Fire Endurance Research at the Forest Products Laboratory

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Fire endurance research activities and facilities at the FPL concern the ability of a wood member or assembly to withstand the effects of fire while acting as a fire barrier and supporting a load. Fire endurance is generally concerned with the post-flashover portion of the fire. The importance of fire endurance in fire safety is ref1ected in building code requirements for fire resistance ratings (1 hour, 2 hours, etc...) for building elements.

The FPL fire endurance research program is oriented largely toward supporting: (1) the increased use of wood in commercial and multifamily buildings where fire-rated assemblies are required by building codes; and (2) the use of new structural wood components. Experience has shown that new wood engineering technologies can conflict with current levels of fire safety.

Research Facilities and Equipment

In addition to the variety of test apparatuses used by the Fire Safety of Wood Products research work unit at the FPL, equipment and support are also available from the FPL Engineering Mechanics Laboratory, and other research work units and support groups. Equipment used in fire endurance research includes a tension/furnace apparatus, an American Society for Testing and Materials (ASTM) E 119/E 152 large vertical furnace, and a small, vertical, fire-resistance furnace. An ASTM E 906 heat-and smoke-release apparatus is also available for charring studies.

Tension/Furnace Apparatus

The FPL tension apparatus and furnace (Fig. 1) was installed in early 1988. The new equipment allows a tension load of up to 100,0001b to be applied to a 16-ft-long specimen, with 6 ft of the specimen subjected to high temperatures or fire exposure. The equipment can test specimens up to 11-3/4 in. wide, and 3/4, 1-1/2, and 2-1/2 in. thick. The tension/furnace apparatus is unique in terms of its size and flexibility. Although ASTM E 119 does not describe tests for tensile members as one of its assembly types, general furnace characteristics arc based on the standard equipment defined in ASTM E 119.

The tension machine is a Metriguard Model 403FPL Tension Proof Tester[1] (Metriguard Inc., Pullman, WA) consisting of a clamp assembly and a support frame. Tensile force is applied by two hydraulic cylinders, with oil supplied by a hydraulic power unit. The machine frame is sufficiently large to accommodate the 5- x 7-ft furnace. Tensile force is measured by an electronic load cell. Deflection measurements are provided by an extensometer system, which consists of a reference arm that goes around the furnace, a linear variable differential transducer (LVDT) at one end, and clamps with magnetic attachment plates. The gauge length is 10-3/4 ft.

The Omega Point Laboratories' furnace (Omega Point Laboratories, San Antonio, TX) is lined with mineral fiber blankets and heated by eight, diffuse-flame, natural-gas burners. Combustion air enters by natural draft through vents at the bottom of the furnace. Inside dimensions measure 3-1/4 ft wide, 6 ft long, and 4 ft high. Openings for the specimen at each end of the furnace measure 9 x 20 in. The furnace is equipped with a removable lid and crane, which allows tire tests to be conducted on small-scale horizonal panels.

A horizontal specimen can be inserted at midheight in the furnace to test a tension member above the protective membrane. In this case, the fire in the bottom chamber is controlled to follow the ASTM E 119 time-temperature curve. Tension specimens are inserted through one grip and into the other grip without removing the furnace lid. Two viewing ports arc located on one side of the furnace. Standard ASTM E 119 thermocouples can be used to control the furnace. An automatic furnace recorder-controller regulates the gas based on the thermocouple signal. Load, deflection, and temperature data are collected by microcomputer. Tests can be recorded on VHS video equipment.

Vertical Furnaces

The capacity of the large ASTM E 119 vertical furnace is originally designed to accommodate 10-x 10-ft walls. When hydraulic jacks and a steel channel were added so that a load could be applied to the wall, the capacity was reduced to accommodate a maximum 8-x 10-ft wall (80 ft^2) ASTM E 119 requires a minimum wall size of 100 ft^2.

The gas-tired furnace bums a mixture (approximately 1:10 ratio) of natural gas and (primary) air in 60 stainless-steel nozzles. Supplemental air enters the furnace around the burner-mounting holes and through eight 3-in. -diameter openings at the bottom of the rear wall. Furnace operation and test criteria arc specified in ASTM E 119 for walls and in ASTM E 152 for doors. In addition to instrumentation for tire endurance measurements, wc can measure the heat-release rate from the wall assembly using oxygen consumption methodology.

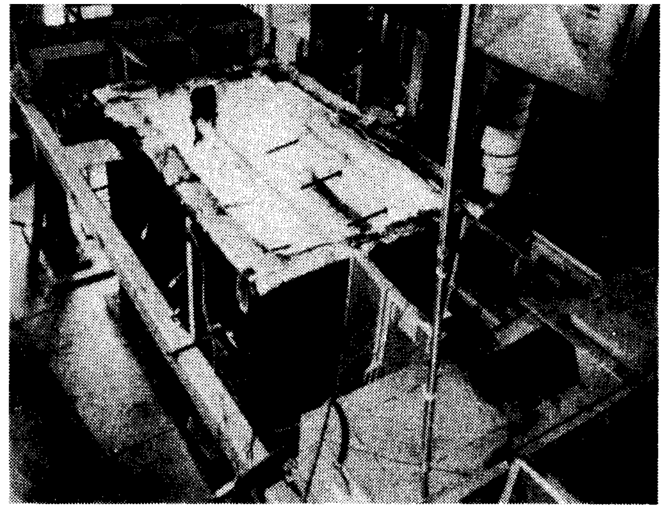

Figure 1. The Forest Products Laboratory tension apparatus and furnace (cover removed for photograph).

