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CBD 71

Fire Performance Ratings

Originally published November 1965

M. Galbreath

Please note

This publication is a part of a discontinued series and is archived here as an historical reference. Readers should consult design and regulatory experts for guidance on the applicability of the information to current construction practice.

With the 1965 edition of the National Building Code of Canada the Associate Committee on the National Building Code issued a revised Supplement No. 2, *Fire Performance Ratings*. The original document provided the information needed to enable the fire endurance provisions of the National Building Code to be implemented, and was in the form of an extensive list of ratings, each purporting to relate to one fire test.

In the new edition of Supplement No. 2 a significant change has been made in the approach to the presentation of fire performance information. It now includes ratings that are, for the most part, conservative values that will be equalled or exceeded by a large proportion of the constructions falling within the described classes. These values are recommended by the Associate Committee on the National Building Code for use when no more specific test or rating information is available for the particular construction involved.

Summaries of individual fire tests, in more detail than was available in the former Supplement, are now being published by the Division of Building Research, National Research Council, as general information not related specifically to the provisions of the NBC.

The Former Supplement No. 2

The widespread use of the former Supplement No. 2 brought to light some of the limitations inherent in a compilation of brief summaries of fire tests. It became evident that it is not possible, even in an extensive list of individual fire tests, to cover all possible combinations of building materials that might be used in practice. There is also the possibility of conflicting results, as two assemblies of essentially the same construction may not give exactly the same fire endurance under test. Over the years the Division of Building Research has received many enquiries regarding the effect of variations in materials, shape of hollow units, methods of fastening, etc., and has found these difficult to answer on the basis of individual test results.

The Associate Committee on the National Building Code, recognizing this need, set up the Fire Test Board, a small technical committee to keep under review and to prepare recommendations for revision of Supplement No. 2. Following careful consideration of the problems involved and a survey of all available fire test data, the new form of publication was evolved. It differed from the old publication in several important respects.

Changes in Supplement No. 2, 1965

Some of the changes in the general approach are as follows:

1. The values included in Supplement No. 2 are ratings based on a comparison of the results of a number of similar tests. They are not, with a few exceptions, the results of individual tests. The information is arranged in such a way that there is some flexibility in determining the fire performance of combinations of materials, and the emphasis is placed on the more significant features of an assembly.

   In light frame construction, for example, it has been found that unprotected framing will fail structurally within a very few minutes when exposed to the standard fire test. The major contribution to fire endurance must, therefore, lie in the membrane exposed to fire and, in particular, in its ability to stay in place. For this reason, and following the example of some British studies, the fire endurance of light frame construction for up to 1½ hours' fire endurance has been broken down into (1) the contribution of the membrane exposed to fire (2) the contribution of the frame, and (3) the contribution of additional insulation or reinforcement. This makes it possible for a designer to assess the fire endurance of a variety of framed assemblies and to consider ways in which materials may be employed most effectively in light frame construction from the standpoint of fire endurance.

2. The minimum specifications of materials and workmanship are those required by the general provisions of the National Building Code.
3. The information presented is related directly to the fire performance requirements of the National Building Code; for example, fire resistance ratings are expressed as ½, ¾, 1, 1½, 2, 3 and 4 hours, the periods required by the National Building Code. The effect of grading fire endurance ratings in this way is that interpolation between test results has been made and the designer can choose the thickness of material closest to his needs.
4. Reference is made only to building materials and assemblies that can be properly identified and reproduced; no proprietary materials or products are described. It was found necessary to make this distinction between identifiable and proprietary materials. Proprietary materials are generally described by trade name; they are the product of an individual or company who may not wish to disclose all the information required for an adequate description of the material. Identifiable materials are those that can be specified with sufficient accuracy to ensure that an assembly can be reproduced in all essential details.

   Fortunately, there is for the manufacturer of a proprietary product an alternative method of having his product rated. This is the service provided by Underwriters' Laboratories of Canada who perform the fire tests, describe the assembly in their Building Construction List, make regular factory inspections, and issue labels as identification of the product. For example, Type X (Special Fire Retardant) gypsum wallboard is described in CSA Specification as having a specially formulated core and providing a greater fire resistance than regular gypsum wallboard of the same thickness. This type of wallboard is not referred to in Supplement No. 2, but ratings for assemblies using this material are available in the Underwriters' Laboratories of Canada Building Construction List.

NBC Provisions

There are now three means by which the fire performance provisions of the National Building Code can be met:

1. By an assembly that is the same in all essential details as a tested assembly. The standard test report, used as evidence, will show details of construction and of fire performance.
2. By an assembly, not covered by test of common building materials assembled in accordance with the provisions of the National Building Code that can be assigned a rating on the basis of Supplement No. 2 *Fire Performance Ratings*.
3. By an assembly as described in Underwriters' Laboratories of Canada Building Construction List and using the labelled materials described therein.

