NATIONAL BUREAU OF STANDARDS REPORT

10 096

REVIEW OF DRAFT
ON
"FIRE-RESISTIVE STANDARDS FOR MATERIALS OF CONSTRUCTION"

U.S. DEPARTMENT OF COMMERCE
NATIONAL BUREAU OF STANDARDS

NATIONAL BUREAU OF STANDARDS

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[1] Headquarters and Laboratories at Gaithersburg, Maryland, unless otherwise noted; mailing address Washington, D.C. 20234.
[2] Located at Boulder, Colorado 80302.
[3] Located at 5285 Port Royal Road, Springfield, Virginia 22151.

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REVIEW OF DRAFT
ON
"FIRE-RESISTIVE STANDARDS FOR MATERIALS OF CONSTRUCTION"

by

I. Benjamin, L. Issen and H. Shoub

Prepared for

State of Wisconsin
Department of Industry, Labor, & Human Relations

U.S. DEPARTMENT OF COMMERCE
NATIONAL BUREAU OF STANDARDS

Review of Draft
on
"Fire-Resistive Standards for Materials of Construction"

Ind 51.04 - Scope

Suggested change--This section shall include standards applicable to various types of fire-resistive construction.

Reason--Some of the standards included herein are not fire-resistive standards. However, the standards are applicable to fire-resistive construction.

Ind 51.041 - Definitions

(1) Automatic--Suggest changing the words "smoke density" to "combustion products."

Reason--The term "combustion products" has a broader scope and allows for a wider range of detection devices.

(2) Ceiling protection--Suggest deletion.

Reason--Problems have arisen because people think a ceiling protection has an intrinsic value separate from the construction itself. If it is defined, we suggest it be defined as follows:

> "The fire protection membrane suspended beneath the floor or ceiling construction which, when included with the construction, develops the fire-resistive rating for the overall assembly."

(6) Fire door--Suggest deletion.

Reason--Fire doors do not exist per se; they only have meaning when they are mounted in an assembly. This definition gives the idea that you can have a fire door without giving consideration to the whole assembly. The next item, fire door assembly, covers the definition.

(8) Fire-resistive classification--Suggest change to make the definition consistent with that in ASTM Standard E176--as follows:

> Fire-resistive classification--a measure of the elapsed time in hours during which a material or assembly continues to exhibit fire resistance under specified conditions of test and performance. As applied to elements of buildings,

it is measured by the "Methods of Fire Test of Building Construction and Materials", ASTM Designation E119; "Methods of Fire Test of Door Assemblies", ASTM Designation E152; or "Methods of Fire Test of Window Assemblies", ASTM Designation E163.

(11) Fire-resistive protection--Suggest change as follows:

> An insulating material applied directly, attached to, or suspended from a structural assembly, to contribute to the fire-resistive classification of the overall construction.

Reason--As indicated in (2) Ceiling Protection, we feel it important to convey the idea that the fire protection is not valid as a separate item, but only as part of the overall construction.

(13) Fire-retardant roof coverings--Suggest elimination of subparagraphs a, b, and c and substitute:

> Roof coverings are classified in accordance with ASTM Standard E108 A, B, or C depending upon the severity of the test exposure to which they are subjected.

(15) Fire window assembly--Suggest addition at the end of sentence as follows:

> .... to give protection against the passage of flame, in accordance with ASTM Standard E163.

(20) Non-combustible material--

Suggested change no. 1--Eliminate paragraph 3.

Suggested change no. 2 (alternate)--Eliminate definition (20) Non-combustible Material and change definition (19) Non-combustible Construction to read as follows:

> An assembly such as a wall, roof or floor which will not contribute more than 2,000 Btu/sq. ft. of projected surface to the fire load of the building; nor shall any item in the construction have a flame spread of greater than 25.

Reason--The definition proposed for non-combustible material does not satisfy the desired need and can be dangerous. The normal use of the

definition in the code has been to define non-combustible constructions for unlimited area fire-resistive types of construction. However, the accepted concept has been that the material does not have to be completely noncombustible. If we truly wanted non-combustible material then paragraph 1 of the definition (20) would be adequate. ASTM E136 by itself adequately measures the noncombustibility of materials. However, the desire of most building code officials has been to have something of "low combustibility." For example, gypsum wallboard would not pass E136 but is considered to be of low enough combustibility to be used in "non-combustible" construction.

Therefore, as a result of this semantic compromise; or misuse of the word "non-combustible", the proposed three-part definition has been used. However, it should be pointed out that under part 3 of this definition fire-retardant treated 3/4-inch plywood or fire-retardant treated plastics could be classed as noncombustible. This not only represents an anomalous situation but directly contravenes the concept of the code in calling for non-combustible construction. For example, using the proposed three-part definition one could build a floor using a steel-bar joist construction with fire-retardant treated plywood over the top and have this qualify for a non-combustible construction. As a more extreme example, one could build a plastic structural member out of fire-retardant treated plastic and have it qualify as a non-combustible member. We know of a recent case where a building department was asked to classify a fire-retardant plastic as noncombustible.

