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FIRE RESISTANCE TESTS OF REDUCED SCALE RAIL CAR FLOOR ASSEMBLIES

SUMMARY
The Federal Railroad Administration contracted Jensen Hughes (JH) to conduct tests to validate the methodology for reducing the size of a test specimen for rail car floor fire resistance compliance test. The tests were conducted on May 20–24, 2019, at Southwest Research Institute (SwRI). Full-scale[1] and reduced-scale floor assemblies were tested with different boundary conditions. Test articles were prepared and evaluated according to the National Fire Protection Association (NFPA) 130, Standard for Fixed Guideway Transit and Passenger Rail Systems 2014 (NFPA, 2014). Reduced scale tests were conducted to evaluate the effects of scaling as well as for validating the scaling methodology. Two of the tests failed structurally due to severe deflection of the specimens, but satisfied the temperature rise requirements on the unexposed side. Failure modes of the specimens were excessive temperatures on the unexposed side or lack of structural integrity were observed and recorded. Future work is recommended to investigate the factors that may have contributed to the performance differences observed due to scaling as well as the disparities between test data and pre-test model simulations.

BACKGROUND
Rail car assemblies used for passenger service in the United States are currently required to demonstrate their fire resistance performance, which includes structural integrity and limited heat transmission, according to ASTM International (ASTM) E119 as specified in Title 49 Code of Federal Regulations Section 238.103 Appendix B and NFPA 130. According to NFPA 130, the floor assembly should be 12 ft. long and as wide as a rail car (approximately 10 ft.). The test article is simply supported along the transverse ends and has a representative applied static load consistent with the vehicle design. In order to pass, the floor assembly must be able to support the design load for 30 minutes and resist unexposed surface temperature rise such that an average temperature rise of 139 °C (250 °F) and a peak rise of 181 °C (325 °F) are not exceeded.

JH used computer modeling to evaluate the feasibility of reduced-scale floor test specimen to predict performance of the full-scale specimen. Modeling suggests that support of the test article on the longitudinal ends better represent the structural response of the floor in the end-use condition (Kapahi et al., 2018). In the computational study, support of the test article on the longitudinal ends better represented the structural response of an actual full-sized rail car floor than by using support on the transverse ends. In addition, reduced-scale test specimen supported longitudinally with a one-third of full-scale length (~ 4 ft.) and the full-width of the rail car floor represent the full-scale behavior.

[1] Full-sized rail car floor: 60 ft. long X 9 ft. wide,
full scale rail car floor: 12 ft. long X 9 ft. wide,
reduced scale rail car floor: 3.8 ft. long X 9 ft. wide

OBJECTIVE

The objective of this effort is to validate the results obtained from computer modeling to support recommendations for reducing the size of rail car floor assemblies required for fire resistance testing.

METHODS

Fire resistance tests of full-scale and reduced-scale rail car floor assemblies were coordinated by JH and conducted at the SwRI, a certified test facility for performing fire resistance tests. The floor designs are based on exemplar floors from surveying various rail cars and discussions with industry. Figure 1 through Figure 3 show design drawings of the floor assemblies.

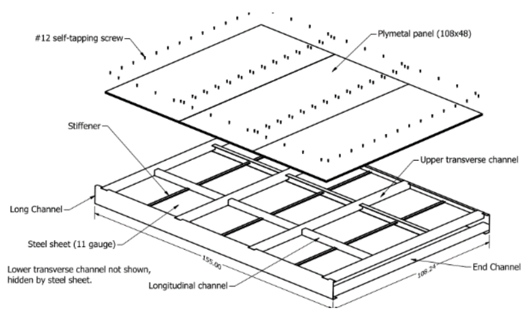

Figure 1: Full scale Assembly Design 1, Tests 1 and 2

The assemblies were fabricated using carbon steel, fiberglass insulation, and plymetal or phenolic composite floor panels. The frame was made of welded carbon steel channels. Fiberglass insulation bats were inserted within the frame. Tests 1, 2, and 3a specimens used a plymetal panel to cover the insulation and frame. The plymetal was made of two 16-gauge facesheets and 3/4-in plywood. Test 3b specimen was covered with a phenolic floor panel.