Standard Fire Endurance Tests

The standard methods of fire test recognized by the National Building Code are ASTM E119-61, BS 476-53 and CSA B54.3-64. All are similar in their more significant aspects. The Standard Fire Test has been described in **CBD 53**, Fire Endurance of Building Constructions by G. W. Shorter. A large sample wall floor, roof, beam or column is exposed to a furnace whose temperature reaches 1000°F in 5 minutes, 1700°F in 1 hour and 2000°F in 4 hours. The criteria for failure in the test of a wall or floor are:

1. collapse;
2. temperature rise of 250°F average or 350°F at one point on the unexposed surface;
3. development of cracks or fissures through which flame or hot gases may pass.

Building Constructions Exposed to Fire

The properties required of a construction exposed to fire are:

1. integrity: the construction must remain intact and in place and carry any loads imposed on it during fire exposure;
2. thermal resistance: the construction may be required to prevent heat transfer through a separating member such as a wall or floor or to act as a protective covering to a heat-sensitive structural member.

The materials most commonly used in structural assemblies are brick, concrete, steel or wood. Brick and other burned clay products, having been exposed to high temperatures during manufacture, are relatively stable in fire endurance test. Brick also displays reasonably good thermal performance.

Concrete, which is similar to brick in thermal performance, loses strength gradually during fire exposure, retaining about half its original strength at 950°F and one third of its original strength at 1300°F. This loss in strength is irreversible because it is associated with the deterioration of the cement binder and in some cases of the aggregate.

Steel has high thermal conductivity and shows a significant loss in strength at temperatures exceeding 1000°F. It is, therefore, usually protected from fire by an insulating layer of another material.

Wood is a good insulator, but when exposed to fire it will burn until it is destroyed. The penetration of surface charring has been measured and it is estimated that the depth of char in wood surfaces exposed to the standard furnace temperature is about 1/40 inch per minute.

In general, an assembly of small members exposing a large surface area to fire is more vulnerable than an assembly of large members arranged in flat planes having a minimum surface exposed to fire.

Hollow Unit Masonry

One of the more significant factors in the fire endurance of hollow unit masonry is the amount of solid material in the wall thickness. To assume that the fire endurance is directly related to the amount of solid material is a rough approximation, but it is sufficiently accurate for application to the fire provisions of the National Building Code. The convenient device "equivalent thickness" has been adopted as a measure of the fire endurance of hollow masonry. Equivalent thickness is described as the thickness of solid material in the unit or component and is obtained by multiplying the over-all thickness by the percentage of solid material in the unit.

Hollow units having thin face shells and webs are subject to stresses resulting from unevenly distributed thermal expansion. The tendency to spalling and shattering has been observed in concrete containing quartz aggregate and in hollow clay tiles. The shell may, however, be effectively protected by a plaster finish on the face exposed to fire. With the reservation that

hollow clay tile and siliceous aggregate concrete units must have a plaster finish on the side exposed to fire, equivalent thickness is used to compare the fire endurance of a variety of solid and hollow units. The thickness of plaster finish is also taken into account in assessing the fire resistance. Equivalent thickness provides a flexible means of assessing the fire endurance of hollow units based on the amount of solid material provided as a barrier to fire.

Concrete

The fire endurance properties of concrete depend on the type of aggregate, the proportions of the concrete mix, and moisture content at the time of fire exposure. A wide variation in performance is therefore possible. The stone used as coarse aggregate can have a significant influence on fire endurance. It has been observed that some quartz or granite aggregate concrete has a tendency to spall when exposed to furnace temperatures. This may cause early failure under the fire test. Limestone aggregate concretes, on the other hand, display generally favourable performance in fire. In Supplement No. 2 concretes having over 65 per cent quartz, chert or flint are not included. These have to be rated on the basis of test. The minimum thicknesses of concrete in walls and floors are shown for varying fire resistance ratings.

Reinforced Concrete

There are two factors to be taken into account in assessing the fire endurance of reinforced concrete. One is the thickness of concrete required to limit the temperature rise on the unexposed surface to 250°F for the period desired; the other is the cover required to keep the temperature of the reinforced steel below that at which it will lose its effective strength.

Prestressed concrete requires greater thickness of cover to the reinforcement than regular reinforced concrete because a lower temperature will release the prestress and bring about collapse of the assembly.