To preclude these undesirable situations, we have suggested two alternative choices. The first choice--that of eliminating paragraph 3 from the definition--allows a truer definition of noncombustible, as the code wishes to use it. If for some reason the building code official wishes to use other materials in non-combustible constructions, exception can be made in the code; they can be used without trying to call obviously combustible materials noncombustible.

The second choice, which is our recommendation, comes closer to the concept of what the code is trying to achieve--basically to eliminate the use of combustible materials in certain assemblies. Also, the idea is to limit the total amount of combustibles which can contribute to a major fire. Therefore, we believe it is more logical to limit the total amount of heat energy (Btu) in the construction, without attempting to define the combustible or non-combustible material per se. The second definition, as suggested, will allow for control of building construction without trying to "define the undefinable."

Ind 51.042 - General Requirements

(1)(a) - Connection of Structural Members

Suggested change--The minimum fire-resistive protection of a connection shall be equal to the maximum required for the two members to which it is attached.

Reason--Where beams frame into columns, the fire-resistive protection of the column is quite often required to be 1 hour more than that of the beam. The connection should therefore contain the same protection as for column.

(1)(b) - Suggested change--For structural components with a fire-resistive rating obtained by a test conducted with restrained end, data on the design of the structure shall be provided to show that the supporting structure can provide external restraint.

Reason--In most cases the amount of restraint developed during a test is undetermined, and therefore the requirement of designing a structure for an unknown quantity is impossible to meet. The suggested change is less specific and allows for engineering judgment.

As further comment, the requirement of designing for restraint becomes even more questionable when one considers that the restraint provided for a small beam in a test furnace is not necessarily the same as that required for a large-scale beam on a 40-, 60- or 80-foot span. Is the restraint to be scaled up in proportion to the cross-sectional area or if not, by what other procedure?

Since restraint is so indeterminate, the last meeting of ASTM Committee E5 Sub I task group on beams agreed upon a new system for evaluating beam performance. They have suggested a threefold requirement for beams tested with restrained ends, as follows:

1. For beams tested under restrained conditions the beam shall sustain the design load for the full rating required.

2. The temperatures in the steel part of the beam shall not exceed the temperature limits given below for one-half the desired rating and not less than 1 hour. The temperature limits being as follows:

    a. For structural steel, 1100° average on the section or 1300° maximum at an individual location.

    b. For reinforcing bars, 1100° average.

    c. For cold-drawn prestressing wire, 800 °F average.

3. The supporting structure should be capable of providing restraint.

These provisions have not yet been adopted by ASTM, but were agreeable to all the building materials interest present and the code body representatives at the meeting. We suggest that this provision may be a desirable addition to (1)(b) of this draft.

(1)(c) - ASTM Standard Methods of Test

Suggest change to read ".... shall be accepted at this time and reviewed every three years."

Reason--The test methods of ASTM have changed over the years as refinements of fire test procedures have developed. For this reason, some of the tests which were conducted in the past are no longer reproducible. These tests, though they were valid tests at the time and are now listed for fire-resistance ratings, are no longer valid. For this reason, it behooves the State to eliminate the grandfather clause and start a review of the invalid ratings.

(1)(d) - Suggest change to read as follows:

> The fire-resistive requirements for floors shall be either Class A or Class B, as developed from the ASTM Standard Test E119. For both Class A and Class B fire-resistive floors the requirements of the conditions of acceptance listed in Section 25a of the Standard shall be as given.
>
> For Class A fire-resistive construction the requirements of 25b shall be as given. For Class B fire-resistive requirements the conditions of acceptance in Section 25b shall be met for one-half the required fire endurance time but not less than 1 hour.

Reason--The concept which you have introduced in this section is an innovation in this country which has great merit. We have attempted to put this concept into more formal form. The temperature transmission requirements of the section may be considered from two points of view:

1. Life safety and

2. Property containment.

We have prepared figure 1 of this report to give some idea of the critical time for the evacuation of a floor which would be subject to a fire exposure. We have picked 180 °F as a limiting temperature--to represent the maximum temperature that could exist on a floor surface and yet allow a person to rapidly pass over for evacuation. From the figure, a floor 3-1/2-inches thick of Type I concrete, would allow an evacuation time of about 25 minutes before the floor gets too hot to step over in the local area where the direct fire exposure has occurred.

The other aspect of life safety has to do with fire-fighting personnel. Since we have maintained the structural integrity of the floor for the full rated period, there would not be any danger to fire-fighting personnel who may have to attack a prolonged fire.

