NATIONAL BUREAU OF STANDARDS REPORT

4683

FIRE TEST

of

STEEL JOIST ROOF DECK

by

J. V. Ryan

U. S. DEPARTMENT OF COMMERCE

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ABSTRACT

A fire endurance test was carried out on a roof deck and ceiling assembly, the primary components of which were cement bonded shredded wood fiber planks on open-web steel joists. The results indicated a fire endurance of 1 hr 25 min.

1. INTRODUCTION

A fire endurance test was carried out in compliance with the provisions of ASTM E-119. The specimen was a roof deck and ceiling assembly of open-web steel joists with a deck of tongue-and-groove planks of shredded cemented wood fiber. The deck was topped with four-ply asphalt rag felt roofing and slag. The ceiling consisted of gypsum perlite plaster on furred metal lath. The floor surface was approximately 18 ft by 13 ft 6 in., and the ceiling 17 ft 3 in. by 12 ft 8 in.

2. TEST SPECIMEN

The materials employed and the details of their assembly are described in the following sections. Some of the materials were obtained on the open market; others were obtained from the manufacturer. Most of the assembly operations were performed by contractors or others regularly engaged in such activities; the remainder by personnel of the Fire Protection Section.

2.1 Materials

The steel joists were of the open-web type, designated SJ 102 by the Steel Joist Institute, and were manufactured by a member-company of that Institute. They were 13 ft 4½ in. long and 10 in. deep. The top chords were formed members of 0.075 in. thick steel. In cross-section, they had the shape of a T with a hollow bulb at the bottom. The member was 1½ in. deep and 2-11/16 in. wide, with the bulb 1 in. wide. The cross bar of the T was turned down 7/16 in. at each side. The bottom chords were similar to the top chords, but inverted. They were 1-3/8 in. deep and 2-3/16 in. wide, and were formed from 0.065 in. thick steel. The webs were single steel rods bent in a zigzag shape. They were made up of 0.445 in. diameter rod over the center 4 ft, 0.550 in. diameter for the next 2 ft, and of 0.612 in. diameter rod to each end. The chords and web were welded together, forming triangular panels of 2 ft base length over the center 8 ft. At each end, a bearing member of 0.131 in. thick steel, in the shape of a plate with an inverted U bent along the center, was welded to the top chord. This member was 7 in. long, 3-13/16 in. wide, and the U 1-1/8 in. deep. Each joist weighed approximately 51 lb. Bridging for the joists was assembled from 1/2 in. diameter steel rods.

The roof deck consisted of planks of shredded wood fiber with binders represented by the manufacturer to have been magnesium oxysulfate and silicate cements, and faced on one side with asphalt saturated felt. The planks were 30 in. wide, 96 in. long, and 1-13/16 in. thick. One of the long sides had a 5/8 in. tongue and the opposite side a matching groove. The asphalt felt facing was carried to the base of the tongue and the near lip of the groove. The planks were received from the manufacturer. Asphalt saturated rag felt, in rolls 36 in. wide, roofing asphalt, and slag granules were used for built-up roofing.

The ceiling was composed of 3/4 in. cold rolled steel furring channels, 3.4 lb/yd^2 (nominal) 3/8 in. V-rib expanded metal lath, gypsum plaster, and expanded perlite plaster-aggregate. The gypsum was a widely available brand; the perlite aggregate from a local producer.

2.2 Assembly

Eight steel joists were placed to span the short dimension of the furnace opening and bear on 4 in. bearing angles bolted to the furnace frame. The joists were placed parallel to the transverse centerline of the furnace opening, and spaced symmetrically therefrom. The spacings between joists on each side of the centerline were 18 in., 36 in., 36 in., and 10 in. No joist was located at the centerline. The joists were welded to the bearing angles by spot welds at each side of the joist bearing member. The welds were of about 1 in. diameter. One-half inch steel rods were welded to the top and bottom chords, transversely, as horizontal bridging at centerspan.