The small, vertical, fire-resistance furnace is concrete and has a 20-in. square opening to accommodate the specimen. Pipe outlets discharge naturral gas into the furnace. Combustion air enters by natural draft through vents at the bottom of the furnace and is baffled for proper distribution. Inside the furnace, a single iron-capped thermocouple is located opposite from the center of the test panel and 2 in. from the exposed surface of the panel.

Heat Release Apparatus

The Ohio State University (OSU) heat- and smoke-release apparatus (ASTM E 906) is used to measure heat-release properties under various constant heat-flux levels. Radiant heat is controlled by regulating the power input to four Globar heater elements (Carboruneum Co., Globar Division, Niagara Falls, NY). The FPL added the capability to measure the weight loss of the 5.9- x 5.9-in. specimen during the tests.

Previous Research

The tire research program has focused on the development of tire endurance models and the accumulation of tire performance data. Current efforts arc concentrated on models for parallel-chord truss floor systems and wood-joist floor systems. Past work resulted in analytical procedures for walls, unprotected joist floors, glued laminated timbers, and unprotected floor trusses.

The tire endurance models were developed largely in cooperation with universities. Virginia Polytechnic Institute and State University and the FPL developed (1) a

[1]The use of trade or firm names in this paper is for reader information and does not imply endorsement by the U.S. Department of Agriculture of any product or service.

reliability-based model for fire endurance of glued laminated beams; (2) a model for unprotected wood joist floors; and (3) a simple model for unprotected wood truss floors, which was limited to evaluating the residual strength of the individual wood component.

In a cooperative effort with the FPL, the University of California-Berkeley developed a fire endurance model for wood-frame walls. Although this wall model predicts the buckling failure of a single stud, it is primarily a heat transfer model for predicting the temperature distribution and thermal degradation within the wall assembly (White, 1988a,b).

Fire performance data have been accumulated in the areas of charring rates of wood, wall performance in the standard test, and wood protection with tire-resistive coatings. The typical method of improving the fire resistance of a wood assembly involves adding a gypsum-board membrane. Spray-on fire-resistive coating materials have been used for steel members for some time and, in recent years, as thermal barriers over foam plastics. The feasibility of protecting wood with fire-resistive coatings was evaluated, and empirical models were developed for predicting the performance of the coatings in wood construction (White, 1989).

Over the years, several studies have been performed on the charring rate of wood when it is directly exposed to the ASTM E 119 fire exposure. Fire affects the strength of the wood member by raising the temperature of the wood and by charring the wood. During a fire, temperature and moisture-content gradients within the wood member are constantly changing. An empirical model for predicting the charring rate of various wood species in the ASTM E 119 test was developed.

In the early 1970s, typical, unrated, wood-frame walls and sandwich-panel walls were tested in our large vertical furnace in a study funded by the U.S. Department of Housing and Urban Development (HUD). These same walls were tested in an actual three-room structure in which the two side walls were loaded. Wood cribs we used to provide the fire load inside the structure.

Current Research

Current research activities include testing of wood stud walls, evaluation of the National Forest Products Association (NFPA) System 1 floor model (Douglas and White, 1990), testing of wood in an ASTM E 906 furnace, and development of a fire endurance model for trusses. Twelve wood-frame walls have been tested to provide data needed for continuing evaluation of the wall model developed by the University of California-Berkeley. Using the oxygen consumption method, the heat-release rates of these gypsum- or plywood-faced walls were also measured (Tran and White, 1990). NFPA System 1 is an enhanced version of the Finite Element Analysis of Floors (FEAFLO) structural floor model (Thompson et al, 1977). With the cooperation of the FPL, the NFPA is evaluating the feasibility of using the System 1 model as a fire endurance model for light-frame floor systems.

Previous work by the FPL with the single-joist model indicated the need to include load sharing and composite action. The ASTM E 906 furnace is being used to determine the charring rate of wood under various defined heat fluxes (most previous charring studies have been performed using the standard ASTM E 119 fire exposure). The major current interest is a fire endurance model for trusses, which is being developed by the University of Wisconsin-Madison.

The primary objective of our work is to develop a model that will predict single-truss performance under combined structural load and fire conditions. The model is being designed for pitched- or parallel-chord metal-plate-connected trusses, but is applicable to all types of trusses. Using the tension/furnace apparatus, property values needed for the development of the model are being obtained. Development of the truss fire-endurance model has been supported by the NFPA.

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