In regard to fire containment, we have searched the NFPA fire records and other sources and find that there is essentially no recorded data of fire transmission having occurred through a floor of an office building. This may indicate that we are designing just right or overdesigning--and our judgment is that these floors have been overdesigned for temperature transmission. The suggested change is conservative since it would require a minimum of 1-hour temperature transmission requirements--so that the temperature could not be above an average value of approximately 325° at the end of an hour regardless of the required rating. For a 3-hour fire-resistive floor, it would take an hour and a half to reach this limit.

The only time where a fire might occur which would exceed this would be in a heavily loaded warehouse, which can have a very large fire load. The only two cases where we have been able to document fire spread by temperature transmission have both been in warehouse situations. Since a warehouse may tend to be of unlimited fire loading, we believe that the Class A or more restrictive containment provisions should be maintained.

For the institutional occupancy, since there can be some delay in evacuation--particularly in hospitals or jails, we suggest that the Class A or more restrictive temperature transmission requirement might be maintained to allow more evacuation time if needed.

In view of the available data we would suggest that the Class B requirement for fire resistance could be applicable to all types of constructions except warehouse and institutional occupancies. In case of office construction we would estimate that this could result in savings of 10 to 30 cents a square foot in cost.

The British in their new building code have further extended this concept to exterior non-load bearing walls. This would require some extensive revisions to other parts of the code in order to be effective and might be considered for future revisions.

To supplement the above discussion we have added to table 2 extra columns which would give the slab thicknesses required for Class B type of fire-resistive constructions.

Comments on Table 2

To facilitate comments on table 2, the rows of structural components have been numbered from 1 to 28, and the comments are ordered in this manner, following general comments on the notes.

Note a

Suggested change--For Type 3 add to last sentence--Includes sanded lightweight concretes, not over 115 lb/cu ft oven-dried density.

Reason--Most fire test data has been for lightweight concretes in the range of 105 to 110 lb/cu ft. We would consider 115 lb/cu ft the upper limit for which the ratings are valid under Type 3 aggregate classification.

Note c

Suggested change--This note is technically incorrect and should be deleted. The "U" value of the construction has no relationship at all to the fire protection. The location of the insulation in respect to the fire exposure and the specific heat of the overall construction are far more important factors. If changes are made, there should be some justification for them other than "U" factor equivalents.

Note d

Suggest elimination since we have included Class A and Class B requirements for fire resistance.

Note k

Suggest elimination since suggested changes to table clearly delineate simple and continuous span constructions. It will not be in rows 6 to 10 if it is continuous.

Note n

Suggest elimination for same reason as note k.

Suggested changes have been indicated on table 2 blueprint attached.

Comments on Table 2 Changes

Row 1 - Columns

Suggested change--To provide for columns with minimum dimension of not less than 10 inches and 120 square inch area.

Reason--The only available tests of reinforced concrete loaded columns dates back to Bureau of Standards Technologic Paper No. 184 and No. 272. The smallest column tests were 110 square inches round and square, about 13-1/2 inches diameter or 10-1/2 inches on a side. Present practice uses higher strength concretes and higher load factors than we used at the time of these tests. In the Ingberg test, the load factors were about 0.3 whereas current design practice uses load factors in the order of 0.5. That is present design allows for loading to a higher percentage of the ultimate strength. The changes in design practice would lead to the conclusion that, if anything, the requirements for columns should be more restrictive than those that were tested--in view of the well-known information indicating that fire resistance is inversely proportional to the load factor.

Row 2 - Girders

Suggested change applicable to rows 2, 3, 4 and 5. These rows should all contain the words "continuous design" or "design for continuity." The reinforcing cover shown in these rows would only be valid if continuity were present.

Suggested change--We have added an asterisk to the cover for Type 2 aggregates in row 2, to indicate that members for 3 and 4 hours using Type 2 aggregates should have supplemental reinforcement of welded wire fabric or rebars to prevent spalling.

Reason--Certain types of siliceous aggregate are worse than others in regard to spalling, but, in general, experience both with columns and beams has indicated that siliceous aggregates tend to spall when the cover over the reinforcing is of too great a depth. This spalling can be prevented by use of supplemental reinforcing approximately 1 inch from the face of the beam.

Row 3 and Row 4 - Concrete Joists and Slabs

Suggested change--Add a note to indicate that the definition of t_2 is given in row 10.

For rows 3 and 4 we have also shown "t" requirements for the Class B fire-resistive construction in additional columns.

Row 5 - Walls and Partitions

Suggested change--The thicknesses required for the different ratings have been changed as indicated.

Reason--We have changed these requirements to agree with those indicated in the Fire Protection Handbook, Section 8, page 100. This data is less conservative than the data that Mr. Menzel developed at PCA several years ago. However, we feel that it is the best data available. We believe that it is more realistic than the thicknesses indicated.

