Restrained vs. Unrestrained

To most structural engineers, code officials and architects, the terms "Restrained" and "Unrestrained" are typically interpreted as referring to the connection of structural elements at ambient temperatures. However, in the fire protection industry, restrained and unrestrained are addressed at elevated temperatures, introducing the concept of "thermal restraint".

The issue of thermal restraint causes some controversy in determining whether an assembly should be considered restrained or unrestrained. The classification of an assembly in one of these categories has a bearing on the thickness of spray-applied fire resistive material (SFRM) needed to satisfy code requirements. Higher SFRM thicknesses are typically required for unrestrained ratings.

In order to clarify whether an assembly should be considered restrained or unrestrained, one may refer to the actual "Fire Test Standards of Building Construction and Materials". According to Appendix X3 of ASTM Standard E119 and Appendix C of UL (Underwriters Laboratories) Standard 263: “Floor and roof assemblies and individual beams in buildings shall be considered restrained when the surrounding or supporting structure is capable of resisting substantial thermal expansion throughout the range of anticipated elevated temperatures. Construction not complying with this definition is assumed to be free to rotate and expand and shall therefore be considered as unrestrained.”

To assist in determining this condition, ASTM Standard E119 and UL 263 also list general construction classifications and whether they denote a restrained or unrestrained condition. This table of classifications, which at one time appeared in the UL Fire Resistance Directory, has been attached for reference purposes. According to UL, this information is intended as a guide for the determination of restrained conditions and is not meant as a specification. Engineering judgment must therefore be exercised to determine what constitutes restraint.
to "substantial thermal expansion". Furthermore, page 14 of the 1997 UL Directory states the following: "Restrained conditions for the fire test assemblies are provided by constructing floor, beam and roof test assemblies within nominal 14 ft x 17 ft frames of composite steel/concrete cross sections having an approximate stiffness (EI/L) of 850,000 kip-in and 700,000 kip-in along the 14 ft and 17 ft sides, respectively." This description provides structural engineers with the stiffness of UL's test frame so that they have a basis of comparison when determining conditions of restraint for beams on a project.

Due to the level of analysis and interpretation required, there is often confusion as to whether a building's construction shall be specified as restrained or unrestrained. Ultimately, the determination of the conditions of restraint remain in the hands of the structural engineer and the authority having jurisdiction. The level at which these conditions are followed by various code bodies differs between organizations. Both the National Building Code (BOCA) and Standard Building Code (SBCCI) address restrained vs. unrestrained criteria referring directly to Appendix X3 of ASTM E119. The Uniform Building Code (ICBO) criteria requires that all construction design be considered unrestrained unless proven otherwise.

After determining restrained vs. unrestrained conditions, the appropriate restrained or unrestrained fire resistance rating must be utilized. Restrained and unrestrained fire ratings specified for both beams/joists and assemblies are used to determine the required fire protection material thicknesses which are listed in the UL Directory. Due to the difference in thickness requirements between restrained and unrestrained hourly ratings, this determination can often have a significant effect on both the fireproofing requirements and life safety integrity of the building.
X2.5.1 Included shall be a statement to the effect that the
construction truly represents field construction. If the con-
struction does not represent typical field construction, then
the deviations shall be noted.
X2.5.2 If construction is unsymmetrical (has different
details on each face) be sure to indicate the fire exposed to
fire with comments on fire resistance from the opposite side.
X2.6 Summarize Results. include:
X2.6.1 Endurance time,
X2.6.2 Nature of failure, and
X2.6.3 Hose stream test results.
X2.7 List Official Observers—Signatures of responsible
persons.
X2.8 Appendix—Include all data not specifically required
by test standard, but useful to better understanding of test
results. Special observations for Building Code approvals
should be in appendix.