Table 1 contains the test matrix with boundary condition, load, and specimen configuration. Test 1 used the NFPA 130 specified boundary condition. Tests 2, 3a, and 3b were supported longitudinally. Tests 3a and 3b were performed simultaneously in the large furnace.

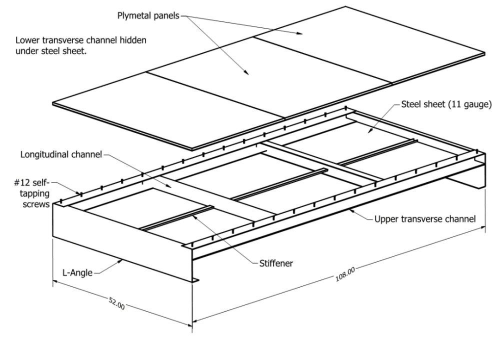

Figure 2: Reduced scale assembly Design 1, Test 3a

Table 1: Floor fire resistance test matrix

Test	Scale	Floor Design	Load (lb/ft^2)	Boundary Condition
1	Full	1	75	NFPA 130
2	Full	1	75	Alternative
3a	Reduced	1	75	Alternative
3b	Reduced	2	40	Alternative

Tests 1, 2, and 3a floor specimen were tested with a 75 lb/ft^2 distributed load applied using a hydraulic load frame, to simulate representative loading. A 40 lb/ft^2 distributed load was applied to Test 3b as the original design was based on a lower load.

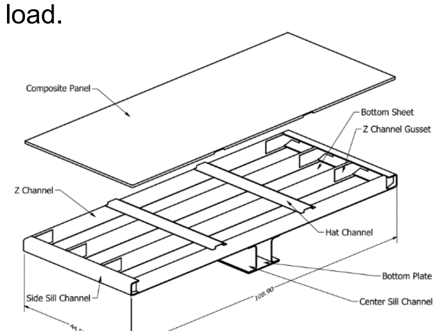

Figure 3: Reduced scale Assembly Design 2, Test 3b

Fire resistance Tests 1, 2, 3a, and 3b were conducted May 20–24, 2019 at SwRI. All tests were conducted in a large horizontal furnace with a 12 ft. by 16 ft. opening. Temperatures were measured on the unexposed side with ASTM E119 standard thermocouple pads, through the thickness of the assembly, and on structural elements. Deflection of the assemblies were measured using string potentiometers at three locations. The tests were also recorded using video and a thermal camera.

RESULTS

The results for Tests 1–3b are shown in Figure 4 through Figure 7. The Test 1 data in Figure 4 include the measured center deflection and unexposed side temperature rise. Test 1 failed due to excessive structural deflection at 28 minutes, indicating the test assembly could not support the load. The peak and average temperature rise on the unexposed side was less than 80 °C (144 °F). Test 2 supported the load up until 45 minutes, when it failed due to exponential increase in structural deflection. Figure 5 contains the center deflection and unexposed side temperature rise data. The unexposed side average and maximum temperatures were similar, and the rise was approximately 125 °C (225 °F) at termination. The average unexposed temperature rise for Test 2 at 28 minutes was approximately 60 °C (108 °F) which was similar to Test 1 as both assemblies had the same design with identical structural members.

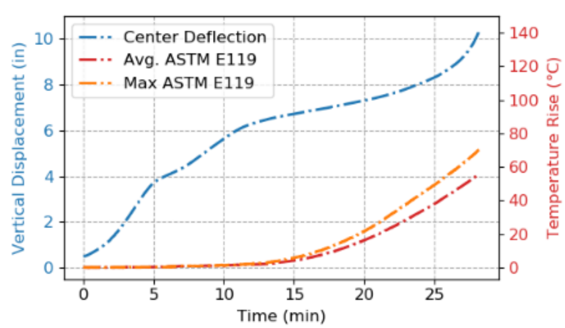

Figure 4: Test 1 deflection and temperature rise

Tests 3a and 3b were conducted simultaneously. Temperature rise and deflection measurements for Tests 3a and 3b are shown in Figure 6 and Figure 7, respectively. Test 3a supported the load for the test duration but failed the average temperature rise requirement at 57 minutes. The test was terminated at 62 minutes due to flaming ignition on the unexposed surface. Test 3b failed due to exceedance of the average temperature rise criterion at 20 minutes and exhibited structural failure due to exponential increase in deflection at 49 minutes.