Rows 6, 7, 8 and 9 - Concrete Beams and Joists

We would like to discuss these rows together.

Suggested change--For rows 7, 8 and 9 the slab thickness requirement would be the same as indicated in rows 3 and 4 for both Class A and Class B requirements.

Suggested change--Make rows 7, 8 and 9 the same as row 6 and show asterisk on Type 2 aggregates for 4-, 3- and 2-hour fire-resistive requirements.

Reason--We do not believe there is any difference between the performance of the beams in rows 6, 7, 8 and 9. They should all reflect the same requirements. In addition, we believe that the Type 2 aggregates should have supplemental reinforcing for the heavy covers indicated.

Field experience with fires has indicated that very thin webs, in the range of 2 inches, are quite sensitive to spalling. Therefore, we also question the 2-1/2-inch webs previously shown in row 9 as being inadequate protection.

Row 10 - Concrete Slabs

Suggested change--Equivalent thickness equal to Total Concrete Area divided by Width. Also add asterisks to indicate that listed precast units may be used in lieu of the specified dimensions.

Comment--There is some unpublished data to indicate that 1-inch minimum shell thickness on the fire side of a cored section may not be enough to provide structural integrity. Therefore, it is also suggested that until more data becomes available a minimum shell thickness of at least 1-1/4 inch or possibly 1-1/2 inch should be specified.

Rows 11 and 12 - Walls and Partitions

Suggest the same thicknesses as indicated in row 5.

Reason--The temperature transmission for an equivalent thickness of concrete is the same regardless of whether the wall is bearing or nonbearing, or reinforced or unreinforced concrete.

Row 14 - Steel Columns

Suggested change--Include statement limiting to 8 inches or larger columns.

Reason--This is consistent with table 8-7e of the Fire Protection Handbook. The reasons indicated in row 1, namely that no data has been run since the early 20's, are applicable here. If 6-inch columns are to be included then another column should be indicated with slightly higher covers as shown in table 8-7e of the Fire Protection Handbook.

Row 15 - Steel Girders

Suggested change--Add 8 inch minimum flange width.

Reason--This is taken from table 8-7d of the Fire Protection Handbook and is for beams with flanges of 8 inches or greater. For reasons given above, these limitations should be maintained. Using the same table, the 1-1/2 shown for Type 2 should be 1-1/4 for 2 hours.

Row 17 - Concrete Joists and Waffles

Suggested change--The values indicated should be for Type 1 and Type 3 aggregates only.

Reason--This data is taken from the fire-resistance ratings of AIA on page 46, and the listing as specifically indicated there is for limestone concrete only.

Row 21 - Partitions

Suggested change--Values indicated should all be moved over to show 1 hour greater rating.

Reason--These values are given on pages 127 and 131 of the fire-resistance ratings published by AIA. They are all shown for 1 hour more than indicated on the table. We presume this is a transcription error.

Row 24 - Partitions

Suggested change--The indicated ratings should be increased by 1 hour. These ratings are shown on pages 134 and 136 of the AIA fire-resistance ratings and are given as 1 hour more than indicated on the table. Again, probably a question of transcription error.

Row 25 - Wood Columns

Suggested change--Minimum normal width of columns 12 by 12.

Reason--Data for wood columns is rather scarce. However, UL Research Bulletin No. 13 indicates that a 12 by 12 column is required for a 1-hour fire-resistive rating. In addition, that column should be protected by a non-conductive, non-combustible cap. Some recent data by the British Research Station on laminated timber columns also indicates a minimum dimension of 300 mm for a 1-hour rating which checks well with the 12 inch found back in the 20's.

Row 26 - Wood Girders

Suggested change--Minimum width of 8 inches on girders and beams.

Reason--Knowing the charring rate of heavy timber and the load factor used, these beams could be designed for any particular situation. Available data and fire tests indicate a loss from each side of about .20 to 0.25 inches per 10 minutes; and about a 0.25 loss per 10 minutes from the bottom. From this basis we feel that a minimum 8-inch width is needed for 1-hour fire-resistive rating with the normally used load factors.

Row 27 - Wood Trusses

Suggested change--Delete.

Reason--No data has ever been recorded to our knowledge to substantiate this rating. The indicated charring rate mentioned above would preclude the 4 by 6 member as a tension member on the underside of a truss being able to act for 1 hour unless the load factor was ridiculously low.

Row 28 - Wood Floors

Suggest change of rating from 1- to 3/4-hour rating.

Reason--This construction is listed on page 4 of the Fire-Resistance Ratings of Less Than 1 Hour published by NBFU. The fire-resistance ratings for both of these constructions are given as 45 minutes.

