WOOD I-JOIST MANUFACTURERS ASSOCIATION

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Establishing Prefabricated Wood I-Joist Composite EI

INTRODUCTION

Composite (glued/nailed) floors are common in both residential and commercial construction, and have been successfully designed by Prefabricated Wood I-Joist (PWIJ) manufacturers for over a decade. This system provides advantages to the consumer including increased stiffness due to composite action.

This document provides an analytical procedure for determining the effective composite bending stiffness of PWIJ's. Shear deflection must still be considered and an increase in shear stiffness is not applicable.

The testing, analysis, and procedure presented in Reference 1 form the basis of computing an effective EI. Testing to confirm that this procedure is applicable to PWIJ's is summarized in Reference 2. Construction adhesives meeting ASTM D3498 standard are utilized.

Composite stiffness developed using non-ASTM D3498 adhesives, or a method other than that presented in Reference 1, is beyond the scope of this document. Alternate adhesives or methodologies must consider the range of conditions evaluated in Reference 1.

METHODOLOGY

The analytical procedure was originally developed in Reference 1. Reference 4 utilizes the same methodology, with current structural panel properties, and provides the basis for the analytical procedure used for PWIJ's. The use of construction adhesives meeting ASTM D3498 standard is assumed.

The equation for effective composite bending stiffness ($EI_{Effective}$) is based on the non-composite EI of the joist (EI_{Joist}), the fully composite EI of the joist and structural panel ($EI_{Composite}$) and a construction factor (C). The formula is as follows:

$$EI_{Effective} = (C \times EI_{Composite}) + [(1 - C) \times EI_{Joist}]$$

EI_{Joist} is determined per ASTM D5055 and matches current code acceptances. The construction factor "C" is set to 0.45 to match Reference 1 for unglued panel edges.

> *Note: A construction factor of 0.90, in residential construction, is inappropriate as it is difficult to assure the tongue and groove edges are in fact glued. Additionally, the experience to date with I-joists has been based on a construction factor approximately equal to 0.45.*

The fully composite bending stiffness ($EI_{Composite}$) is computed per Reference 4. Panel properties are selected from Reference 3 and the tributary width is based on joist spacing.

> *Note: Effective composite EI is directly influenced by the structural panel tributary width. Effective EI's should be calculated for each joist spacing or the effective EI should be based on the minimum spacing. See Appendix A for more information on reference panel properties.*

Joist flange axial stiffness (EA_{Flange}) is based on the gross area and the apparent or published MOE of the flange. Joist web EA is determined consistent with methodology used to establish the joist EI.

> *Note: A conservative alternative for establishing joist web EA is to use panel properties from Appendix A and Reference 3. These properties are minimum performance standards and may not be applicable to selected suppliers.*

EXAMPLE

General

- Compliant ASTM D3498 construction adhesive
- Unglued panel edges, C = 0.45
- Floor panel design values per Appendix A and Reference 3
- Joists spaced at 24" o/c

Prefabricated Wood I-Joist Section and Design Properties

- Depth = 9½"
- Flange = 1½" x 1¾" - 2.2E LVL
- Web = ⅜" OSB
- EI_{Joist} = 200×10^6 lbs-in^2 (per ASTM D5055 and code evaluation report)
- EA_{Flange} = 2.2×10^6 psi x (2 x 1½" x 1¾") = 11.55×10^6 lbs
  (Flange rout need not be considered)
- EA_{Web} = Establish consistent with assumptions used to determine web portion of code accepted joist EI, or establish using panel properties. For this example, assume ⅜" 24/0 OSB Sheathing (stress perpendicular to strength axis) from Appendix A and Reference 3.
  EA_{Web} = 2.9×10^6 lbs/ft of panel width (Appendix A and Ref. 3, Table M9.2-2)
  EA_{Web} = 2.9×10^6 lbs/ft of panel width x (9½" - 3") / 12" = 1.57×10^6 lbs
- EA_{Joist} = 11.55×10^6 lbs + 1.57×10^6 lbs = 13.12×10^6 lbs