The cemented wood fiber roof planks were laid on the joists, transversely thereto. They were laid with the asphalt saturated felt face up and were aligned and forced together to form tight, straight, tongue-and-groove and butt joints. The planks were cut to lengths such that the butt joints fell over the centerlines of joists. Each length was supported by three or four joists, including those under the butt joints. The planks were attached to the joists by formed sheet metal clips that fit into the tongue-and-groove joint and bent around the top chord of the joist. These clips were located at each intersection of a joist and a longitudinal joint. Along each longitudinal edge, where there were not joints, large head nails were driven through the planks into the top chords of the joists. Figure 1 shows the specimen during placement of the roof planks.

Long length 6 in. wide strips of perforated No. 15 roofing felt were laid over all the joints between the roof planks and the entire surface was mopped with hot asphalt at the coverage of 1 $gal/100\ ft^2$. Full 36 in. width strips of felt were laid on with hot asphalt mopped on between strips at the coverage of 1 $gal/160\ ft^2$. Each strip overlapped 27-1/2 in. of the width of the preceding one to provide a four-ply roof. After all the roofing felt was down, the entire surface was covered with a hot asphalt flood coat of 1 $gal/24\ ft^2$ and slag was spread on at 3 lb/ft^2 coverage.

The 3/4 in. steel furring channels were tied transversely to the bottom chords of the joists at 16 in. oc. Each length of channel was cut to provide about 1 in. clearance from the furnace wall at each end. The V-rib expanded metal lath was tied to the furring channels, with the V-ribs transversely thereto. Six inch wide strips of flat expanded metal lath were bent longitudinally and attached to the ceiling lath and to the furnace wall around the ceiling periphery. Wooden ground strips for 11/16 in. thickness of plaster were tied to the bottom face of the metal lath.

The scratch coat plaster was mixed 1 bag (nominal 100 lb) of gypsum to 2 ft^3 of expanded perlite plaster aggregate, applied, and scratched. The brown coat was mixed 1 bag of gypsum to 3 ft^3 of expanded perlite and was applied out to the grounds. The wooden strips were removed and their places filled with plaster. The ceiling was given a 1/16 in. white finish coat to make a total thickness of 3/4 in. of plaster, measured from the bottom face of the metal lath.

3. TEST METHOD

The specimen was tested in general compliance with the methods defined in the Standard Methods for Fire Tests of Building Construction and Materials, ASTM E-119.

3.1 Furnace

The furnace was in the shape of a large, fire-brick lined box with the specimen filling the otherwise open top. The furnace was equipped with a steel frame to restrain and support the specimen, with gas-air burners, thermocouples, loading apparatus, means for measuring deflections, and windows through which the exposed surface was observed during test.

3.2 Aging

The specimen was aged 32 days from the day the brown coat plaster was applied. During the latter part of this period, the furnace chamber was closed with a dehumidifier operating inside to assist the natural drying of the specimen.

3.3 Loading

The design load was computed at 85.4 lb/ft^2 from the load tables of the Steel Joist Institute, for SJ 102 joists at the spacing and clear span in the test specimen. The nominal dead weight was 21.1 lb/ft^2. Therefore, the applied live load was 64.3 lb/ft^2. The load was distributed by a hydraulic system to 36 steel channels on the unexposed surface, each 5 in. wide and 24 in. long. The channels were in six rows of six each. Each row was centered above a joist and the channels in each row were spaced 27 in. oc along the joist.

3.4 Temperatures

Temperatures were measured by means of thermocouples connected to self-balancing potentiometers calibrated to read in degrees centigrade. Thermocouples were placed in the furnace chamber, on the steel joists, the unexposed surface, on the back of the metal lath, in the plenum air space, and on the top surface of the fiber roof planks. Those in the furnace chamber were in porcelain insulators and encased in wrought iron pipes; the others were in glass fiber sleeving. The furnace fires were controlled to produce average temperatures as close as feasible to those defined by the Standard Time-Temperature Curve in ASTM E-119, which include: 1000°F at 5 min, 1300°F at 10 min, 1550°F at 30min, 1700°F at 1 hr, 1850°F at 2 hr, and 1925°F at 3 hr.