Ind 51.046 - Calculation Method

Comment--We believe that philosophically one should be able to employ rational design for the fire resistance of structural members. However, with the state of the art today this is not possible. We suggest that this section be held in abeyance until sometime in the future when the tools for structural analysis are available to accomplish this end.

To indicate some of the factors involved in rational design which can not be elucidated at this time, we might mention:

1. Scaling factors are not well defined. Although modeling techniques have been well developed for structural analysis and thermal flow, they have not been completely verified for fire exposure tests. Whether we can predict the behavior of a 60- or 80-foot beam from a test on a 20-foot long specimen has not been demonstrated.

2. Although some work has been done to study the effects of restraint on the performance of beams, the problem of translating this data into actual real buildings has not yet been solved. The restraints provided by a heavy rigid frame construction would be quite different than those provided by light skeleton frame type of buildings. The application and range of effectiveness of various types of buildings in developing restraint can not be calculated at this time.

3. The action of a continuous beam on column supports is not clearly known. Although, one can make a very "neat" analysis of the continuous beam as long as the supports do not change in vertical elevation. The building fire almost predicates some vertical movement of the beam supports. We need to better develop our ability to predict structural behavior such as the degree of column shortening and elongation in a building fire before we can employ rational analysis of the continuous beam.

The above comments indicate why we feel that this section can not be rationally used by the building official at this time and might be a source of considerable confusion to him.

In addition, we have a few specific comments on section Ind 51.046.

(1)(a) - Suggested change--Appropriate research data and design criteria to substantiate the method, interpreting between known information, shall accompany the above material and shall include ....

Reason--We suggest that this be limited to interpolation and not extrapolation. The extrapolation of performance characteristics is not practical or safe.

We also suggest that if this section be retained that the mode of structural failure be required part of the information.

(1)(a)4. - We are wondering why data from any qualified laboratory having research personnel can not be acceptable.

Ind 51.047 - Openings in Fire Rated Construction

(1)(a)1. - Openings

Suggested change--Add sentence on end "Door assemblies protecting openings on exitways shall have a minimum transmitted endpoint of not more than 450 °F at the end of 30 minutes in the fire exposure test."

Reason--The labeled fire door does not necessarily carry any restriction as to temperature rise on the exposed surface. As a result, doors opening on to exit stairways could have a temperature rise of over 1000° on the stairways' side.

This represents an energy level in excess of 2-1/2 watts/sq cm or beyond a tolerance level for people attempting to use the exitway. Some of the code groups have seen fit to introduce this temperature criteria.

(1)(a)1.a. - Suggested change--For any door assembly require labeled doors or acceptable test data from a laboratory.

Reason--Many 1-3/4-inch solid wood flush doors will not meet 30 minutes fire endurance. Some, in fact, will go less than 20 minutes. There are many ways to make a solid wood-core door. To guarantee that quality wood-core doors are being used, it would be desirable to have a label or at least have some test data showing the particular door assembly will meet 30 minutes. The use of the label guarantees that the door will be continued to be made in the way it was tested.

(1)(a)1.a.4 - Suggested change--Change "3/4 inch at bottom" to read "3/8 inch at bottom edge of a single swing door and 1/4 inch at the bottom of a pair of doors."

Reason--This is in accord with the recent revision of the UL Standard for Fire Test of Door Assemblies (UL 10b).

(1)(a)1.a.5 - Suggested change--All fire doors shall be equipped with either a self-closing or an automatic closing device.

Reason--We would suggest that all fire doors should be self-closing either by themselves or by means of an automatic detector system. The term "where required" indicates that there are fire doors which are not self-closing.

(1)(b)1. - Openings

Suggested change--Where openings are allowed in fire rated walls they shall be protected with ....

Reason--Window openings would not be allowed in 3-hour fire walls. This change clarifies the wording to limit the window assemblies only to fire rated walls where they are allowed.

(1)(d)1. - Suggested change--The label shall identify the time rating, and temperature limitation when used, for fire door assemblies and class of fire window assemblies.

Reason--Refer to discussion of (1)(a)1. of Ind 51.047.

(1)(d)3. - Suggested change--Labels shall be securely attached and permanent in nature; and located to permit visual inspection.

Reason--Most fire inspectors find it quite desirable to have a label of permanent nature so that the doors can be regularly checked as the building is periodically inspected.

(1)(e)1. - Suggested change--Openings around ducts, pipes, ... shall be solidly filled with non-combustible material to preserve the fire-resistive rating of the assembly penetrated.

Reason--Recent construction practices have tended to evade the intent of the code by not providing for fire-resistive protection at the openings. This has been done by building the floor system and indiscriminately drilling holes through the floor construction to pass conduit and other types of fittings through the construction. This has resulted in multiple heat-conducting openings through the floor, and in many cases possible flame and gas passage through the floor.