Steel

The fire endurance of steel in a structural assembly depends primarily on the thermal protection provided by other materials interposed between the steel and the fire exposure. Some light materials such as plaster and wallboard are effective as thermal protection. Stronger materials such as concrete or masonry may also contribute to the load-carrying capacity of the assembly, thus extending in some cases the fire endurance. The new Supplement No. 2 shows minimum thickness of a number of materials that may be used as protective cover of steelwork for varying degrees of fire endurance. The protection may be in the form of encasement of individual members or of a membrane applied to the face of a group of members as in light frame construction.

Wood

The fire endurance of a wood assembly depends mainly on the residual strength of the members. Wood exposed to fire is gradually destroyed by charring. The reduction in effective cross-sectional area is dependent on the number of faces exposed to the fire.

There are two ways by which a measure of fire endurance can be provided in wood assemblies. One is to arrange the wood in massive flat planes so as to minimize the effect of charring. The other is to add a protective covering or membrane to the wood structure. Supplement No. 2 shows the minimum thickness of solid wood assemblies for varying degrees of fire endurance. Values are also assigned to various materials used as a protective membrane on wood frame assemblies.

The Contribution of the Membrane

A study of available reports on fire tests of light frame walls and floors suggested the possibility of assigning a value to the membrane on the fire-exposed side and of adding appropriate values for the structural frame and for additional protection such as that provided by batt insulation.

The time during which the membrane remains in place is of great significance in the fire endurance of an assembly. Consequently, membranes having metal reinforcement, e.g., plaster

on metal lath or double thickness of wallboard with wire mesh between the layers generally contribute more to fire endurance than the more easily shattered materials. The method of fastening by nails, screws or wire hangers is also of great importance, particularly when the membrane is used as a protective ceiling. Close attention should, therefore be paid to specification details if a fire resisting assembly is to be achieved.

Flame Spread

The National Building Code places certain limits on the flame spread properties of interior finish materials in assembly, residential and institutional buildings. There are also more stringent limitations on interior finishes in all corridors and stairs forming part of possible escape routes. The test recognized by the National Building Code is ASTM E84-61. The test method and the requirements of the National Building Code are described more fully in **CBD 45**, *Flame Spread*, by G. W. Shorter.

Both the surface finish material and the material to which it is applied may contribute to the flame spread performance of an assembly. The contribution of the supporting material may be neglected only when the thickness of the surface coating exceeds 1/8 inch. The glue used in plywoods and veneers is also of importance. It has been found that phenolic adhesives have satisfactory performance in fire, but that inferior glue allows the surfaces to peel off, exposing more surface area and increasing flame spread. Opaque paints generally reduce the flame spread of the base to which they are applied. Shellac and lacquer, however, may produce significant increases.

The values shown in Supplement No. 2 for flame spread performance of common building materials are based on a study of all available published reports of tests. The scarcity of test data in accordance with the recognized standard method of test, ASTM E84, made it necessary to take into account information derived from other comparable tests also. The values are classified in the flame spread groups required by the National Building Code. The effect of several combinations of surface finish and base material are recorded.

Test Information

One of the results of the study involved in the preparation of the revised Supplement No. 2 has been the collection and examination of test information from the published literature. Digests of this information are published by the Division of Building Research. The basic information that is available to the user of the National Building Code on fire performance of building materials will now be as follows:

- Reports of Standard Tests.
  The Division of Building Research publishes a number of these in the Fire Study Series. Others are issued by Research Organizations throughout the world.

1. Fire Performance Ratings.
   Supplement No. 2 to the National Building Code, available from the Associate Committee on National Building Code. National Research Council, Ottawa, 25¢. This provides ratings for a variety of assemblies of common building materials based on the judgement of the ACNBC and acceptable under the provisions of the National Building Code.
2. List of Equipment and Materials, Vol. 11, Building Construction Underwriters' Laboratories of Canada, 7 Crouse Road, Scarborough, Ontario, no charge. Lists of fire-tested assemblies of proprietary and nonproprietary building materials that may be identified by the U.L. label.
3. Summaries of available published fire test reports.
4. style="list-style: none">>
5. Flame Spread Performance of Common Building Materials, by M. Galbreath. Division of Building Research, National Research Council, Ottawa, NRC 7820, April 1964, 75¢.
6. Fire Endurance of Protected Steel Columns and Beams, by M. Galbreath and W. W. Stanzak. Division of Building Research, National Research Council, Ottawa, NRC 8379, April 1965, 75¢.

7. Fire Endurance of Unit Masonry Walls, by M. Galbreath. Division of Building Research, National Research Council, Ottawa, NRC 8740, Oct. 1965, $1.
8. Fire Endurance of Concrete Assemblies - in preparation.
9. Fire Endurance of Light Frame Assemblies - in preparation.