NATIONAL BUREAU OF STANDARDS REPORT

5821

FIREPROOFING STRUCTURAL STEEL

by
E. W. Bender

U. S. DEPARTMENT OF COMMERCE
NATIONAL BUREAU OF STANDARDS

THE NATIONAL BUREAU OF STANDARDS

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NBS PROJECT		NBS REPORT
1002-20-4875	March 27, 1958	5821

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E. W. Bender

Report to
Office of the Chief of Engineers
Bureau of Yards and Docks
Headquarters, U. S. Air Force

U. S. DEPARTMENT OF COMMERCE
NATIONAL BUREAU OF STANDARDS

FIREPROOFING STRUCTURAL STEEL

ABSTRACT

An investigation of the effectiveness of fire-retardant materials which can be applied directly to structural steel members by spray techniques has been initiated. Test specimens have been prepared with protective coatings applied in three different thicknesses by a number of manufacturers, using normal field methods of application. Results of fire tests on specimens protected by 1/2 in. fire-retardant coatings are reported.

1. INTRODUCTION

In certain types of buildings such as aircraft hangars, it is common procedure to leave the structural steelwork unprotected. In cases where automatic sprinkler protection cannot be furnished, the fire hazard may be high and losses great. There are on the market today various materials which can be applied by spray techniques directly to the steelwork, and which are claimed to be useful for protection against fire. The aim of this investigation was to obtain performance data on these materials.

2. MATERIALS

A metal support structure to be fire-tested consisted of a 2-ft square, 16 ga, hot-rolled steel plate, spot-welded to a grid composed of 3/4 in. cold-rolled plasterers' furring channels. Specimens of these structures were sent to various manufacturers to be coated with fire-retardant materials in three different thicknesses, namely, 1/2 in., 1-in., and 2-in. Each manufacturer was supplied with four specimens for each thickness, two with the hot-rolled finish as received, and two shop-coated. Metal grounds were welded around the periphery of the surface to be coated, to insure obtaining the proper thickness of the fireproofing. Only the specimens coated to a thickness of 1/2 in. are included in this report.

The fire-retardant coatings were said to have been applied with the same equipment and techniques normally used in the field. In surface finish the coatings ranged from a felted nap-like finish to a hard troweled finish, and the materials ranged in density from 12.2 to 64.9 lbs/ft^3 or 0.52 to 2.7 lbs/ft^2 for

a 1/2 in. thickness. Following is a list of the manufacturers who applied the materials tested, together with a brief note regarding the major components of each product:

Air-O-Therm Application Company
Jet-Sulation
A mixture of all glass fibers and binder.

Columbia Acoustics and Fire Proofing Company
Cafco Spray Standard Fiber
A mixture of all glass fibers and binder.

Keasbey and Mattison Company
Sprayed "Limpet" Asbestos
A mixture of all asbestos fibers and Portland cement binder.

Larson Products
"Plaster Weld"
A liquid bonding agent for plaster. A plaster of perlite, asbestos fiber, and gypsum was applied over the "Plaster Weld" by means of a plastering machine.

National Gypsum Company
Thermacoustic
A mixture of mostly glass with some asbestos fibers.

Smith and Kanzler Jetbestos Inc.
Spray Craft
A mixture of glass and asbestos fibers and binder.

United States Gypsum Company
Audicote
A mixture of perlite, bentonite clay, and asbestos fiber.

Zon-O-Lite Company
Zon-O-Lite Acoustical Plastic
A mixture of vermiculite, bentonite clay, and asbestos fiber.

3. METHOD OF TEST

The tests were performed in a firebrick furnace that forms a cube-shaped combustion chamber, the specimen, with the fireproofed face down, providing the cover for the cube. The furnace is gas fired and vented by means of a baffled flue and chimney to the outside. The temperature in the the combustion chamber is automatically regulated so that it follows the time-temperature curve prescribed in ASTM Spec. E119

Standard Curve for Fire Tests. The times and temperatures specified are 1000°F at 5 min, 1700°F at 1 hour, 2000°F at 4 hours, and 2300°F at 8 hours.

The specimen is placed over the top of the combustion chamber, with 1/2 in. of the face of the specimen resting on the firebrick wall on all sides. An asbestos or mineral wool gasket is placed around the edges of the specimen to minimize heat flow from the specimen.

A transducer made of insulating firebrick, 2 ft long by 12 in. wide by 1 in. thick, is placed over the channel iron backing of the specimen plate. The underside of the transducer is blackened and thermocouples are placed on the under and upper surfaces. Two pieces of asbestos millboard, 24 in. long by 6 in. wide and 1/2 in. thick, with thermocouples placed on the upper and lower surfaces, are laid on either side of the transducer. Thus, a 3/4 in. sealed air space is formed by the millboard and transducer and the 16 ga steel sheet of the specimen. A thermocouple is placed on the geometric center of the steel sheeet to indicate the temperature on the unexposed face of the fireproofed specimen. The transducer gives an indication of the heat flow from the combustion chamber through the fireproofing and steel sheet.