Summary

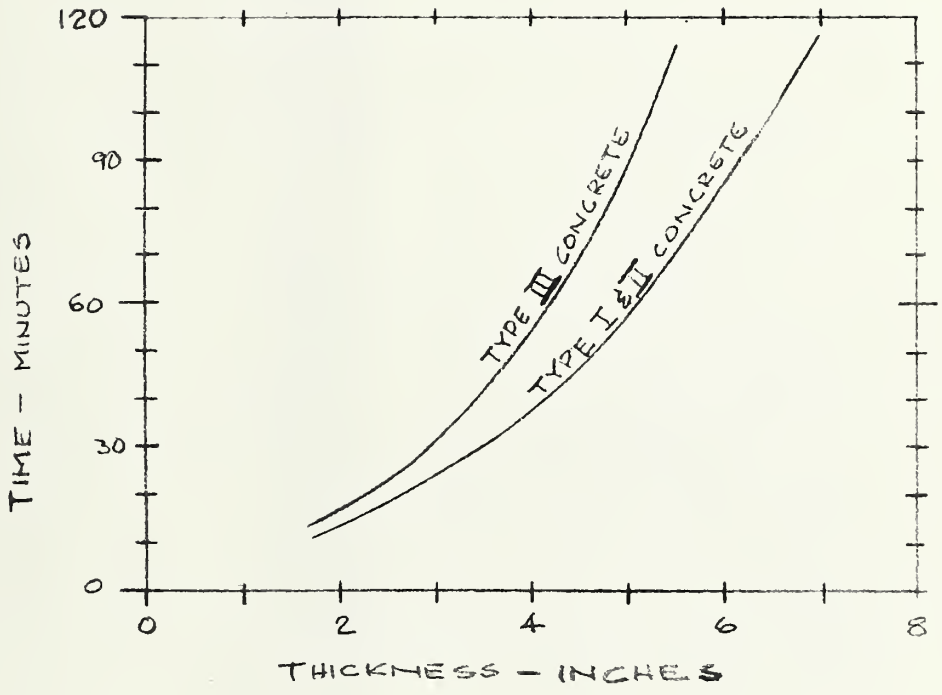
The above comments represent the "state of the art" in fire protection to the best of our knowledge. We have only commented on the data which the State of Wisconsin has presented us; and have not attempted to add to or modify their range and scope of topics.

I. Benjamin, Chief, Fire Research Section
L. Issen, Research Engineer
H. Shoub, General Engineer

September 1969

Attachments
Figure 1 - Times Required for Surface Temperatures to Rise to 180 °F (Rise of 110 °F Above Ambient)
Table 2 - Typical Examples of Fire-Resistive Structural Components

USCOMM-NBS-DC



TIMES REQ'D FOR SURFACE TEMPERATURES TO RISE TO 180°F (RISE OF 110°F ABOVE AMBIENT)

FIGURE 1.

ENTS (ℓ)

	E CLASSIFICATION		
	3½ HR.	½ HR.	
II ½ 48 20			
1 4			
¾ 4 2¾	SEE ROW 10 FOR DEFINITION ... NOTE ...		

... ⅜"	TWO ⅜"	
PLASTER 1" HEX. MESH	9/16"	
	¾"	
	¾"	

A B L E

... 8" 2X12 ... 8"	
8X10 ... 10"	
... 6"	
... OR ... SOLID ...	→ ...

TABLE 2

TYPICAL EXAMPLES OF FIRE RESISTIVE STRUCTURAL COMPONENTS (1)