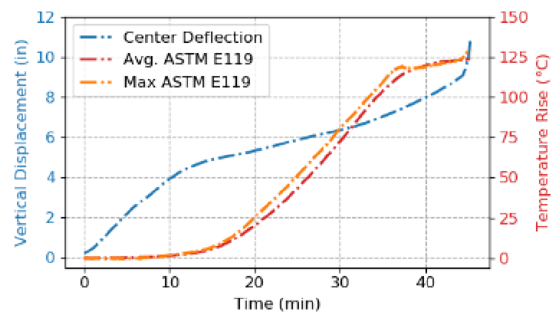

Figure 5: Test 2 deflection and temperature rise

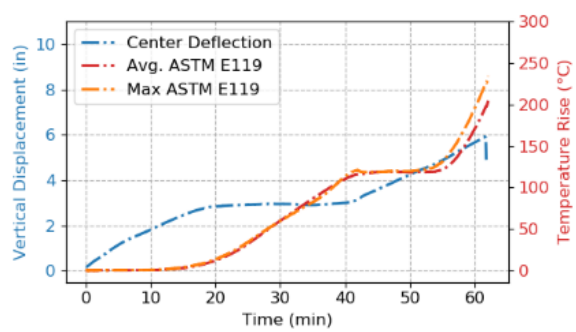

Figure 6: Test 3a deflection and temperature rise

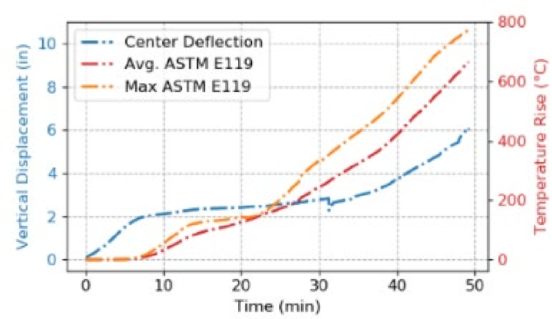

Figure 7: Test 3b deflection and temperature rise

Temperature rise on unexposed surface for Test 3b was significantly higher than the rise for Test 3a. The may be contributed to Test 3b specimen having a phenolic-faced composite panel—instead of plymetal—and being constructed of thinner gauge steel than Test 3a. Test 3b specimen phenolic floor panel delaminated, which may have resulted in the steep rise in deflection at 31 minutes in Figure 7. The response of Test 2 and Test 3a was expected to be same based on the computer simulation. The temperature rise for these tests was similar. The scaling methodology did not alter the thickness of individual members of the assembly, resulting in an identical thermal resistance for both scaled specimens. Both tests were expected to have similar deflection, but there was more deflection in Test 2 than Test 3a, see Figure 5 and Figure 6. While the structural design and distributed load of these were the same, the edges of the assemblies were partially shielded from the furnace exposure with the thermal blanket to prevent hot gasses from escaping. This may be more pronounced in Test 3a since this may have partially shielded the transverse beams on the edges in the assembly.

CONCLUSIONS

In May 20–24, 2019, four fire resistance tests were conducted to evaluate the effect of reducing the rail car floor assembly size. For the same structural design (Design 1), temperature rise was similar but the floor assembly with modified boundary condition (Test 2) deflected less than the floor with NFPA 130 boundary conditions (Test 1). Test 2 and Test 3a floors had the same structural design and boundary condition. Temperature rise data were similar in the two tests but the full-scale Test 2 floor deflected 4.1 inches more than the one-third length scale Test 3a floor. A longer fire resistance for the Test 3a floor assembly may be in part due to partial shielding of the thermal exposure at the edges where the transverse members are located. The design with the phenolic panel (Test 3b) had faster unexposed side temperature rise compared with the other design (Test 3a).

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