standard grade
The following permissible stresses are the grade stresses (except tension stresses) taken from Engku (1980) and increased for medium term loading where applicable.

Bending (f) = 12.4 × 1.25 = 15.5 $Nmm^2$
Tension (t) = 7.4 × 1.25 = 9.2 $Nmm^2$ (based on 0.6 × bending and not from Engku (1980)

Compression parallel ($c_{//}$) = 10.0 × 1.25 = 12.5 $Nmm^2$
Compression perpendicular ($c_{\perp}$) = 1.24 × 1.25 = 1.55 $Nmm^{-2}$ (based on basic stress with no wane)



Design and Fabrication of All-Plywood Beams 20

**Modulus of Elasticity in Pure Bending (E)**
From PDS Table 3, the Modulus of Elasticity for plywood having face plies of Group 1 species is 1,800,000 psi. This value may be increased 10% to obtain E in pure bending when shear deflection is considered separately.

E = 1,800,000 x 1.10 = 1,980,000 psi

**Shear Modulus (G)**
From PDS Table 3, G = 90,000 psi for plywood having face plies of Group 1 species.

**A2. Determine Total Load Based on Allowable Web and Flange Bending Stress**

*A2.1 Net Moment of Inertia ($I_n$)*

For this design example, the following beam cross-sections are possible at web or flange joint locations:

A visual comparison of the three possible cross-sections reveals that the *minimum* section for bending stress calculations occurs at a web joint (Case 1).

Case I (web joint) Case II (flange joint) or

$$I_{ws\,(web\ splice\ plate)} = \frac{\Sigma t_b\, h_s^3}{12} = \frac{0.289 \times 15.875^3}{12} = 96\ in.^4$$

$$I_{f\,(flanges)} = \frac{\Sigma t_b\, [h_w^3 - (h_w - 2d)^3]}{12} = \frac{2 \times 0.289\,(23.875^3 - 16.375^3)}{12} = 444\ in.^4$$

$$I_n = I_{ws} + I_f = 96 + 444 = 540\ in.^4$$

*A2.2 Calculate Total Load Based on Allowable Web and Flange Bending Stress ($w_b$)*

$$w_b = \frac{8\,F_b\,I_n}{12c\,L^2} = \frac{8 \times 3800 \times 540}{12 \times \frac{23.875}{2} \times 24^2} = 199\ lb/ft$$

**A3. Determine Total Load Based on Allowable Web Shear Stress**

*A3.1 Total Moment of Inertia ($I_t$)*

$$I_{w\,(web)} = \Sigma t_b\, h_w^3 = \frac{0.289 \times 23.875^3}{12} = 328\ in.^4$$

$I_{f\,(flanges)} = 444\ in.^4$ (from A2.1)

$$I_t = I_w + I_f = 328 + 444 = 772\ in.^4$$

*A3.2 Effective Total Web Shear Thickness ($t_s$)*

For this design example, the effective web thickness ($t_s$) for shear calculations is shown on the following cross-sections which may occur along the beam:

$t_s$ $t_s$ $2t_s$
Case I (continuous web) Case II (web joint) Case III (web stiffener)

A visual comparison of the three possible cross sections reveals that the minimum thickness for horizontal shear calculations occurs at either a continuous (unreinforced) web (Case I), or at a web joint (Case II). If the beam is detailed so that web joints are kept out of high-shear areas, then the controlling location will be in the unreinforced web, at the edge of the bear-

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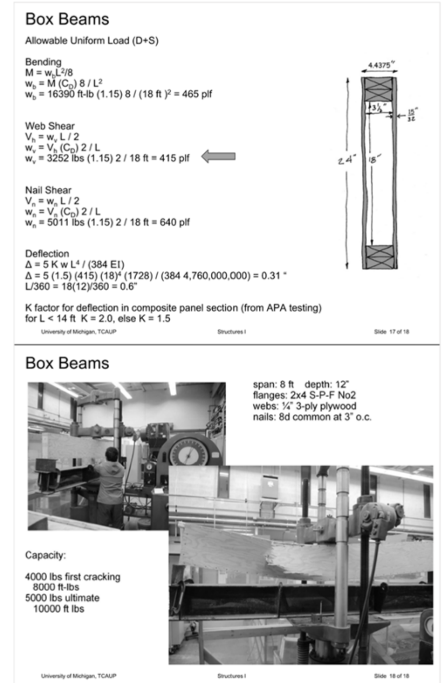


Box Beams

Allowable Uniform Load (D+S)

Bending
$M = w_b L^2/8$
$w_b = M\,(C_D)\,8 / L^2$
$w_b$ = 16390 ft-lb (1.15) 8 / (18 ft )$^2$ = 465 plf

Web Shear
$V_h = w_v\,L / 2$
$w_v = V_h\,(C_D)\,2 / L$
$w_v$ = 3252 lbs (1.15) 2 / 18 ft = 415 plf

Nail Shear
$V_n = w_n\,L / 2$
$w_n = V_n\,(C_D)\,2 / L$
$w_n$ = 5011 lbs (1.15) 2 / 18 ft = 640 plf

Deflection
$\Delta = 5\,K\,w\,L^4 / (384\,EI)$
$\Delta$ = 5 (1.5) (415) (18)$^4$ (1728) / (384 4,760,000,000) = 0.31 "
L/360 = 18(12)/360 = 0.6"

K factor for deflection in composite panel section (from APA testing)
for L < 14 ft K = 2.0, else K = 1.5

4.4375"
24"
18"

University of Michigan, TCAUP Structures I Slide 17 of 18

Box Beams

span: 8 ft depth: 12"
flanges: 2x4 S-P-F No2
webs: ¼" 3-ply plywood
nails: 8d common at 3" o.c.

Capacity:

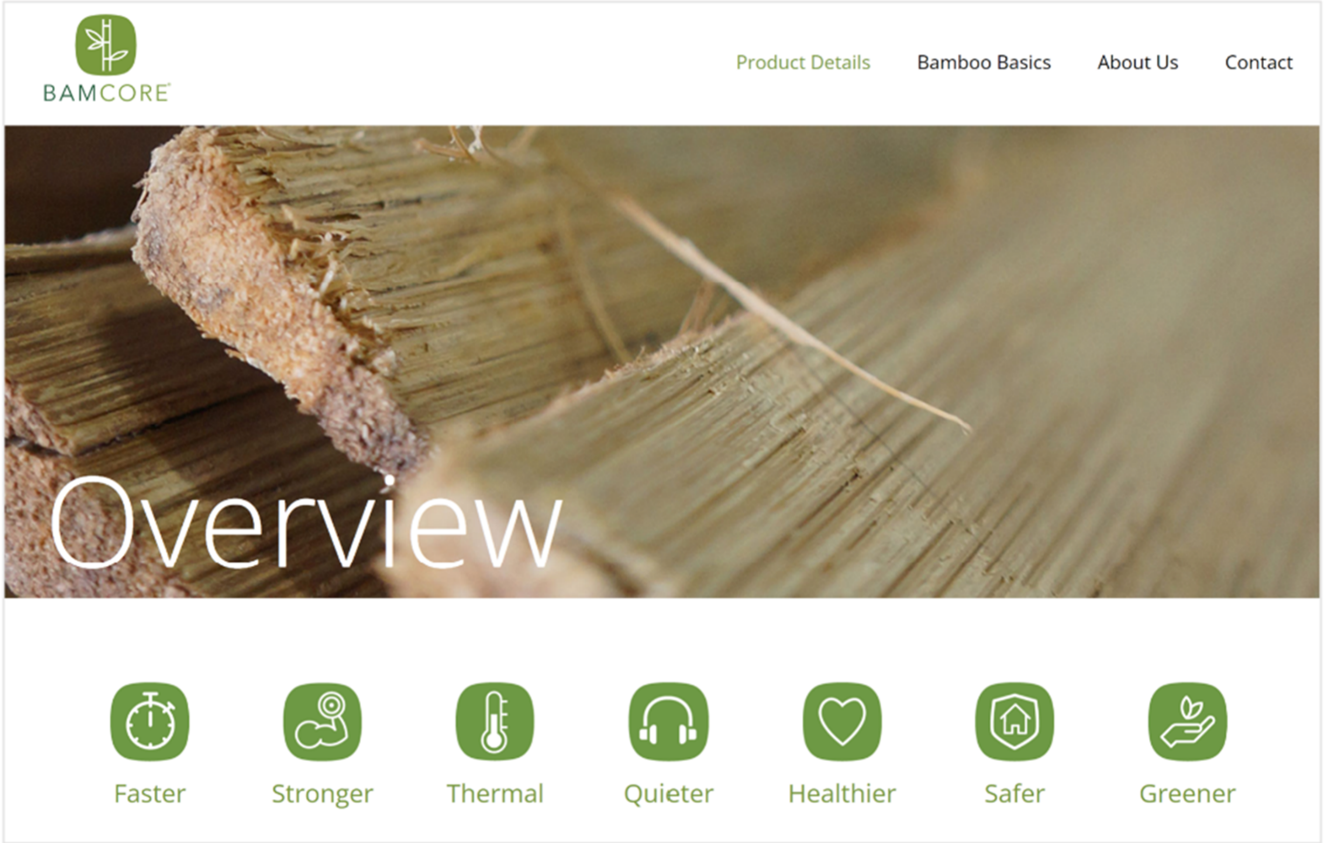
4000 lbs first cracking
8000 ft-lbs
5000 lbs ultimate
10000 ft lbs