TYPE OF CONSTRUCTION	STRUCTURAL COMPONENTS	SKETCHES	INSULATING MATERIAL	DESCRIPTION	MIN. REQTS. FOR FIRE RESISTIVE CLASSIFICATION 4 HR.	3 HR.	2 HR.	1 HR.	3/4 HR.	1/2 HR.
APPLIED PROTECTION — COMPONENTS WITHOUT — CONCRETE CAST IN PLACE AND PRECAST	COLUMNS (4)		CONCRETE TYPE I II & III (a) (b)	REINF. COVER	I II III: 2 2 2	I II III: 2 2 2	I II III: 1½ 1½ 1½	I II III: 1½ 1½ 1½		
				MIN. DIMENSION SQ. IN.	12/144	10/120	8/64	8/64		
	GIRDERS AND BEAMS (3)		CONCRETE TYPE I II & III (a) (b) (n)	REINF. COVER	2 2 2	1½ 1½ 1½	1½ 1½ 1½	1 1 1		
				WIDTH (w)	8 8 8	8 8 8	6 6 4	4 4 4		
	JOISTS & WAFFLES WITHOUT FILLERS OR PARTIAL FILLERS OF TYPE I OR II MASONRY OR CLAY TILE (2)		CONCRETE TYPE I II & III (a) (b) (c) (d) (e) (n)	REINF. COVER	2 2 2	1 1 1	¾ ¾ ¾	¾ ¾ ¾	¾ ¾ ¾	see ROW 10 FOR DEFINITION OF t_2. NOTE $t_2 \geq t$
				WIDTH REQ'D (w)	8 8 8	5 5 5	4 4 4	4 4 4		
				TH. TOP SLAB (t) / t_2	6¾ 7 5½	5¾ 6¼ 4¾	4¾ 5 3¾	3¾ 3½ 2¾		
	SLABS OR JOISTS & WAFFLES WITH TYPE I OR II MASONRY OR CLAY TILE FILLER (n) (2)		CONCRETE TYPE I II & III (a) (b) (c) (d) (e) (n)	REINF. COVER	1 1 1	1 1 1	¾ ¾ ¾	¾ ¾ ¾	¾ ¾ ¾	SEE ROW 10 FOR DEFINITION OF t_2. NOTE $t_2 \geq t$
				TOP SLAB (t) / t_2	6¾ 7 5½	5¾ 6¼ 4¾	4¾ 5 3¾	3¾ 3½ 2¾		
	WALLS & PARTITIONS BEAR. & NON-BEAR. (5)		CONCRETE TYPE I II & III (a) (b) (e) (n)	REINF. COVER	1 1 1	1 1 1	¾ ¾ ¾	¾ ¾ ¾		
				THICKNESS (t)	6 6½ 8	4½ 5 6	4 4½ 4	3 3 3		
	CONCRETE: GIRDERS AND BEAMS (3)		CONCRETE TYPE I II & III (a) (b) (k)	AVE. COVER (w)	I II III: 3½ 3 3 / 11 10	I II III: 3 2¾ 2¾ / 9½ 8	I II III: 2½ 2 2 / 7 6¼	I II III: 1¾ 1¾ 1¾ / 4 4		
	CAST IN PLACE POSTTENSION OR PRETENSION SIMPLE SPAN (1)		CONCRETE TYPE I II & III (a) (b) (c) (d) (e) (k)	AVE. COVER / AV. WEB TH. (w) / SLAB THICKNS (t) / AVE. COVER / AV. WEB TH. (w) / TOP THICKNS (t_2)	I II III: 3½ 3 3 / 11 10 / 6¾ 7 5½ / 3 2¾ 2¾ / 9½ 8 / 6¾ 7 5½	I II III: 3 2¾ 2¾ / 9½ 8 / 5¾ 6¼ 4¾ / 2¾ 2½ 2½ / 8 8 / 5¾ 6¼ 4¾	I II III: 2½ 2 2 / 7 6¼ / 4¾ 5 3¾ / 2 1¾ 1¾ / 6¼ 5 / 4¾ 5 3¾	I II III: 1¾ 1¾ 1¾ / 4 4 / 3¼ 3½ 2¾ / 1½ 1½ 1½ / 4 4 / 3¼ 3½ 2¾	SEE ROW 10 FOR DEFINITION OF t_2. NOTE $t_2 \geq t$	
	SINGLE TEE (1)		CONCRETE TYPE I II & III (a) (b) (c) (d) (e) (k)	SLAB COVER / AV. WEB TH. (w) / TOP THICKNS (t_2)	BY TEST OR LISTING APPROVED TESTING LAB.				CONCRETE	
	MULTI-TEE UNITS SLABS (1)		CONCRETE TYPE I II & III (a) (b) (c) (d) (e) (k)	t_2 / t_1 / AV. COVER	EQUIVALENT THICKNS = TOTAL AREA / WIDTH. NOT LESS THAN t_1 FOR SOLID SLAB: 6¾ 7 5½ / 5¾ 6 4 / 2½ 2¾	4¾ 5 3¾ / 3¾ 4 2¾ / 2 2¼	3¼ 3½ 2¾ / 2½ 2¾ / 1½ 1¾	2¾ / 2 / 1		
	SOLID (CORED) (1)									
	MASONRY BEARING AND NON BEARING: UNREINFORCED CONCRETE WALLS AND PARTITIONS (1)		CONCRETE TYPE I II & III (a)	WALL THS. (t)	SAME AS ROW 6					
	SOLID MASONRY WALLS & PARTITIONS... BRICK TILE CORED BRICK CAVITY WALLS (2)		MASONRY TYPE I II (g) (m)	EQUIV. THICKNS.	6.7	5.7	4.5	3.0		
					SAME AS ROW 6	AS ROW 6	AS ROW 6	AS ROW 6		
