Establishing Shear Capacities for Prefabricated Wood I-Joists with Holes

1. Scope

1.1 General. This document provides a test methodology and a procedure for evaluating test results to establish the shear capacity of Prefabricated Wood I-joists (PWIJ) with holes. The intent is to provide direction on Section 6.6.3 of ASTM D5055 on Web Openings. Shear capacities are developed for circular and rectangular holes. Testing is for qualification purposes and is required for each significant combination of materials and manufacturing process. On-going quality control testing is not required. Requalification is required if a significant change is made in materials or process.

1.2 Scope. Tests define shear capacities for joists with varying size and shape holes, such that for a given application the holes can be located in an area with appropriate design shear. Additionally, multiple hole spacing and the minimum distance that a hole must be located from the joist end are established. The holes considered are limited to the web portion of the PWIJ. The moment capacities of PWIJ with holes, qualified using the ASTM D5055 empirical method for moment capacity is beyond the scope of this procedure.

2. Design Considerations

2.1 General. The design value adjustments in ASTM D5055, Section 4.1 and 4.2, for duration of load, treatments, environment, and shear design apply to this procedure.

3. Qualification Testing

3.1 General. Factors which influence joist capacity with holes are discussed in Appendix XI. Qualification testing shall consider each of these factors. Each factor is permitted to be evaluated on a worst-case basis or over the requested range of a particular product line.

3.2 Joist Factors

3.2.1 Test Specimens. Materials and fabrication procedures of test specimens shall be as typical of intended production as can be obtained at the time of manufacturing qualification specimens.

3.2.2 Web Factors. Each generic web type, for which design values are requested, (i.e., plywood, OSB, etc.) shall be qualified individually. For each generic web type considered, the critical combination (lowest shear capacity) of web/flange joint, web/web joint and web panel shear strength, for the range of products under consideration, shall be utilized.

> Exception: Web/flange capacity need not be considered for circular holes.

3.2.3 Flange Factors. For each combination of web factors above, the lowest flange stiffness for the range of products under consideration shall be utilized for testing to determine the capacity of rectangular holes.

> Exception: Flange stiffness need not be considered in developing capacity of circular holes.

3.3 Hole Factors

3.3.1 General. Circular holes shall be considered separately from rectangular holes.

> Exception: Circular holes that can be inscribed in a rectangular holes are permitted to be assigned the same design value as the tested rectangular hole.

3.3.2 Hole Location. The spacing between holes and the location of rectangular holes in relation to the end of the joist must be considered.

3.4 Testing. For each significant combination of joist and hole factors, the following minimum testing is required to allow interpolation of test results. Multiple depth testing is not required if shear capacity is limited to that obtained using the maximum size hole in combination with the minimum depth joist.

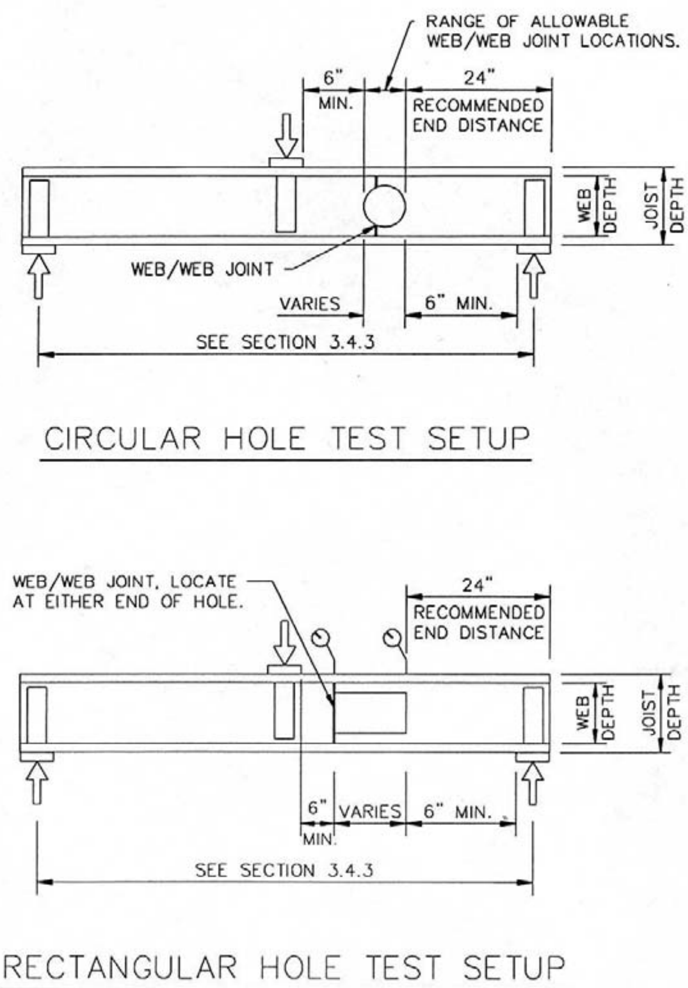
3.4.1 Circular Holes. Testing for circular holes shall include three joist depths (shallowest [+4"/-0], deepest [+0"/-4"], and mid depth (+/-4"]) that encompass the product range. Establish the maximum percent of web depth that will be permitted to be removed in application. For each joist depth tested, five tests are required at three even increments of web depth removed up to the maximum hole size.