University of Michigan, TCAUP Structures I Slide 18 of 18

# Precedent Studies

- "Strength of Plywood Web Box Beam" (Chu et al.)
- "Design and Fabrication of All-Plywood Beams" (APA)
- Empirical study on box beams by the University of Michigan

# BamCore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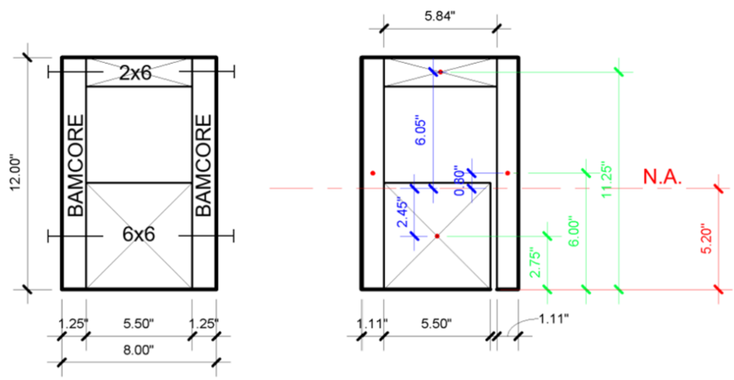
# BamCore Installation

## Analysis

ORIGINAL SECTION  TRANSFORMED SECTION




The objective of this study was to begin development of a composite box header that was able to span long openings with minimal deflection, and to develop span tables with a tight L/800 deflection limit. The following analysis was performed to obtain maximum uniform load values, and an expanded calculation follows. For different header sizes, span lengths, and overall depths, the same process was carried out in a spreadsheet.

**Elasticity**

$E_{Header} = 1{,}600{,}000\ psi$

$E_{BamCore} = 1{,}420{,}000\ psi$

$E_{2x6} = 1{,}700{,}000\ psi$

**Transformation to $E_{Header}$**

$\frac{EBamCore}{EHeader} = 0.89$

$\frac{E2x6}{EHeader} = 1.06$

**Neutral Axis**

$N.A. = \frac{\Sigma yA}{\Sigma A} = 5.2 \quad (d = |5.2 - y|)$

**Moment of Inertia**

$I = \Sigma I_{parts} + \Sigma Ad^2 = 397.4 + 519.5 = 917\ in^4$

**Demand vs. Capacity**

$F'_b = .99(1200\ psi) = 1200\ psi$

$F'_t = 825\ psi$

$F'_c = .57(1500\ psi) = 852\ psi$

**6x6:**

$M_{allow} = \frac{F'_t I}{y} = 145485\ \#in = 12123\ \#ft$

$w_{allow} = \frac{8M_{allow}}{L^2} = 1349\ plf$

**SECTION BENDING:**

$M_{allow} = \frac{F'_b I}{y} = 150246\ \#in = 12520\ \#ft$

$w_{allow} = \frac{8M_{allow}}{L^2} = 1001\ plf$

**2x6:**

$M_{allow} = \frac{F'_c I}{y} = 145485\ \#in = 12123\ \#ft$

$w_{allow} = \frac{8M_{allow}}{L^2} = 1349\ plf$

**L/800 DEFLECTION LIMIT:**

$w_{allow} = \frac{384E_{Header}I(L/800)}{5L^4} = 81.5\ plf$

**MAX WEB SHEAR:**

Horizontal Shear of BamCore = $F_v = 465\ psi$

$t = 1.11"\ (transformed)$

$F_v t_v = 516\ \#/in$

$V_h = \frac{(F_v t_v) I (N_{webs})}{Q_t}$

**Statical Moment of Area:**

Area of Flange & Web Above N.A.

$Q_{top} = Q_{bottom} = Q$

$Q_{2x6} = 1.5"x5.84"(h - .75" - y) = 1.5"x5.84"(12" - .75" - 5.2") = 53\ in^3$

$Q_{BamCore} = 2x1.11(h - y)(\frac{h-y}{2}) = 2x1.11(12 - 5.2)(\frac{12-5.2}{2}) = 51.3\ in^3$