Floor Structural Panel

Assume a 23/32" OSB Span Rated Sheathing 48/24 or 24oc (stress perpendicular to strength axis)

- EI_{Panel} = 80,500 lbs-in^2/ft of panel width (Ref. 3, Table M9.2-1 for a 24oc)
  EI_{Panel} = 80,500 lbs-in^2/ft of panel width x (24" o/c / 12"/ft) = 161,000 lbs-in^2
- EA_{Panel} = 4.5×10^6 lbs/ft of panel width (Appendix A and Ref. 3, Table M9.2-2)
  EA_{Panel} = 4.5×10^6 lbs/ft of panel width x (24" o/c / 12"/ft) = 9.0×10^6 lbs

> *Note: Note that since there is no way to control the field installation to limit the use of plywood or OSB, the panel design values should be based on the more conservative values (lowest design values) of both panel span ratings (i.e. 48/24 vs 24oc and plywood vs OSB), unless the floor sheathing is clearly specified in the design calculations or in the allowable span tables.*

Neutral Axis (N.A.) of Composite Floor Section (compute from base of joist):

- Distance to N.A. of joist = $\frac{d_{Joist}}{2} = \frac{9½''}{2} = 4.75''$
- Distance to N.A. of structural floor panel = $d_{Joist} + \frac{t_{Panel}}{2} = 9½'' + \frac{23/32''}{2} = 9.859''$
- EA$_{Total}$ = $EA_{Joist} + EA_{Panel} = 13.12 \text{ x } 10^6 \text{ lbs} + 9.0 \text{ x } 10^6 \text{ lbs} = 22.12 \text{ x } 10^6 \text{ lbs}$
- N.A. = $\frac{EA_{Joist} \times \frac{d_{Joist}}{2} + EA_{Panel} \times \left(d_{Joist} + \frac{t_{Panel}}{2}\right)}{EA_{Joist} + EA_{Panel}}$
- N.A. = $\frac{(13.12 \text{ x } 10^6 \text{ lbs} \times 4.75'') + (9.0 \text{ x } 10^6 \text{ lbs} \times 9.859'')}{(13.12 \text{ x } 10^6 \text{ lbs} + 9.0 \text{ x } 10^6 \text{ lbs})} = 6.829''$

Bending Stiffness of composite floor section:

- EI$_{composite}$ = $EI_{Joist} + EA_{Joist} \times \left(N.A. - \frac{d_{Joist}}{2}\right)^2 + EI_{Panel} + EA_{Panel} \times \left(N.A. - d_{Joist} - \frac{t_{Panel}}{2}\right)^2$
- EI$_{composite}$ = $(200 \text{ x } 10^6 \ lbs - in^2) + (13.12 \text{ x } 10^6 \ lbs \times (6.829'' - 4.75'')^2)$ $+ (161000 \ lbs - in^2) + (9.0 \text{ x } 10^6 \ lbs \times (6.829'' - 9.859'')^2) = 339.5 \text{ x } 10^6 \ lbs - in^2$

Effective bending stiffness of composite floor section:

- EI$_{Effective}$ = $(C \times EI_{Composite}) + [(1 - C) \times EI_{Joist}]$
  EI$_{Effective}$ = $(0.45 \times 339.5 \text{ x } 10^6 \text{ lbs} - \text{in}^2) + [(1 - 0.45) \times 200 \text{ x } 10^6 \text{ lbs} - \text{in}^2] = 262.8 \text{ x } 10^6 \text{ lbs} - \text{in}^2$

REFERENCES

1. *Field-Glued Plywood Floor Tests*, Laboratory Report 118 (1978). American Plywood Association, Tacoma, WA.
2. *Evaluation of the Construction Factor used in Establishing Composite Joist EI's* (1994). Trus Joist MacMillan, Boise Idaho.
3. *2005 ASD/LRFD Manual* American Forest and Paper Association, Washington, DC.
4. *Design Example for APA Glued Floor System using APA Rated Sturd-I-Floor Panels* (1996). APA - The Engineered Wood Association, Tacoma, WA.