A reinforced sheet-metal pan, 43 in by 43 in. with 2-in. high sides, is suspended from the ceiling of the test room. This pan is held 8 in. above the top of the transducer with the center of the pan above the center of the specimen. Water is piped to the pan and the outlets are arranged so that 1/2 in. of water covers the bottom of the pan at all times. Records of the water flow rate and the temperature of water entering and leaving the pan provide another method of measuring heat flow from the specimen.

The end point of the test was considered reached when the temperature on the unexposed surface of the steel plate reached 1000°F.

4. RESULTS

The density, weight per sq ft for 1/2 in. application, and time to reach 1000°F on the steel plate are given in Table 1. The materials are listed in order of performance in the fire test, that with the longest average endurance being listed first.

5. DISCUSSION OF RESULTS

The Plaster Weld plus gypsum-perlite plaster would be expected to give the best fire resistive performance of the group, inasmuch as gypsum has more chemically combined water than any other of the materials tested. This reasoning was supported by early results in the tests of this combination, which gave lower steel plate temperatures than any other material until the plaster fell from the plate at 11 minutes. At that time the stresses developed by shrinkage of the dehydrating gypsum and expansion of the heating metal were such as to shear the plaster from the surface of the plate.

The results obtained with the other materials tested are shown graphically in Figure 1 where density in lbs per ft^3 is plotted against time required for the steel plate to reach 1000°F. All of these materials contained either asbestos or glass fibers, or a mixture of the two. Although no attempt was made to determine the composition of the various binders, it appears that, where the fire retardant components consisted entirely of glass fibers or a mixture of glass and asbestos fibers, the fire endurance varied with the density of the material. The mixture of vermiculite, bentonite clay, and asbestos showed a similar relation between fire endurance and density. However, the mixture of perlite, bentonite clay, and asbestos, and also the material consisting entirely of asbestos fibers, showed greater fire endurance for a given density than the other materials tested.

The fire endurance data given in this report may be used in estimating the protection which might be obtained for a roof, floor, or ceiling section. Predictions of the endurance of columns, beams, or braces from these data is not simple, although it is expected that some estimates of this type may be feasible with use of the analog computer. The endurance of 1-in. thick and 2-in. thick materials will be reported when the tests are finished.

6. CONCLUSIONS

Seven materials continued to bond to the steel plate for the duration of the fire exposure. The results indicate that these seven materials show some merit for use as fire-protective covering when applied directly to steelwork.

TABLE 1

Fire Test Results On Specimens with One-Half Inch Fireproofing

Manufacturer and Material	Finish on Plate and Specimen Number		Density lbs/ft^3	Weight for $\frac{1}{2}$ In. Thickness lbs/ft^2	Time Steel Plate reached 1000°F Min:Sec	Fiber or Mineral
Natl Gypsum Co.						
Thermacoustic	Unpainted	7	27.2	1.13	66:00	Glass & asbestos
do	Unpainted	8	24.3	1.00	56:35	
do	Shop-coated	65	28.4	1.18	88:00	
do	Shop-coated	66	28.1	1.17	71:00	
	Average		27.0	1.12	70:24	
U. S. Gypsum Co.						
Audicote	Unpainted	49	20.3	0.85	63:00	Perlite & Asbestos
do	Unpainted	50	20.7	0.86	57:33	
do	Shop-coated	107	17.5	0.73	40:00	
do	Shop-coated	108	17.6	0.74	41:05	
	Average		19.0	0.80	50:24	
Air-O-Therm Application Co.						
Jet-Sulation	Unpainted	13	26.4	1.10	38:30	All glass
do	Unpainted	14	25.1	1.05	43:25	
do	Shop-coated	71	21.4	0.89	45:00	
do	Shop-coated	72	15.9	0.66	35:00	
	Average		22.2	0.93	40:29	
Keasbey & Mattison Co.						
Limpet	Unpainted	25	12.9	0.54	43.35	All asbestos
do	Unpainted	26	13.2	0.55	35:00	
do	Shop-coated	83	12.4	0.52		
do	Shop-coated	84	12.7	0.53	37:58	
	Average		12.8	0.54	38:51	
Zon-O-Lite Co.						
Zon-O-Lite Acoustical						
Plastic	Unpainted	37	16.8	0.70	29:20	Vermiculite & asbestos
do	Unpainted	38	16.9	0.70	32:50	
do	Shop-coated	91	18.0	0.75	45:45	
do	Shop-coated	92	16.8	0.66	35:00	
	Average		17.1	0.70	35:44	
Smith & Kanzler						
Jetbestos Inc.						
Spray Craft	Unpainted	31	21.1	0.88	63:05	Glass & asbestos
do	Unpainted	32	16.3	0.68	32:00	
do	Shop-coated	85	16.7	0.70	25:00	
do	Shop-coated	86	15.2	0.64	22:05	
	Average		17.3	0.73	35.33	

TABLE 1 (continued)