	SOLID MASONRY... BRICK BLOCK, CLAY TILE WITH LESS THAN 25% VOIDS OR WITH THE CORES FILLED... (2)		MASONRY TYPE I II CLAY, SLAG, CONCRETE (m) SAND OR LIME	EQUIV. THICKNS.	5.7	4.8	3.8	2.4		
				WALL THICKNS. (t)	8"	8"	8"	4"		
COMPONENTS WITH DIRECT APPLIED PROTECTION	COLUMNS (5)		CONCRETE TYPE I II & III (a) (o) SOLID MASONRY (r)	THICK OF PROTECTION	I II III: 2 2½ / 3¾ 3¾	I II III: 1½ 2 / 3¾ 3¾	I II III: 1 1½ / 2¼ 2½	I II III: 1 1 / 2¼ 2½		
	GIRDERS BEAMS TRUSSES (13)	8" MIN. FLANGE	CONCRETE TYPE I II & III (a) (p)	THICK OF PROTECTION	I II III: 2 2½	I II III: 1½ 2"	I II III: 1 1½	I II III: 1 1		
	COLUMNS, BEAMS, GIRDERS TRUSSES, JOISTS & STEEL FLOOR UNITS (14)		SPRAYED FIBER CEMENTITIOUS MIXTURE INTUMESCENT PAINTS		BY TESTS OR LISTING BY APPROVED TESTING LAB.					
COMPONENTS WITH SUSPENDED OR ATTACHED PROTECTION — CONCRETE	CONCRETE JOISTS OR WAFFLE (17)		CONCRETE TYPE I II OR III ¾" COVER VERMICULITE, GYPSUM, OR PERLITE GYPSUM ON METAL LATH	t_2 THICK OF SLAB / t_1 THICK OF INSULATION	3" / 1"	2" / ¾"				
	STEEL STEEL COLUMNS (2)		TYPE I & II MASONRY ½" AIR SPACE	THICK OF INSULATION	4" SOLID					
	STEEL GIRDERS... BEAMS... TRUSSES... JOISTS, COLUMNS INDIVIDUALLY PROTECTED (18)		SPRAYED FIBRE... CEMENTITIOUS MIXTURE... LATH & PLASTER		BY TESTS... OR LISTING BY APPROVED TESTING LAB.					
	STL. BMS., GIRDERS, TRUSSES, & JOISTS... W/ CEILING PROTECTION MIN. 2½" TH. TYPE I OR II CONC. SLAB (20)		SPRAYED FIBRE, CEMENTITIOUS MIXTURE... LATH & PLASTER ACOUSTICAL TILE		BY TESTS... OR LISTING BY APPROVED TESTING LAB.					
	STEEL STUD PARTITION NON BEARING (21)		GYPSUM PERLITE PLASTER ON PERF. GYPSUM LATH... 2½" STUD / GYPSUM WALL BOARD, 5/8" STUD	t_p PLASTER / t_l LATH / NO. LAYERS / THICKN. EACH						
	WOOD JOISTS MIN. 2"x10" (22) WOOD FLOOR SUSPENDED CEILING		GYPSUM WALL BOARD, 5/8" TYPE X FIRE CODE 1/2" PLYWOOD FLOORING / GYPSUM WALL BOARD, 5/8" TYPE X FIRE CODE 1/2" PLYWOOD OR 1"x6" T. & G. SUBFLOORING	t_1 INSUL. / FLOORING / t_p						
	WOOD JOISTS MIN. 2"x10" (23) WOOD FLOOR SUSPENDED CEILING		NON COMBUSTIBLE ACOUSTICAL TILE W. 5/8" PLYWOOD OR 1"x4" T. & G. SUB-FLOORING	t_1 INSUL. / FLOORING / t_p						
	WOOD STUD PARTITION MIN. 2"x4" STUD (24)		GYPSUM WALLBOARD GYPSUM PERLITE PLASTER ON 3/8" GYPSUM LATH / GYPSUM WALLBOARD GYPSUM PERLITE PLASTER ON 3/8" GYPSUM LATH	NO. LAYERS OF EA. / t_p / t_t / t_t						
			GYPSUM & SAND PLASTER ON METAL LATH / GYPSUM & VERMICULITE PLASTER ON METAL LATH							

(h) HEAVY TIMBER CONSTRUCTION TABLE

HEAVY TIMBER CONSTRUCTION	COLUMNS (25)	WOOD ALL SPECIES	FLOOR, WIDTH, DEPTH MIN. NOM. / ROOF, WIDTH, DEPTH MIN. NOM.	8"x8" 12"x12" 8'
	GIRDERS & BEAMS (26)	WOOD ALL SPECIES	MIN. WIDTH & DEPTH (NOM.)	8"x10" 15'
	ROOF DECK (27)	WOOD ALL SPECIES	MIN. WIDTH, DEPTH, SPAN MEMBER	
	FLOOR & ROOF DECK (28)	WOOD ALL SPECIES	ROOF / FLOOR	3" SOLID

REFERENCES (a) THRU (p) SEE PAGES 10 & 11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