$Q = 53 + 51.3 = 104.3\ in^3$

$V_h = 9076\ \#$

$V = \frac{w_{allow} L}{2}$

$w = \frac{2V}{L} = 1815\ plf$

**MAX NAIL SHEAR:**

For analysis, use 10d nails; $t_s = 1\frac{1}{4}"$; $G = .50$

$Z = 118\ \#$

$q = \frac{2\ nails(118\ \#/nail)}{6"} = 39\ \#/in = 472\ \#/ft$

$q = \frac{VQ}{I}$

$39\ \#/in = \frac{V(104.3\ in^3)}{917\ in^4} \rightarrow V = 342.9\ \#$

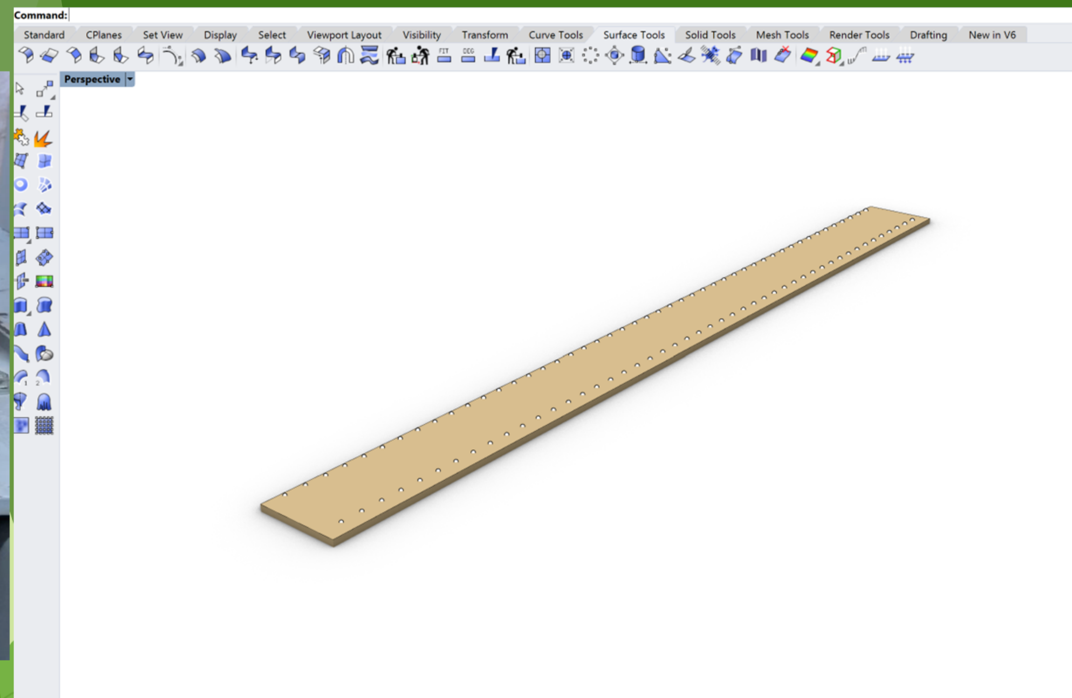
$w = \frac{2V}{L} = 68.6\ plf \rightarrow try\ @\ 4"\ o.c.$

$q = \frac{2\ nails(118\ \#/nail)}{4"} = 59\ \#/in \rightarrow 518.7\ \#$

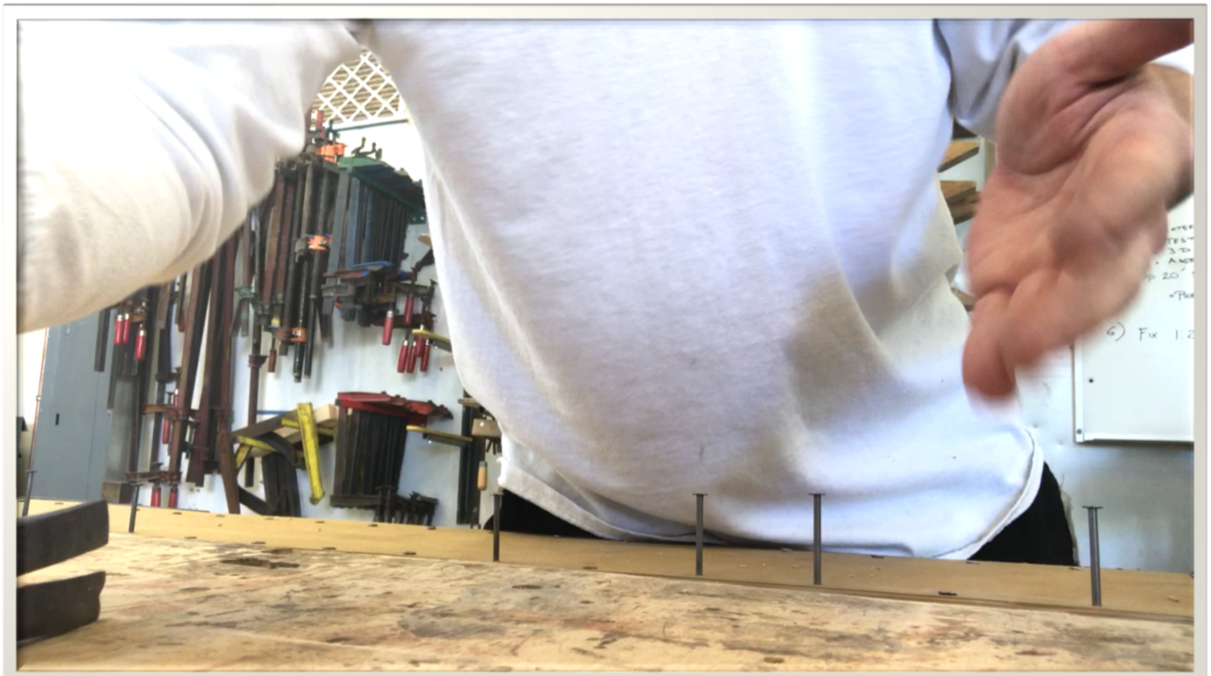
$w = \frac{2V}{L} = 104\ plf \geq 81.5\ plf$ ✓

# Fabrication

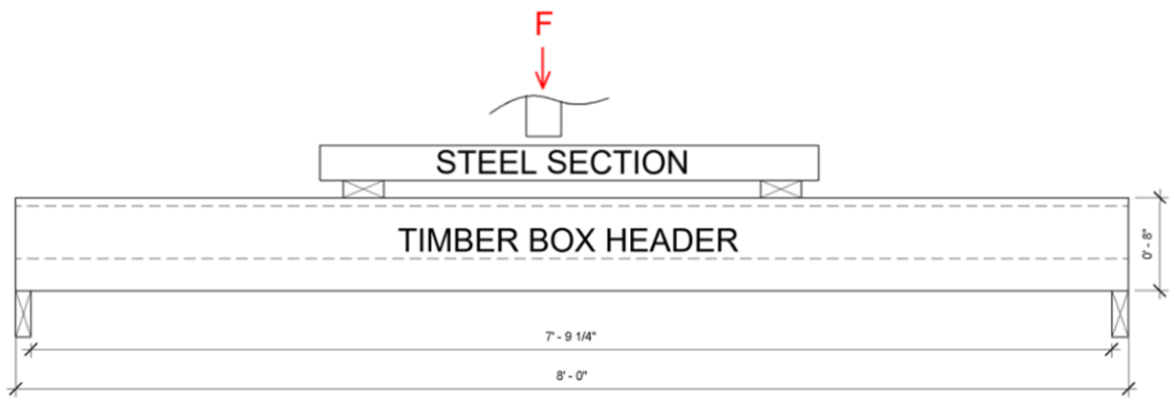
# CNC Router

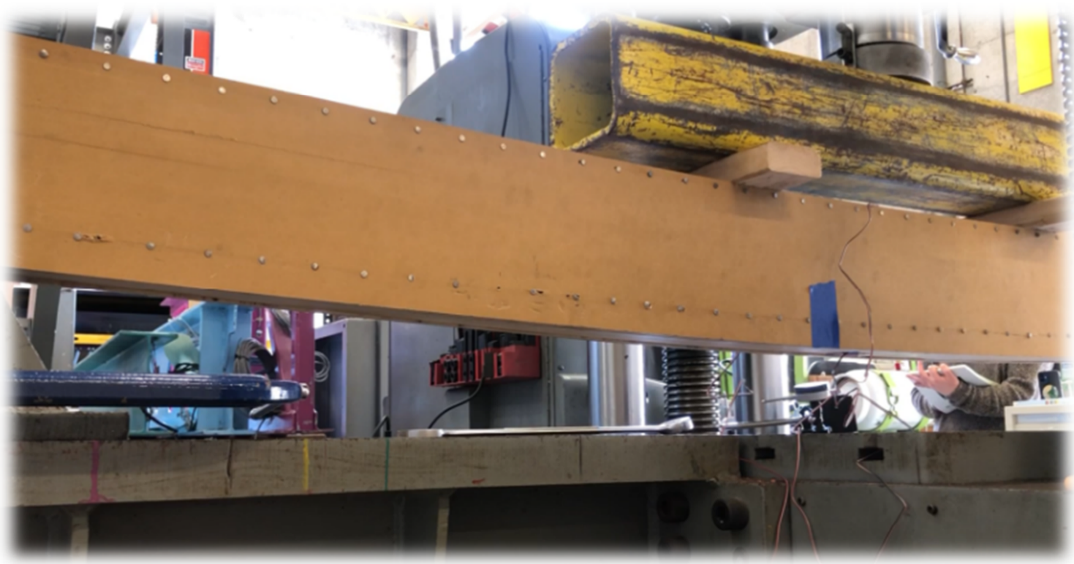

Command:
Standard
CPlanes
Set View
Display
Select
Viewport Layout
Visibility
Transform
Curve Tools
Surface Tools
Solid Tools
Mesh Tools
Render Tools
Drafting
New in V6
Perspective