APPENDIX A. Reference Panel Properties for Computing Composite EI for Prefabricated Wood I-Joists

A.1 INTRODUCTION

The wood structural panel industry is revising some of the published wood structural panel properties, including EA in the across panel direction, in Reference 3. This change was made in response to two factors:

1) APA testing of the axial stiffness of oriented strand board (OSB) in the across panel direction (EA-perp) indicated lower capacities than expected, and
2) A recent ASTM standard (D7033) proposes characterization of panel stiffness on a "near minimum" basis rather than on its historical basis of the average value.

A.2 CONSIDERATION FOR ESTABLISHING REFERENCE PANEL PROPERTIES

Focusing solely on 20oc and 24oc span ratings, the updated panel property table lowered the EA-perp design values for OSB by approximately 30% on average. This change is based on recent tests from 12 OSB mills (23 test cells with 15 test replications each). It is important to note that there is no indication of any deficiency in the primary properties that are typically monitored for PS2-compliant panels. Because EA-perp is a minor property of minimum significance in structural design without life safety implications, the wood structural panel industry elected to lower the published EA-perp values without a more extensive study to include all OSB mills. It must also be noted that plywood panels were not tested in the recent study because the plywood EA-perp values are established based on an engineering analysis.

While panel EA-perp is a property that is rarely important in structural calculations, it is one factor in composite floor stiffness calculations. The prefabricated wood I-joist industry in particular uses this property in its calculations as outlined in the main body of this document. After considering the effects of using the recently reduced OSB EA-perp values, manufacturers of prefabricated wood I-joists have determined that reasonable technical justification may be exercised to validate the continued use of the existing OSB EA-perp values when calculating the composite EI for I-joist floor systems. The purpose of this appendix is to provide such justification as follows:

1. While the data indicate reductions in panel EA-perp that might appear to be significant, 30% on average for 20oc and 24oc, the resultant span reductions are very small, typically less than 2%.

2. A broad range of users, such as code officials, designers, and consumers, benefit from the stability of I-joist floor span tables that do not change regularly.

3. Allowable floor spans computed using the current methodology are conservative. For example:
   a. As-manufactured I-joist bending stiffness (EI) is typically higher than published values due to strict quality assurance procedures as employed by I-joist manufacturers. An actual EI that is 5% above the published I-joist EI value, which is likely, will result in an increase in the allowable floor spans of approximately 2%, which would be sufficient to offset the span reduction due to the reduced panel EA-perp value.
   b. Variability in I-joist EI is extremely low, typically less than 10%, which results in consistent floor performance.
   c. The "construction factor" used in the composite EI methodology is known to be conservative. A recent study under laboratory conditions with limited floor assemblies suggested that the "construction factor" for glued-nailed I-joist floor systems may be increased from the existing 0.45 to 0.57, resulting in an increase in the allowable floor spans of 1 to 2%, which would partially offset the span reduction due to the reduced panel EA-perp value.

   d. All of these factors indicate that prefabricated I-joist floors are stiffer than the calculations would suggest, even if EA-perp values are lower than expected.

4. There is no evidence that the current allowable spans published by the I-joist manufacturers are inadequate. On the contrary, I-joist floor systems have performed very well in the past. This is due in part to the industry practice of using L/480 for floor live load deflection criterion, which is beyond the code minimum of L/360.

A.3 REFERENCE PANEL PROPERTIES

For the reasons stated above, it is the position of the prefabricated wood I-joist industry that the currently published allowable spans may be retained. For practical purposes, it is recommended that the panel EA-perp values published in Reference 3 dated 2005 (i.e., 4.5×10^6 lbf/ft for both 20oc and 24oc panels, and 2.9×10^6 lbf/ft for 24/0 web materials) be used when computing the floor composite EI despite the fact that these values will be revised in the next update of the reference. This "reference EA value" will be reviewed if a further significant reduction in the OSB EA-perp value is observed. The wood structural panel industry will continue to monitor any future changes in the panel EA-perp properties and advise WIJMA of any such changes.