> Example: Assume the maximum desired circular hole removes 75% of the web depth. For three joist depths, test at three increments up to 75% (i.e., 25%, 50%, and 75%) of the web depth removed.

3.4.2 Rectangular Holes. Testing for rectangular holes shall include three joist depths (shallowest [+4"/-0"], deepest [+0"/-4"] and mid depth [+/-4"]) that encompass the product range. Establish the maximum rectangular hole length and maximum percent of web depth that will be permitted to be removed in application. For each joist depth tested, five tests are required at three even increments for both hole length and percent of web depth removed. The maximum hole size permitted shall be tested.

> Example: Assume the maximum desired rectangular hole is 18" long and removes 75% of the web depth. For each joist depth, five tests at three increments of hole length and depth, including the maximums permitted, are required (i.e., 25%, 50%, and 75% of the web depth removed at hole lengths of 6", 12" and 18").

3.4.3 Test Setup. The test setup for single circular or rectangular holes is shown in Figure No. 1. Holes are centered vertically in the web.



NOTE: FOR MULTIPLE HOLE TESTS, LOCATE TWO HOLES WITH SPECIFIED SPACING BETWEEN HOLES. REQUIRED WEB/WEB LOCATION SHALL BE MAINTAINED FOR ONE HOLE ONLY. APPLIED LOAD MAY BE LOCATED OFF MIDSPAN.

FIGURE NO. 1

Note: the web/web joint location is mandated for rectangular holes. The web/web joint location is permitted to be located within the area shown on Figure No. 1 for circular holes.

Specimen length shall be that which usually produces failures in shear. Web stiffeners are installed as required in the manufacturers' literature. Additional reinforcement may be installed under the load point, provided such reinforcement is not wider than the load pad and the sole purpose of the reinforcement is to prevent a localized failure due to the applied load. Bearing length shall be adequate to produce shear failures at the hole. Minimum specimen temperature at the time of test shall be 40 degrees. Rate of loading is as specified in D5055.

3.5 Multiple Holes. Multiple hole testing is required if more than one hole is to be located in any joist span. Specimen configuration and test setup as described in figure No. 1 may need to be modified to insure shear failures. Testing is required to determine the minimum spacing to isolate the affects of each hole such that the capacity for a single hole is not reduced. The testing below shall be performed for each significant combination of joist and hole factors.

Required testing for multiple circular holes is performed on the deepest joist in a series. Two holes are located at the desired minimum distance between two holes. Three tests are required at three increments of web depth removed up to the maximum permitted.

Example: Assume the maximum desired circular hole removes 75% of the web depth. For the maximum joist depth in a combination, perform three tests at three increments up to 75% (i.e., 25%, 50% and 75%) of web depth removed.

Required testing for rectangular holes is performed using square holes in the deepest joist in a series. Two square holes are located at the desired minimum distance between holes. Three tests are required at three increments of web depth removed up to the maximum permitted.

Example: Assume the maximum desired rectangular hole removes 75% of the web depth. For the maximum joist depth in a combination, perform three tests, using square holes, at three increments up to 75% (i.e., 25%, 50% and 75%) of web depth removed.

3.6 Required Data. The test data required includes ultimate shear capacity and shear versus local deflection across rectangular holes that exceed 12" in length and remove more than 50% of the web depth.

Exception - Deflections at rectangular holes need not be recorded if data from tests at larger holes demonstrates that deflection does not control.

4. Analysis of Results

4.1 Capacity. Design shear capacity at each hole combination is limited to the lessor of the average ultimate capacity divided by 3.0 or the minimum ultimate capacity divided by 2.4. Additionally design shear capacity at a hole cannot be less than 200 lbs., and is limited such that local deflections across rectangular holes are limited to 3/16" maximum.

Capacities for joists with multiple holes must equal or exceed 95% of the assigned capacity of joists with single holes. Joists with multiple holes shall be retested with an increased hole spacing if the above criteria is not met.

4.2 Interpolation. Linear interpolation of a given series or of combined test data is permitted provided the coefficient of determination (r^2) exceeds 0.8 and a minimum of three data points is utilized. Shear capacity test data (without holes) is not permitted to be used for interpolation. Extrapolation beyond the largest hole tested is not allowed. Extrapolation beyond the smallest hole tested is allowed.