# Nailing



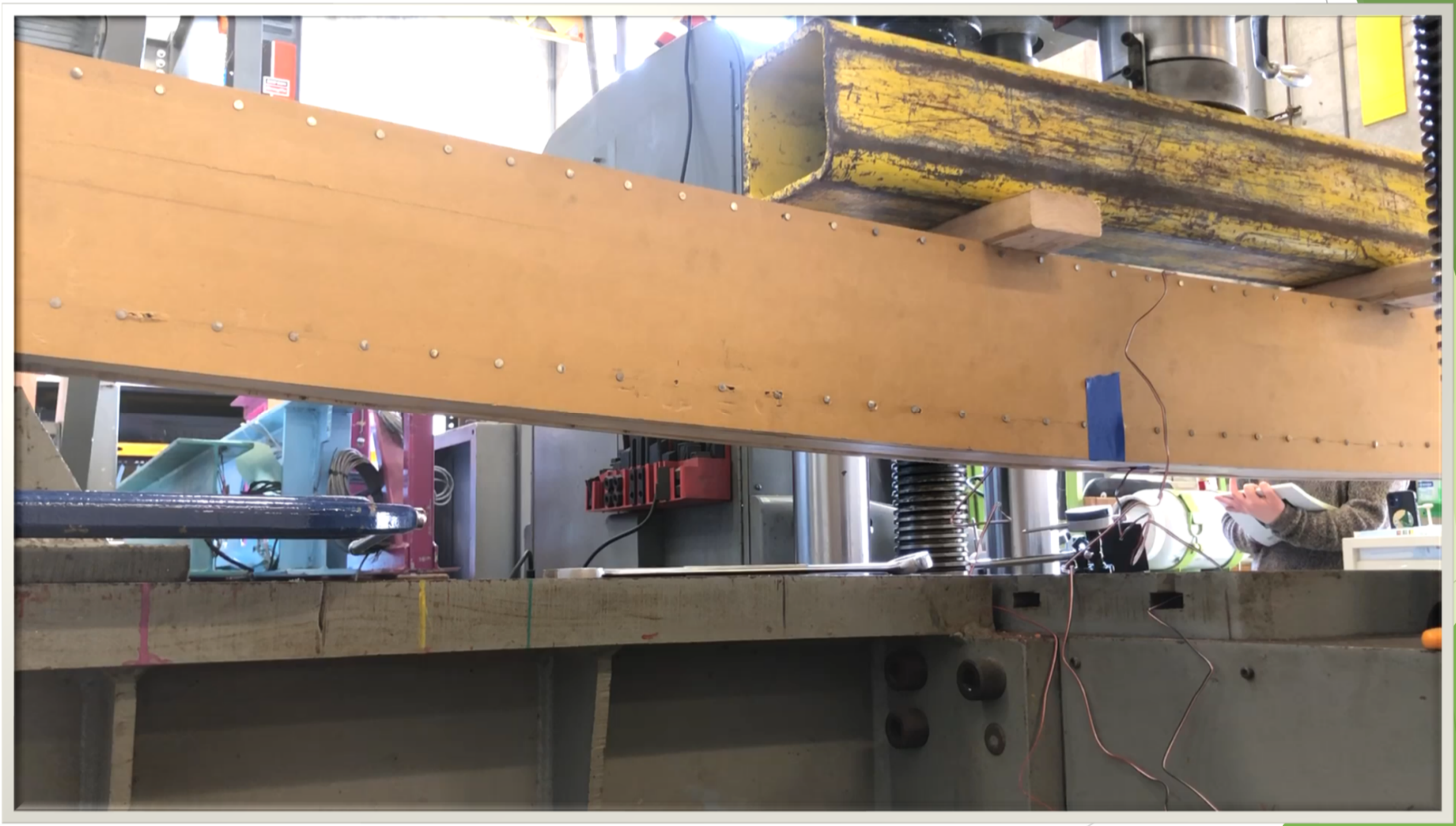
# Testing



# Strain Gages

# Fracture



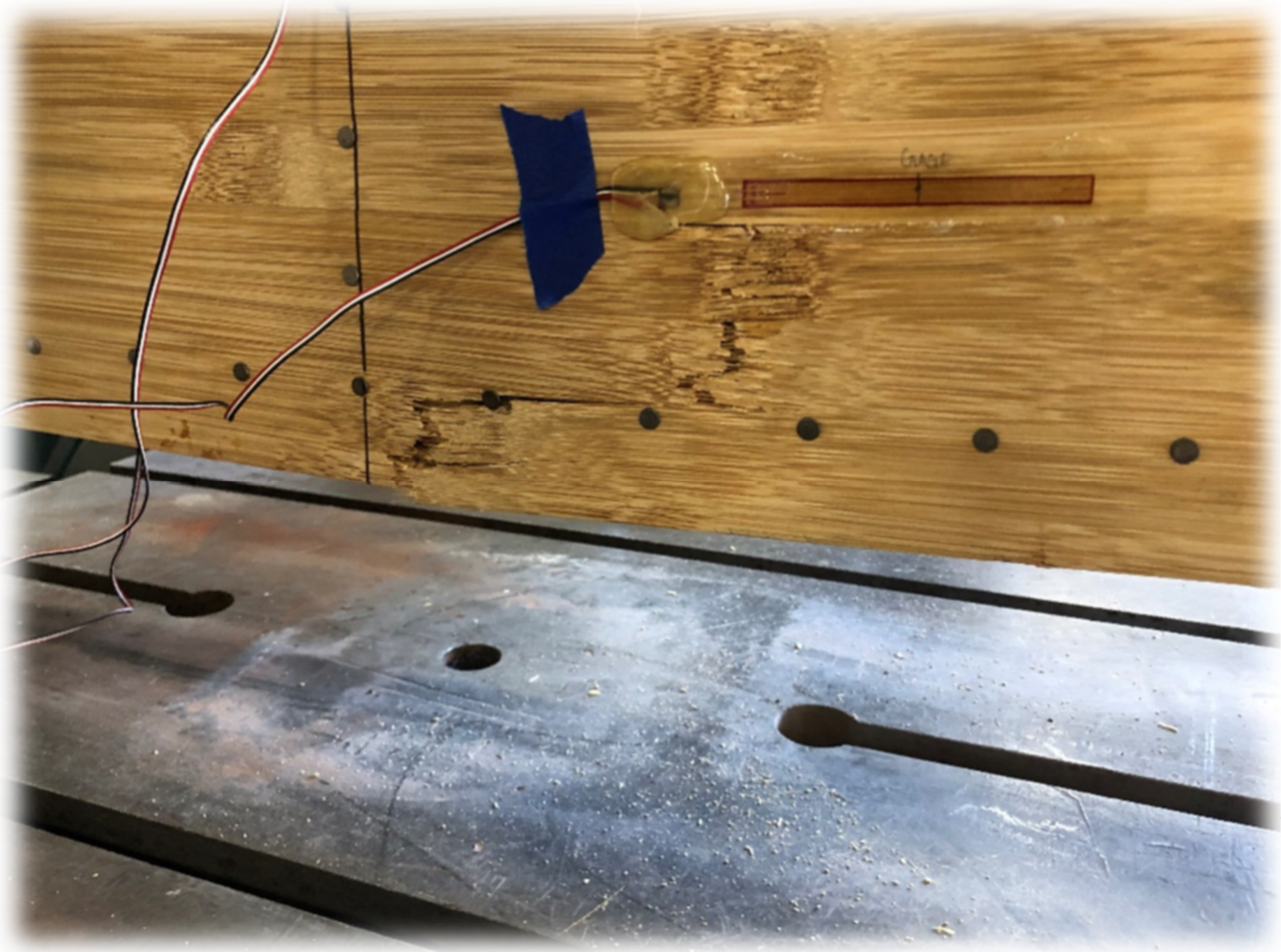
# Results

# Results

# Results

# Results

# Results



## Results

# Appendix & Spreadsheet Calculations

## MOMENT OF INERTIA AND N.A. SPREADSHEET FOR 6X6:

### SET DATA

| Moduluses of Elasticity | psi |
|---|---|
| $E_{Headers}$ | 1600000 |
| $E_{Bamcore}$ | 1420000 |
| $E_{2x6}$ | 1700000 |