Manufacturer and Material	Finish on Plate and Specimen Number	Density	Weight for ½ In. Thickness	Time Steel Plate reached 1000°F	Fiber or Mineral
		lbs/ft^3	lbs/ft^2		
Columbia Acoustics and Fireproofing Co.					
Cafco Spray	Unpainted 1	18.3	0.76	35:00	All glass
Standard Fiber	Unpainted 2	16.7	0.70	33:45	
do	Shop-coated 55	13.5	0.56	37:20	
do	Shop-coated 56	14.1	0.59	35:00	
	Average	15.65	0.65	35:16	
Larson Products					
Plaster Weld	Unpainted 43	54.7	2.3	25:00 *	Perlite
do	Unpainted 44	64.9	2.7	32:45 *	asbestos
do	Shop-coated 97	52.0	2.2	21:05 *	gypsum
do	Shop-coated 98	47.8	2.0	21:45 *	
	Average	54.8	2.3	25:09	

* Plaster fell from steel plate at approximately 11 min in all these tests.

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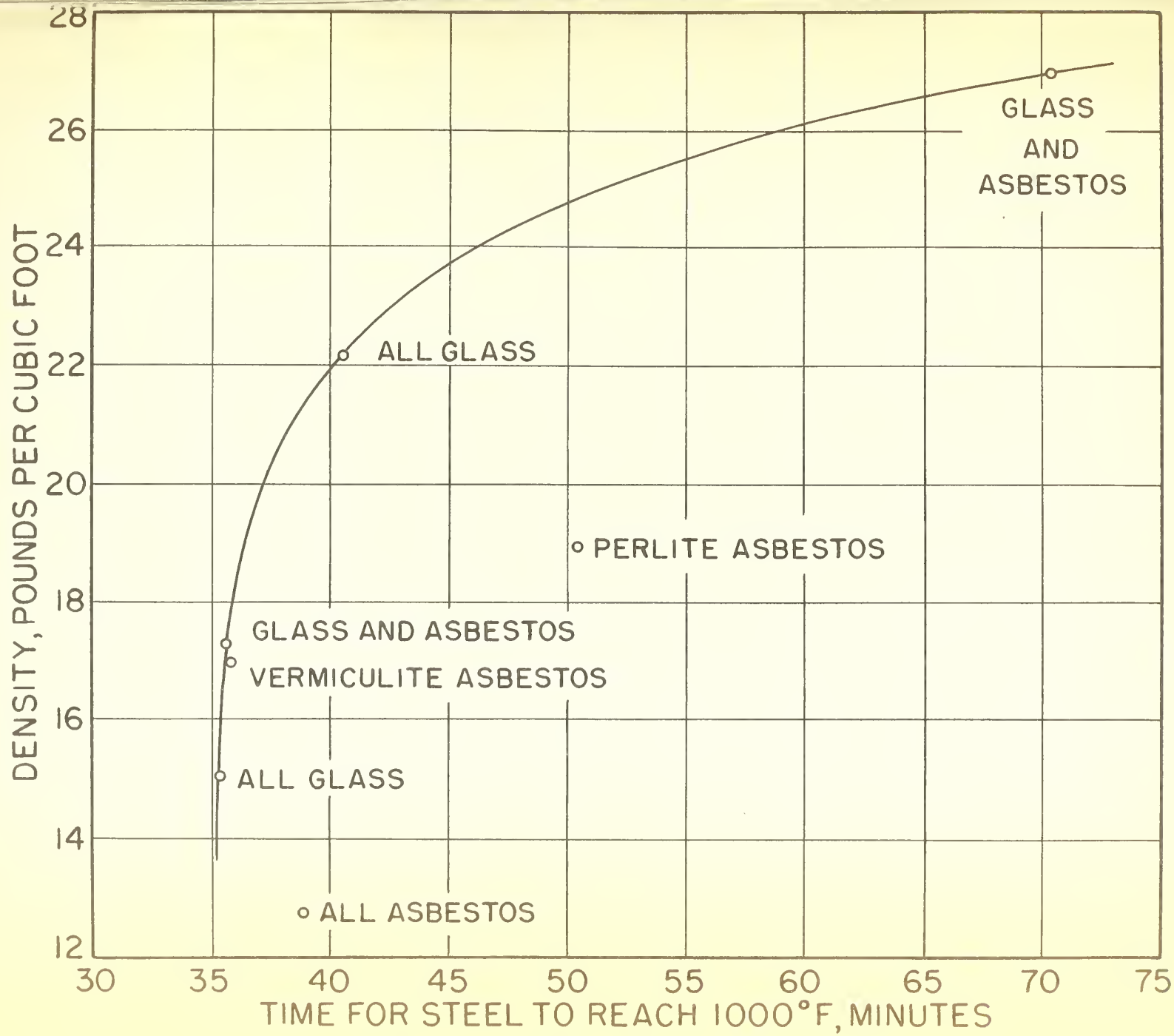

FIG. 1.—FIRE ENDURANCE

U. S. DEPARTMENT OF COMMERCE
Sinclair Weeks, *Secretary*

NATIONAL BUREAU OF STANDARDS
A. V. Astin, *Director*

THE NATIONAL BUREAU OF STANDARDS

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