4.3 Hole Location. The end distance selected in the test setup defines the minimum end distance in application. Allowable holes may be located vertically in the web as required in application.

Appendix X1

X1.1 General Philosophy. This portion of the standard describes a means for testing a range of holes in the web of a Prefabricated Wood I-Joist to determine capacities that are related to actual performance. Although there are many variables that can affect the web hole performance, the described procedures and resulting data can be used to qualify a method for logical adjustment of hole capacity within a range of material and manufacturing variables.

X1.2 Factors Influencing Joist Capacity at Holes. There are a wide range of material, manufacturing and application variables that affect web hole capacity. Some known variables are listed below:

1. Hole size - This factor includes consideration of the hole height and width as well as the overall percentage of vertical web depth removed.

2. Hole shape - Stress concentrations that result from sharp corners can affect web hole shear performance.

3. Hole location - The location of the web hole along the length of the joist or the proximity of one web hole to another web hole affects joist performance. Consideration is required for the amount of remaining web material between the edge of the hole and the end of the joist (or an adjacent web hole).

4. Hole quality - The quality of the web hole, whether it is cut by saw, drilled or punched can have an affect on web hole performance.

5. Flange stiffness (MOI and MOE) - Flange size and stiffness generally affect the joist's ability to transfer shear across large rectangular holes where most of the web is removed.

6. Web material - Web shear performance and web hole performance is affected by the web material. Differences in thickness, material and species can result in different levels of performance.

7. Web-to-flange connection strength - For large rectangular holes, the rout configuration, construction and adhesive characteristics will affect web hole performance.

8. Web member to web member joint parameters - The type of web-to-web joint (i.e., butt, fingered, grooved, etc.) can affect the shear transfer across the hole, especially when the joint is positioned at or near the edge of a rectangular hole.

9. Localized hole deflection - Long or large holes generate a localized shear deflection that affects the web hole performance.

X1.3 Configuration and Material Changes That Require Retesting.

X1.3.1 General. Typically each combination of web material and flange combination needs to be tested separately if holes are to be allowed for use. If a wide range of flange or web combinations are used, all sizes and combinations are to be tested unless all design values to be qualified are based on tests using:

The smallest flange size with the lowest flange stiffness;
The least thickness web material of a particular type;
The most critical web-to-flange joint; and
The most critical web-to-web joint type.

When a range of flange species, grades or sizes, and a wide range of web materials or thicknesses are going to be qualified for use with web holes, then preliminary tests should be conducted to determine the critical combinations or variables.

X1.3.2 Hole Size. Usually, for web hole sizes that displace a third or less of the vertical web material and have a length equal to or less than the hole height, then a comparison of shear capacity can be used to indicate the most critical material or manufacturing combinations. This is because the web material and the web-to-web joints are the primary stressed elements in both a shear capacity qualification test and a hole capacity qualification test. If the desired holes are larger in proportion, then the stiffness of the flange material and the web-to-flange connection usually become critical. A web hole comparison test using a square hole sized to remove all the web material will generally reveal the critical combination.

X1.3.3 Examples. Some examples of material or manufacturing changes that may not require requalification testing follow:

Example 1 - Change in flange size or grade only

If the joist flanges are dimensionally different, have a different grade, are of a different material, or have a different web-to-flange connection, but qualify for the same shear capacity, then separate web hole qualifications for each flange material are generally not necessary. This generally is true if the hole's size is limited in dimension to approximately a third of the web depth. Larger holes are more dependent upon flange stiffness and may need separate qualification testing.

If the web hole qualifications are based on the flange configuration having the least stiffness (flange modulus of elasticity multiplied by the vertical orientation flange moment of inertia), then a stiffer flange can usually be qualified without test for the entire range of allowed holes.

Example 2 - Change in web material only

If the web material is of the same material group (i.e., plywood is a material group, oriented strand board would represent a different material group) but qualifies for the same shear capacity, then separate web hole qualifications for each web material are generally not necessary.

Similarly, if the web hole qualifications are based on the least thickness web material, then a thicker web of the same material group can usually be qualified without test for the entire range of allowed holes.

X1.4 Hole Performance Evaluation Criteria. Although web hole performance for strength is closely related to shear capacity, it is desirable to exclude web hole testing from ongoing quality assurance process due to the wide range of possible configurations and applications. It is believed that the periodic reevaluation process for shear capacity will provide an acceptable indicator for the ongoing performance of web holes. Since the qualification process for web holes is based on the initial testing only, the basis for evaluation is more stringent than the criteria used for qualifying shear capacity. The expected variability between tests is also higher due to the greater number of significant variables involved. Therefore dual performance criterion were developed that provide for a limitation on both the average and minimum test results.