| Transformation to $E_{Heade}$ | n |
|---|---|
| Ebamcore/Eheader= | 0.89 |
| E2x6/Eheader= | 1.06 |

| Header Depths (in) |
|---|
| 12 |
| 16 |
| 24 |

### 12" TOTAL DEPTH

| Part Dimensions | $b_{Original}$ | $b_{Transformed}$ | h | Area | I |
|---|---|---|---|---|---|
| 6x6 | 5.5 | 5.5 | 5.5 | 30.25 | 76.26 |
| (2) Bamcore Panels | 2.5 | 2.22 | 12 | 26.63 | 319.50 |
| 2x6 | 5.5 | 5.84 | 1.5 | 8.77 | 1.64 |
| | | | Σ(A)= | 65.64 | 397.40 |

| Centroid | in |
|---|---|
| $y_{Header}$= | 2.75 |
| $y_{Bamcore}$ = | 6 |
| $y_{2x6}$ = | 11.25 |

*distance from datum at y=0 (bottom of header) to centroid of individual part*

| | |
|---|---|
| Σ(y*A)= | 341.55 |
| **N.A.** | **5.20** |

*N.A. = Σ(y*A)/ΣA*

**in from bottom**

| | |
|---|---|
| $d_{Header}$= | 2.45 |
| $d_{Bamcore}$ = | 0.80 |
| $d_{2x6}$ = | 6.05 |

*distance from centroid of individual part to section N.A.*

| $Ad^2$ | $in^4$ |
|---|---|
| Bamcore | 16.90 |
| Header | 182.07 |
| 2x6 | 320.49 |
| Total | 519.46 |

| Moment of Inertia | $in^4$ |
|---|---|
| Σ (I parts) | 397.40 |
| Σ ($Ad^2$) | 519.46 |
| **Moment of Inertia** | **917** |

| | |
|---|---|
| c= | 6.80 |

*largest distance between extreme fiber and neutral axis*

| | | |
|---|---|---|
| Section Modulus (S | **134.9** | $in^3$ |

### 16" TOTAL DEPTH

| Part Dimensions | $b_{Original}$ | $b_{Transformed}$ | h | Area | I |
|---|---|---|---|---|---|
| 6x6 | 5.5 | 5.5 | 5.5 | 30.25 | 76.26 |
| (2) Bamcore Panels | 2.5 | 2.22 | 16 | 35.50 | 757.33 |
| 2x6 | 5.5 | 5.84 | 1.5 | 8.77 | 1.64 |
| | | | Σ(A)= | 74.52 | 835.23 |

| Centroid | in |
|---|---|
| $y_{Header}$= | 2.75 |
| $y_{Bamcore}$ = | 8 |
| $y_{2x6}$ = | 15.25 |

| | | |
|---|---|---|
| Σ(y*A)= | 500.86 | |
| **N.A.** | **6.72** | **in** |

| | |
|---|---|
| $d_{Header}$= | 3.97 |
| $d_{Bamcore}$ = | 1.28 |
| $d_{2x6}$ = | 8.53 |

| $Ad^2$ | $in^4$ |
|---|---|
| Bamcore | 58.02 |
| Header | 477.15 |
| 2x6 | 637.56 |
| Total | 1172.73 |

| Moment of Inertia | $in^4$ |
|---|---|
| Σ (I parts) | 835.23 |
| Σ ($Ad^2$) | 1172.73 |
| **Moment of Inertia** | **2008** |

| | |
|---|---|
| c= | 9.28 |

| | | |
|---|---|---|
| Section Modulus (S | **216.4** | $in^3$ |

### 24" TOTAL DEPTH

| Part Dimensions | $b_{Original}$ | $b_{Transformed}$ | h | Area | I |
|---|---|---|---|---|---|
| 6x6 | 5.5 | 5.5 | 5.5 | 30.25 | 76.26 |
| (2) Bamcore Panels | 2.5 | 2.22 | 24 | 53.25 | 2556.00 |
| 2x6 | 5.5 | 5.84 | 1.5 | 8.77 | 1.64 |
| | | | Σ(A)= | 92.27 | 2633.90 |

| Centroid | in |
|---|---|
| $y_{Header}$= | 2.75 |
| $y_{Bamcore}$ = | 12 |
| $y_{2x6}$ = | 23.25 |

| | | |
|---|---|---|
| Σ(y*A)= | 925.99 | |
| **N.A.** | **10.04** | **in** |

| | |
|---|---|
| $d_{Header}$= | 7.29 |
| $d_{Bamcore}$ = | 1.96 |
| $d_{2x6}$ = | 13.21 |

| $Ad^2$ | $in^4$ |
|---|---|
| Bamcore | 205.38 |
| Header | 1605.90 |
| 2x6 | 1530.54 |
| Total | 3341.81 |

| Moment of Inertia | $in^4$ |
|---|---|
| Σ (I parts) | 2633.90 |
| Σ ($Ad^2$) | 3341.81 |
| **Moment of Inertia** | **5976** |

| | |
|---|---|
| c= | 13.96 |

| | | |
|---|---|---|
| Section Modulus (S | **427.9** | $in^3$ |

# Inertia Summary Table

| Header Section | Total Depth (in) | Moment of Inertia ($in^4$) | N.A. from bottom (in) | Q (in3) |
|---|---|---|---|---|
| 6x6 | 12 | 917 | 5.20 | 104.2 |
| | 16 | 2008 | 6.72 | 148.5 |
| | 24 | 5976 | 10.04 | 269.3 |
| 6x8 | 12 | 936 | 5.39 | 101.5 |
| | 16 | 2012 | 6.69 | 149.1 |
| | 24 | 6102 | 9.66 | 281.1 |
| 6x10 | 12 | 1033 | 5.78 | 95.9 |
| | 16 | 2048 | 6.90 | 144.9 |
| | 24 | 6119 | 9.55 | 284.7 |
| 6x12 | 12 | 1255 | 6.31 | 89.0 |
| | 16 | 2179 | 7.27 | 137.6 |
| | 24 | 6132 | 9.63 | 282.0 |