3.5 End Point Criteria

The Standard Test Method, E-119, required that : 1) the specimen continued to sustain the applied load; 2) flames, or gases hot enough to ignite cotton waste, not have passed through the specimen; 3) transmission of heat through the specimen not have been such that the average temperature of the unexposed surface had increased 250 degrees F nor the one-point temperature increased 325 degrees F above their initial values. The fire endurance was defined as the time at which the first of these end points was reached, with correction to the time for variation, if any, of the furnace temperatures from those defined.

4. RESULTS

All times were from the start of the test. By 39 min, a full length crack had developed in the plaster about 3 ft from the East wall, another ran all but about 1 ft of the width along the centerline, and several other transverse cracks were 3 to 8 ft long. From 58 min to 1 hr 4 min several thumps were heard, probably the sounds of welds breaking. At 1 hr the maximum net deflection of the floor was 1.3 in., the average temperature of the bottom chords of the joists was 642°F, and on the unexposed surface was 67 deg F above the initial. At 1 hr 25 min the deflection had reached 3.2 in. and was increasing so rapidly that load failure was taken to have occurred. By 1 hr 30 min, there were numerous cracks over the ceiling, the deflection had reached 5 in., was increasing rapidly, and the applied load was removed. The temperatures of the bottom chords averaged 903°F and those on the unexposed surface had risen 95 deg F above the initial. By 2 hr the room outside the furnace was filled with smoke despite ventilation, the deflection had reached 6.1 in. without applied load, the average temperature of the bottom chords was 1051°F, and the unexposed surface average had risen 108 deg F above the initial. The maximum one-point rise was 122 deg F. The ceiling surface was wavy and covered with cracks. At 2 hr 13 min the asphalt was bubbling on the unexposed surface. At 2 hr 38 min flames issued into the furnace chamber from the specimen and thick yellow smoke issued from the unexposed surface. By this time the maximum deflection had exceeded 10 in., the bottom chord average temperature was 1193°F, and the unexposed surface temperature at one point had reached the limiting rise of 325 deg F. The roof surface burst into flames at 2 hr 45 min. The furnace fires were shut off and a water stream played on the burning roof. The roof fires were extinguished with difficulty and

reignited frequently up to 2 hr after the end of the test, despite almost continuous application of water.

The roofing was pulled off disclosing that the roof planks had been charred through from half to all of their thickness, leaving a black or gray powdery residue. All of the joists were bowed down and several had relatively sharp bends in the top chords, as shown in figure 2. Three of them had maximum deflections of more than 10 in. from their original positions. Several of the welds between joists and the furnace bearing angles were broken. The plaster was cracked badly but most of the scratch and brown coats remained in place.

The following is a summary of the deflections at the North and South quarter points and the center, along the longitudinal centerline, observed during the test. They are net deflections under fire exposure, and do not include the initial deflection as the result of load application:

Time	North	Center	South
0:00	0	0	0
:15	0.2 in.	0.2 in.	0.2 in.
:30	.2	.3	.3
:45	.4	.8	.4
1:00	.9	1.4	.8
1:15	1.4	2.0	1.0
1:30*	4.3	5.0	---
1:45	4.4	5.2	1.8
2:00	5.2	6.1	2.2
2:15	6.1	7.1	3.0
2:30	7.1	9.0	4.1
2:40	8.2	>10.	5.0

* Load removed shortly after these observations.

The fire endurance of the particular roof deck tested was limited by load failure at 1 hr 25 min. The one-point maximum temperature rise on the unexposed was reached at 2 hr 38 min, followed by ignition of the roofing asphalt at 2 hr 45 min. By the end of the test, the average temperature of the bottom chords had exceeded 1200°F and the maximum exceeded 1300°F; those of the top chords were essentially the same. Much of the reduced temperature data are given in figure 3. The fire exposure severity, defined as the ratio of the area under the curve of average furnace temperatures to the area under the standard curve, was 102.2 percent up to the time of load failure and 101.7 percent for the full duration. The correction to the fire endurance, computed by the formula given in E-119, was plus 2 min. Therefore, the corrected fire endurance of the roof deck-ceiling assembly tested was 1 hr 27 min.

