Components

Testing Apparatus for Metal-Plate-Connected Wood-Truss Joints

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Abstract
A testing apparatus with computerized data acquisition and control system was developed to test metal-plate-connected wood-truss joints. The apparatus enabled testing of several different types of joints under various loading conditions without major modifications. The apparatus shows potential as an efficient testing procedure to assess joint behavior.

Introduction
The structural performance of metal-plate-connected (MPC) wood-truss joints has received extensive research attention in the last 20 years (Wolfe, 1990). However, most of the research has focused on the performance of tensile joints, and even then, only under axial loads. Tensile joints under combined loads, and structural performance of other joints (e.g., heel and web joints) under realistic loads, have received little or no attention.

The American Society for Testing and Materials (ASTM) standard D 1761 (ASTM, 1988b) provides a test method for determining strength and stiffness of MPC tensile joints under axial loads only. Other standards, such as ASTM E 489 (ASTM, 1988a), ASTM E 767 (ASTM, 1988c), CSA S347 (CSA, 1980), and the European Union of Agreement (UEAtc, 1979) cover test methods that determine the lateral resistance of teeth, and tensile and shear strength of metal plates. However, no standard exists for testing actual truss joints under simulated, in-service, loading conditions.

Truss joint tests are necessary to obtain the strength and stiffness values for more accurate and probability-based design of trusses. This will also help to establish a database for strength and stiffness values, and characterize the failure modes of MPC joints. To do this, a standard test apparatus is needed that enables testing of different MPC joint configurations, and that simulates the in-service loading conditions on joints. With such a system, the standardization of testing methods can be achieved and the design of new connections can be evaluated. Such a testing apparatus was developed and constructed, and is described in this paper.

Testing Apparatus
The testing apparatus consists of a horizontal, rigid, steel frame [3- x 3-in. (76- x 76-mm) box section] bolted to the floor at five places (Figure 1). The test frame is shaped as a half of a hexagon, with each side about 6 ft (1830 mm) long. The test frame supports reaction fixtures, links, restraints, cylinders, and the test specimen.

The load was applied through hydraulic cylinders. The cylinders were double acting and had 3-in. (76-mm) bore and an 8-in. (203-mm) throw. A system of calibrated force transducers (strain-gauge load cells), which measured the forces in the members that formed the joints, were threaded onto the piston rods of the cylinders. The cylinders were actuated by a single, variable-volume, hydraulic pump through a manifold system. Mounting brackets affixed the cylinders to the test frame. The various hydraulic components were mounted on a plywood board, including an oil filter, pressure gauges, directional control valve, fixed-orifice valve, electronically controlled hydraulic-pressure-control valves, and manifold connections for both pressure and return lines. The

![Test frame with web at the bottom chord joint.](image)

![Test frame with tension splice joint under axial loading.](image)

![Test frame with heel joint.](image)

Figure 1. Test frame with three types of joints: (a) a web-to-bottom-chord joint; (b) a bottom chord tensile-splice joint; and (c) a heel joint.

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cylinder action could be reversed by a directional-control valve. The fixed-orifice valve regulated the fluid flow for proper operation of the pressure-control valve. The pressure-control valve was the “heart” of the system, permitting close control of the pressure in the cylinders and, thereby, the forces exerted by the cylinders. A schematic diagram of the assembly of the hydraulic devices and controls is shown in Figure 2.

Displacements of the test specimens were monitored using two linear variable differential transformers (LVDT). An IBM-PC/PS2 (Model 50) computer and a data-acquisition system monitored and controlled the hydraulic pressures applied to the hydraulic cylinders. Load cells with signal-conditioning amplifiers provided signals proportional to the forces exerted by the hydraulic cylinders. The analog signals were converted into digital signals by the data-acquisition's analog to digital (A/D) converter, and then converted into corresponding force and displacement values using calibration equations for the load cells and LVDTs. These values were then recorded. A schematic diagram of the data-acquisition and control system is shown in Figure 3.

Testing Procedure
The test specimens were fabricated seven days prior to testing and were stored in a relatively uniform environment. Each test specimen was loaded such that its deformation was unrestrained in the load plane, but movement out of the plane was restricted. The loading procedure is as follows:

1. Set up and initialize the system. This procedure applies an initial, minimum, line pressure. This lightly preloads the test specimen, and deflection is set to zero.

2. Read load cell and LVDT signals (in volts) after 8 sec. The readings should be stabilized within this time.

3. Apply a ramp loading from zero to failure. The loading rate is chosen so that failure will occur in about 12 min.

4. Convert volt signals into actual forces and displacements. Print and store the data.

5. Terminate loading when the deformation increases with no detectable increase in load-cell readings, or when a failure is observed. Otherwise, repeat Steps 2 to 5.

Discussion
Three types of joints were tested with the newly developed apparatus: heel, tensile, and web joints (Figure 1). Tensile joints were tested under pure axial tension, pure bending, and at four levels of combined tension and bending. The combined loads were applied as an eccentrically applied load with four different eccentricities: 0.5 in. (13 mm), 1.0 in. (25 mm), 1.5 in. (38 mm), and 2.0 in. (51 mm). Heel joints were tested by applying a compressive force at the top chord. The bottom chord was attached to the testing frame by a link. Web joints were tested by applying a compressive force to one of the web members and a tensile force to the other. The details of joint testing are given in Gupta (1990). Joints were fabricated using Southern Pine No. 2 and 20-gauge punched-metal plates. All joints were tested to failure, and their load-deflection characteristics and failure modes were recorded.

The system provided a method of loading that was consistent with in-service loadings. In this particular set of metal-plate connections, the characteristic failure traits were identified. For example, 90% of the tensile joints under pure tension and combined loading failed due to a combination of wood tearing and teeth withdrawal. The dominant mode of failure for tensile joints under pure bending was plate tension. The most common mode of failure for web joints was teeth withdrawal at the tension web member. Heel joints mainly failed by teeth withdrawal at the bottom chord. For other plate designs or material combinations, the failure modes could be quite different.
Summary
A system to test metal-plate-connected truss joints is described. The apparatus and test procedure provide a method to properly evaluate in-service types of loadings and design alternatives. Further work on the system is being conducted to standardize the test.

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References


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