# Maximum Uniform Loads Tables

| | | | TENSION | | COMPRESSION | | BENDING | | DEFLECTION | SHEAR | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Header | Depth (in) | Mallow (#-ft) | wallow (plf) | Mallow (#-ft) | wallow (plf) | Mallow (#-ft) | wallow (plf) | wallow (plf) | V (#) | wallow (plf) | MAX PLF |
| 10' SPAN | 6x6 | 12 | 12114 | 969 | 16862 | 1349 | 17621 | 1410 | 81.5 | 9076 | 1815 | 81 |
| | | 16 | 20538 | 1643 | 27051 | 2164 | 29873 | 2390 | 178.5 | 13954 | 2791 | 178 |
| | | 24 | 40935 | 3275 | 53493 | 4279 | 59542 | 4763 | 531.2 | 22898 | 4580 | 531 |
| | 6x8 | 12 | 11945 | 956 | 17706 | 1416 | 17374 | 1390 | 83.2 | 9522 | 1904 | 83 |
| | | 16 | 20668 | 1653 | 27024 | 2162 | 30062 | 2405 | 178.9 | 13927 | 2785 | 178 |
| | | 24 | 43432 | 3475 | 53191 | 4255 | 63174 | 5054 | 542.4 | 22400 | 4480 | 542 |
| | 6x10 | 12 | 10054 | 804 | 20761 | 1661 | 20108 | 1609 | 91.8 | 11115 | 2223 | 91 |
| | | 16 | 16695 | 1336 | 28123 | 2250 | 33389 | 2671 | 182.0 | 14584 | 2917 | 182 |
| | | 24 | 36051 | 2884 | 52927 | 4234 | 72102 | 5768 | 543.9 | 22181 | 4436 | 543 |
| | 6x12 | 12 | 11190 | 895 | 27541 | 2203 | 22380 | 1790 | 111.5 | 14553 | 2911 | 111 |
| | | 16 | 16868 | 1349 | 31195 | 2496 | 33735 | 2699 | 193.7 | 16345 | 3269 | 193 |
| | | 24 | 35813 | 2865 | 53346 | 4268 | 71626 | 5730 | 545.1 | 22438 | 4488 | 545 |

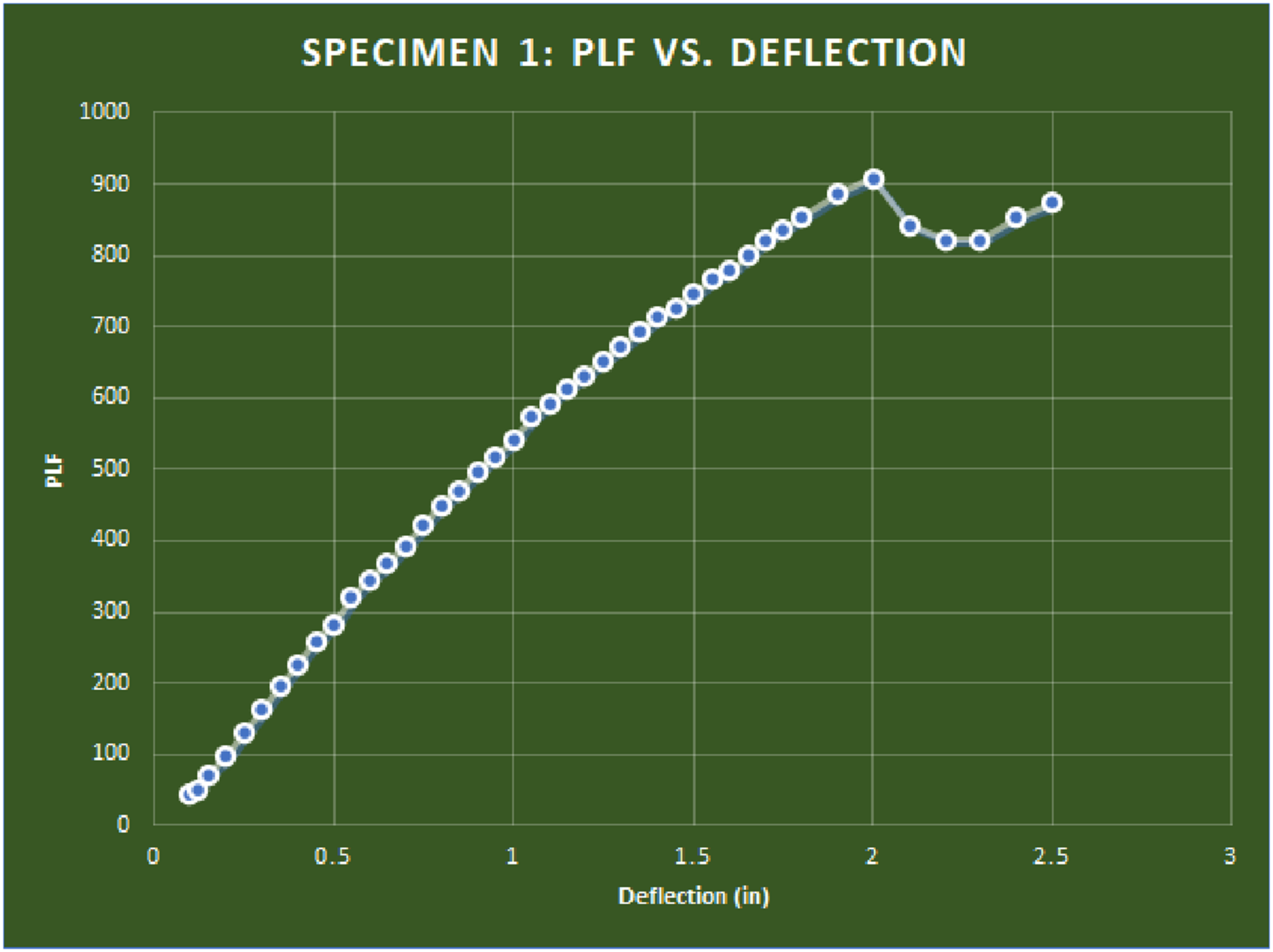
| | | | TENSION | | COMPRESSION | | BENDING | | DEFLECTION | SHEAR | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Header | Depth (in) | Mallow (#-ft) | wallow (plf) | Mallow (#-ft) | wallow (plf) | Mallow (#-ft) | wallow (plf) | wallow (plf) | V (#) | wallow (plf) | MAX PLF |
| 12' SPAN | 6x6 | 12 | 12114 | 673 | 16862 | 937 | 17621 | 979 | 47.2 | 9076 | 1513 | 47 |
| | | 16 | 20538 | 1141 | 27051 | 1503 | 29873 | 1660 | 103.3 | 13954 | 2326 | 103 |
| | | 24 | 40935 | 2274 | 53493 | 2972 | 59542 | 3308 | 307.4 | 22898 | 3816 | 307 |
| | 6x8 | 12 | 11945 | 664 | 17706 | 984 | 17374 | 965 | 48.2 | 9522 | 1587 | 48 |
| | | 16 | 20668 | 1148 | 27024 | 1501 | 30062 | 1670 | 103.5 | 13927 | 2321 | 103 |
| | | 24 | 43432 | 2413 | 53191 | 2955 | 63174 | 3510 | 313.9 | 22400 | 3733 | 313 |
| | 6x10 | 12 | 10054 | 559 | 20761 | 1153 | 20108 | 1117 | 53.1 | 11115 | 1852 | 53 |
| | | 16 | 16695 | 927 | 28123 | 1562 | 33389 | 1855 | 105.3 | 14584 | 2431 | 105 |
| | | 24 | 36051 | 2003 | 52927 | 2940 | 72102 | 4006 | 314.8 | 22181 | 3697 | 314 |
| | 6x12 | 12 | 11190 | 622 | 27541 | 1530 | 22380 | 1243 | 64.5 | 14553 | 2425 | 64 |
| | | 16 | 16868 | 937 | 31195 | 1733 | 33735 | 1874 | 112.1 | 16345 | 2724 | 112 |
| | | 24 | 35813 | 1990 | 53346 | 2964 | 71626 | 3979 | 315.4 | 22438 | 3740 | 315 |