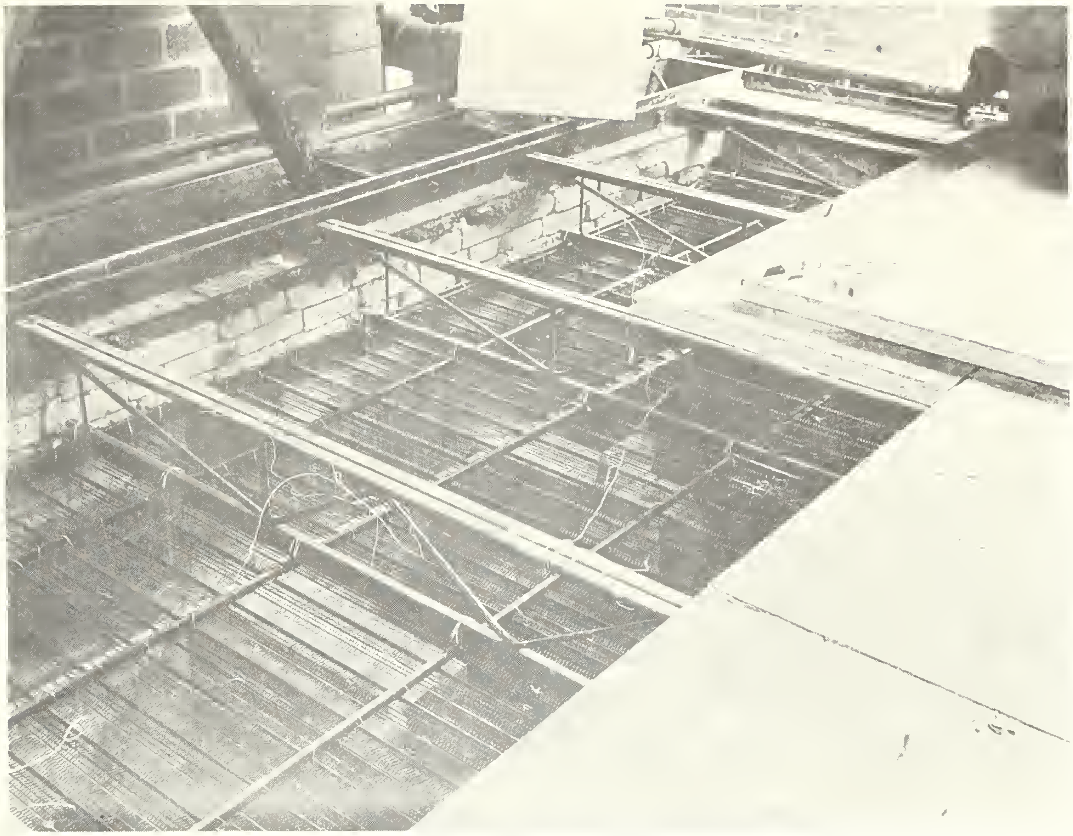
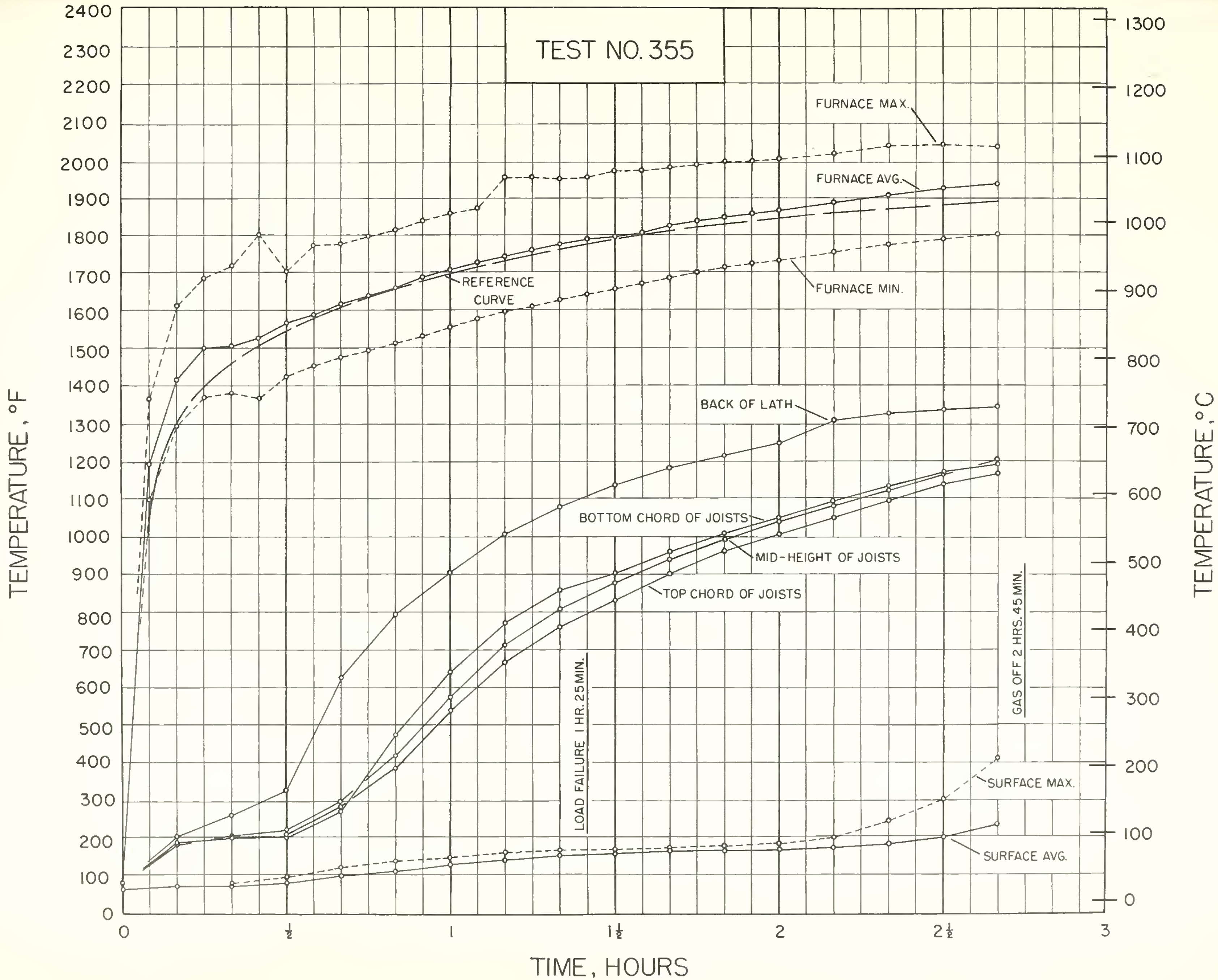


Fig. 1. Joists; furring channels and v-rib metal laths for ceiling; bonded-fiber roof planks being placed.

Fig. 2. Joists and top of ceiling after removal of much of roof deck.


TEST NO. 355
FURNACE MAX.
FURNACE AVG.
REFERENCE CURVE
FURNACE MIN.
BACK OF LATH
BOTTOM CHORD OF JOISTS
MID-HEIGHT OF JOISTS
TOP CHORD OF JOISTS
LOAD FAILURE 1 HR. 25 MIN.
GAS OFF 2 HRS. 45 MIN.
SURFACE MAX.
SURFACE AVG.
TEMPERATURE, °F
TEMPERATURE, °C
TIME, HOURS

THE NATIONAL BUREAU OF STANDARDS

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