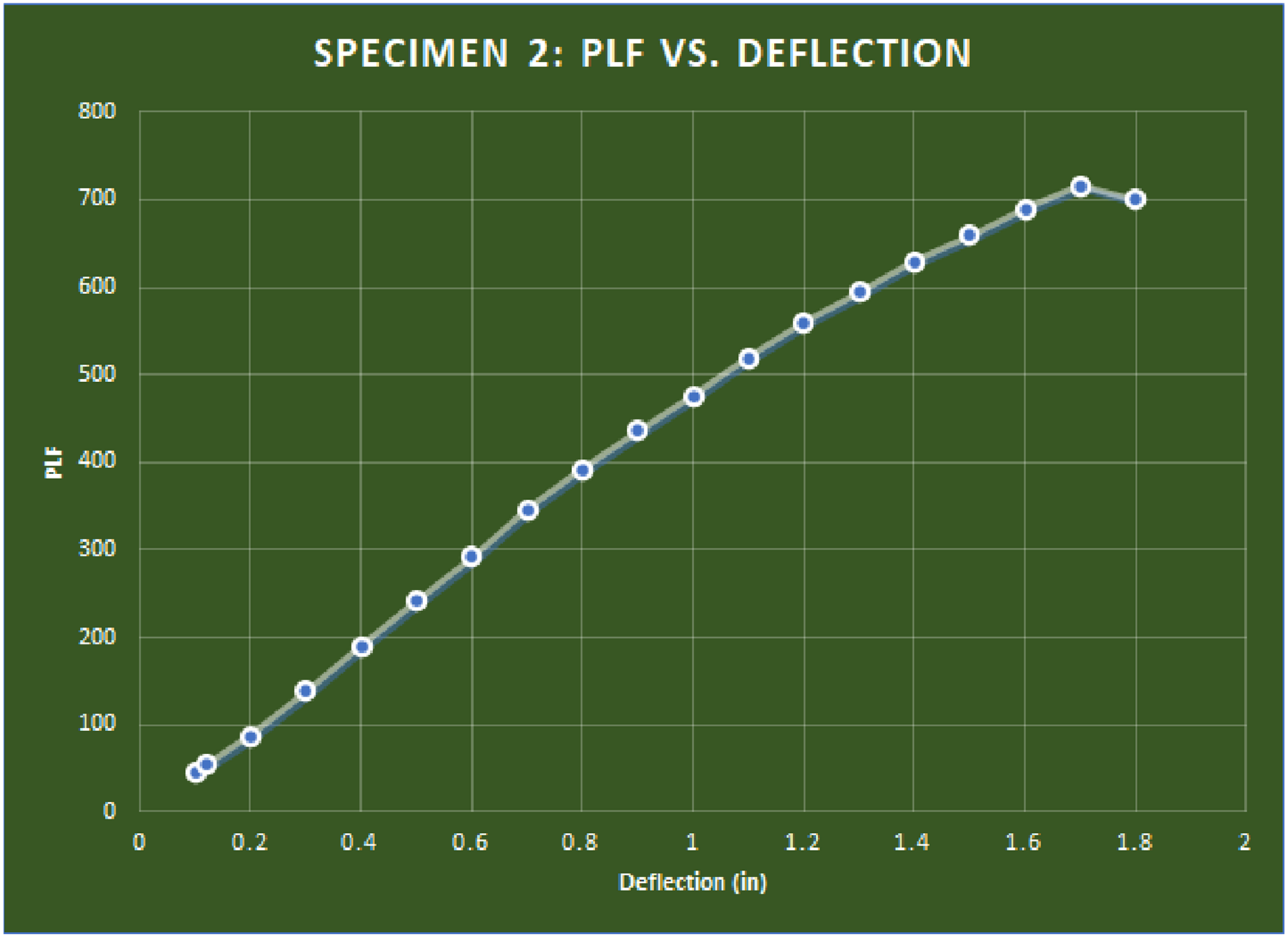
| | | | TENSION | | COMPRESSION | | BENDING | | DEFLECTION | SHEAR | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Header | Depth (in) | Mallow (#-ft) | wallow (plf) | Mallow (#-ft) | wallow (plf) | Mallow (#-ft) | wallow (plf) | wallow (plf) | V (#) | wallow (plf) | MAX PLF |
| 14' SPAN | 6x6 | 12 | 12114 | 494 | 16862 | 688 | 17621 | 719 | 29.7 | 9076 | 1297 | 29 |
| | | 16 | 20538 | 838 | 27051 | 1104 | 29873 | 1219 | 65.0 | 13954 | 1993 | 65 |
| | | 24 | 40935 | 1671 | 53493 | 2183 | 59542 | 2430 | 193.6 | 22898 | 3271 | 193 |
| | 6x8 | 12 | 11945 | 488 | 17706 | 723 | 17374 | 709 | 30.3 | 9522 | 1360 | 30 |
| | | 16 | 20668 | 844 | 27024 | 1103 | 30062 | 1227 | 65.2 | 13927 | 1990 | 65 |
| | | 24 | 43432 | 1773 | 53191 | 2171 | 63174 | 2579 | 197.7 | 22400 | 3200 | 197 |
| | 6x10 | 12 | 10054 | 410 | 20761 | 847 | 20108 | 821 | 33.5 | 11115 | 1588 | 33 |
| | | 16 | 16695 | 681 | 28123 | 1148 | 33389 | 1363 | 66.3 | 14584 | 2083 | 66 |
| | | 24 | 36051 | 1471 | 52927 | 2160 | 72102 | 2943 | 198.2 | 22181 | 3169 | 198 |
| | 6x12 | 12 | 11190 | 457 | 27541 | 1124 | 22380 | 913 | 40.6 | 14553 | 2079 | 40 |
| | | 16 | 16868 | 688 | 31195 | 1273 | 33735 | 1377 | 70.6 | 16345 | 2335 | 70 |
| | | 24 | 35813 | 1462 | 53346 | 2177 | 71626 | 2923 | 198.6 | 22438 | 3205 | 198 |

| | | | TENSION | | COMPRESSION | | BENDING | | DEFLECTION | SHEAR | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 16' SPAN | Header | Depth (in) | Mallow (#-ft) | wallow (plf) | Mallow (#-ft) | wallow (plf) | Mallow (#-ft) | wallow (plf) | wallow (plf) | V (#) | wallow (plf) | MAX PLF |
| | 6x6 | 12 | 12114 | 379 | 16862 | 527 | 17621 | 551 | 19.9 | 9076 | 1135 | 19 |
| | | 16 | 20538 | 642 | 27051 | 845 | 29873 | 934 | 43.6 | 13954 | 1744 | 43 |
| | | 24 | 40935 | 1279 | 53493 | 1672 | 59542 | 1861 | 129.7 | 22898 | 2862 | 129 |
| | 6x8 | 12 | 11945 | 373 | 17706 | 553 | 17374 | 543 | 20.3 | 9522 | 1190 | 20 |
| | | 16 | 20668 | 646 | 27024 | 845 | 30062 | 939 | 43.7 | 13927 | 1741 | 43 |
| | | 24 | 43432 | 1357 | 53191 | 1662 | 63174 | 1974 | 132.4 | 22400 | 2800 | 132 |
| | 6x10 | 12 | 10054 | 314 | 20761 | 649 | 20108 | 628 | 22.4 | 11115 | 1389 | 22 |
| | | 16 | 16695 | 522 | 28123 | 879 | 33389 | 1043 | 44.4 | 14584 | 1823 | 44 |
| | | 24 | 36051 | 1127 | 52927 | 1654 | 72102 | 2253 | 132.8 | 22181 | 2773 | 132 |
| | 6x12 | 12 | 11190 | 350 | 27541 | 861 | 22380 | 699 | 27.2 | 14553 | 1819 | 27 |
| | | 16 | 16868 | 527 | 31195 | 975 | 33735 | 1054 | 47.3 | 16345 | 2043 | 47 |
| | | 24 | 35813 | 1119 | 53346 | 1667 | 71626 | 2238 | 133.1 | 22438 | 2805 | 133 |

| | | | TENSION | | COMPRESSION | | BENDING | | DEFLECTION | SHEAR | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 18' SPAN | Header | Depth (in) | Mallow (#-ft) | wallow (plf) | Mallow (#-ft) | wallow (plf) | Mallow (#-ft) | wallow (plf) | wallow (plf) | V (#) | wallow (plf) | MAX PLF |
| | 6x6 | 12 | 12114 | 299 | 16862 | 416 | 17621 | 435 | 14.0 | 9076 | 1008 | 13 |
| | | 16 | 20538 | 507 | 27051 | 668 | 29873 | 738 | 30.6 | 13954 | 1550 | 30 |
| | | 24 | 40935 | 1011 | 53493 | 1321 | 59542 | 1470 | 91.1 | 22898 | 2544 | 91 |
| | 6x8 | 12 | 11945 | 295 | 17706 | 437 | 17374 | 429 | 14.3 | 9522 | 1058 | 14 |
| | | 16 | 20668 | 510 | 27024 | 667 | 30062 | 742 | 30.7 | 13927 | 1547 | 30 |
| | | 24 | 43432 | 1072 | 53191 | 1313 | 63174 | 1560 | 93.0 | 22400 | 2489 | 93 |
| | 6x10 | 12 | 10054 | 248 | 20761 | 513 | 20108 | 497 | 15.7 | 11115 | 1235 | 15 |
| | | 16 | 16695 | 412 | 28123 | 694 | 33389 | 824 | 31.2 | 14584 | 1620 | 31 |
| | | 24 | 36051 | 890 | 52927 | 1307 | 72102 | 1780 | 93.3 | 22181 | 2465 | 93 |
| | 6x12 | 12 | 11190 | 276 | 27541 | 680 | 22380 | 553 | 19.1 | 14553 | 1617 | 19 |
| | | 16 | 16868 | 416 | 31195 | 770 | 33735 | 833 | 33.2 | 16345 | 1816 | 33 |
| | | 24 | 35813 | 884 | 53346 | 1317 | 71626 | 1769 | 93.5 | 22438 | 2493 | 93 |

| | | | TENSION | | COMPRESSION | | BENDING | | DEFLECTION | SHEAR | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 20' SPAN | Header | Depth (in) | Mallow (#-ft) | wallow (plf) | Mallow (#-ft) | wallow (plf) | Mallow (#-ft) | wallow (plf) | wallow (plf) | V (#) | wallow (plf) | MAX PLF |
| | 6x6 | 12 | 12114 | 242 | 16862 | 337 | 17621 | 352 | 10.2 | 9076 | 908 | 10 |
| | | 16 | 20538 | 411 | 27051 | 541 | 29873 | 597 | 22.3 | 13954 | 1395 | 22 |
| | | 24 | 40935 | 819 | 53493 | 1070 | 59542 | 1191 | 66.4 | 22898 | 2290 | 66 |
| | 6x8 | 12 | 11945 | 239 | 17706 | 354 | 17374 | 347 | 10.4 | 9522 | 952 | 10 |
| | | 16 | 20668 | 413 | 27024 | 540 | 30062 | 601 | 22.4 | 13927 | 1393 | 22 |
| | | 24 | 43432 | 869 | 53191 | 1064 | 63174 | 1263 | 67.8 | 22400 | 2240 | 67 |
| | 6x10 | 12 | 10054 | 201 | 20761 | 415 | 20108 | 402 | 11.5 | 11115 | 1111 | 11 |
| | | 16 | 16695 | 334 | 28123 | 562 | 33389 | 668 | 22.8 | 14584 | 1458 | 22 |
| | | 24 | 36051 | 721 | 52927 | 1059 | 72102 | 1442 | 68.0 | 22181 | 2218 | 67 |
| | 6x12 | 12 | 11190 | 224 | 27541 | 551 | 22380 | 448 | 13.9 | 14553 | 1455 | 13 |
| | | 16 | 16868 | 337 | 31195 | 624 | 33735 | 675 | 24.2 | 16345 | 1634 | 24 |
| | | 24 | 35813 | 716 | 53346 | 1067 | 71626 | 1433 | 68.1 | 22438 | 2244 | 68 |


SPECIMEN 1: PLF VS. DEFLECTION
1000
900
800
700
600
500
400
300
200
100
0
PLF
0
0.5
1
1.5
2
2.5
3
Deflection (in)


SPECIMEN 2: PLF VS. DEFLECTION
800
700
600
500
400
300
200
100
0
PLF
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
Deflection (in)

## Timber Box Header Span Tables

| | Header | Depth (in) | Uniform Load (PLF) |
|---|---|---|---|
| 10' SPAN | 6x6 | 12 | 81 |
| | | 16 | 178 |
| | | 24 | 531 |
| | 6x8 | 12 | 83 |
| | | 16 | 178 |
| | | 24 | 542 |
| | 6x10 | 12 | 91 |
| | | 16 | 182 |
| | | 24 | 543 |
| | 6x12 | 12 | 111 |
| | | 16 | 193 |
| | | 24 | 545 |

| | Header | Depth (in) | Uniform Load (PLF) |
|---|---|---|---|
| 12' SPAN | 6x6 | 12 | 47 |
| | | 16 | 103 |
| | | 24 | 307 |
| | 6x8 | 12 | 48 |
| | | 16 | 103 |
| | | 24 | 313 |
| | 6x10 | 12 | 53 |
| | | 16 | 105 |
| | | 24 | 314 |
| | 6x12 | 12 | 64 |
| | | 16 | 112 |
| | | 24 | 315 |

| | Header | Depth (in) | Uniform Load (PLF) |
|---|---|---|---|
| 14' SPAN | 6x6 | 12 | 29 |
| | | 16 | 65 |
| | | 24 | 193 |
| | 6x8 | 12 | 30 |
| | | 16 | 65 |
| | | 24 | 197 |
| | 6x10 | 12 | 33 |
| | | 16 | 66 |
| | | 24 | 198 |
| | 6x12 | 12 | 40 |
| | | 16 | 70 |
| | | 24 | 198 |

| | Header | Depth (in) | Uniform Load (PLF) |
|---|---|---|---|
| 16' SPAN | 6x6 | 12 | 19 |
| | | 16 | 43 |
| | | 24 | 129 |
| | 6x8 | 12 | 20 |
| | | 16 | 43 |
| | | 24 | 132 |
| | 6x10 | 12 | 22 |
| | | 16 | 44 |
| | | 24 | 132 |
| | 6x12 | 12 | 27 |
| | | 16 | 47 |
| | | 24 | 133 |

| | Header | Depth (in) | Uniform Load (PLF) |
|---|---|---|---|
| 18' SPAN | 6x6 | 12 | 13 |
| | | 16 | 30 |
| | | 24 | 91 |
| | 6x8 | 12 | 14 |
| | | 16 | 30 |
| | | 24 | 93 |
| | 6x10 | 12 | 15 |
| | | 16 | 31 |
| | | 24 | 93 |
| | 6x12 | 12 | 19 |
| | | 16 | 33 |
| | | 24 | 93 |

| | Header | Depth (in) | Uniform Load (PLF) |
|---|---|---|---|
| 20' SPAN | 6x6 | 12 | 10 |
| | | 16 | 22 |
| | | 24 | 66 |
| | 6x8 | 12 | 10 |
| | | 16 | 22 |
| | | 24 | 67 |
| | 6x10 | 12 | 11 |
| | | 16 | 22 |
| | | 24 | 67 |
| | 6x12 | 12 | 13 |
| | | 16 | 24 |
| | | 24 | 68 |

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