X3. GUIDE FOR DETERMINING CONDITIONS OF RESTRAINT FOR FLOOR AND ROOF ASSEMBLIES
AND FOR INDIVIDUAL BEAMS

X3.1 The revisions adopted in 1970 have introduced, for
the first time in the history of the standard, the concept of
fire endurance classifications based on two conditions of
support: restrained and unrestrained. As a result, most
specimens will be fire tested in such a manner as to derive
these two classifications.
X3.2 A restrained condition in fire tests, as used in this
test method, is one in which expansion at the supports of a
load carrying element resulting from the effects of the fire is
resisted by forces external to the element. An unrestrained
condition is one in which the load carrying element is free to
expand and rotate at its supports.
X3.3 Some difficulty is recognized in determining the
condition of restraint that may be anticipated at elevated
temperatures in actual structures. Until a more satisfactory
method is developed, this guide recommends that all con-
structions be temporarily classified as either restrained or
unrestrained. This classification will enable the architect,
engineer, or building official to correlate the fire endurance
classification, based on conditions of restraint, with the
construction type under consideration.
X3.4 For the purpose of this guide, restraint in buildings
is defined as follows: “Floor and roof assemblies and
individual beams in buildings shall be considered restrained
when the surrounding or supporting structure is capable of
resisting substantial thermal expansion throughout the range
of anticipated elevated temperatures. Construction not com-
plying with this definition are assumed to be free to rotate
and expand and shall therefore be considered as unre­
strained.”
X3.5 This definition requires the exercise of engineering
judgment to determine what constitutes restraint to “sub­
stantial thermal expansion.” Restraint may be provided by
the lateral stiffness of supports for floor and roof assemblies
and intermediate beams forming part of the assembly. In
order to develop restraint, connections must adequately
transfer thermal thrusts to such supports. The rigidity of
adjoining panels or structures should be considered in
assessing the capability of a structure to resist thermal
expansion. Continuity, such as that occurring in beams
acting continuously over more than two supports, will
induce rotational restraint which will usually add to the fire
resistance of structural members.
X3.6 In Table X3.1 only the common types of construc­
tions are listed. Having these examples in mind as well as the
philosophy expressed in the preamble, the user should be
able to rationalize the less common types of construction.
X3.7 Committee E-5 considers the foregoing methods of
establishing the presence or absence of restraint according to
type and detail of construction to be a temporary expedient,
necessary to the initiation of dual fire endurance classifica­
tions. It is anticipated that methods for realistically predeter­
mining the degree of restraint applicable to a particular fire
endurance classification will be developed in the near future.
X4. METHOD OF CORRECTING FIRE ENDURANCE FOR CONCRETE SLABS DETERMINED BY UNEXPOSED SURFACE TEMPERATURE RISE FOR NONSTANDARD MOISTURE CONTENT

X4.1 Scope

X4.1.1 The standard fire endurance is the time determined by unexposed surface temperature rise of a test specimen at a standard moisture level.

X4.1.2 This appendix gives a procedure to correct the fire endurance of unprotected vertical or horizontal slabs (solid or hollow), made from essentially inorganic building materials; and conditioned on both sides, when moisture content at the time of test is other than at a standard moisture level.

X4.1.3 From among the common inorganic building materials, only the hydrated Portland cement products can hold (after due conditioning in accordance with Section 11) sufficient amount of moisture to affect noticeably the result of the fire test. Consequently, correcting the experimental fire endurance of constructions containing less than 5% moisture content in the Portland cement paste is not necessary.

X4.2 Symbols

X4.2.1 The symbols used in this Appendix are defined as follows:

- \( m \) = moisture content, volume fraction \( \text{ft}^3/\text{ft}^2 \) or \( \text{cm}^3/\text{cm}^2 \),
- \( m_s \) = average moisture content of test specimen,
- \( m_c \) = average moisture content of cement paste,
- \( m_e \) = nominal equilibrium moisture content of cement paste for a given RH (see Table X4.3),
- \( m_{es} \) = equilibrium moisture content of cement paste at the standard RH level (see Table X4.3),
- \( m_l \) = average moisture content of a standard conditioned cement specimen of same concrete and cement paste volume as the test specimen, and
- \( v \) = volume fraction of cement paste, \( \text{ft}^2/\text{ft}^3 \) or \( \text{cm}^2/\text{cm}^3 \).

X4.3 Method of Correcting Fire Endurance for Concrete Slabs Determined by Unexposed Surface Temperature Rise for Nonstandard Moisture Content

To correct the fire endurance of concrete slabs, the following steps can be followed:

1. **Determine Standard Fire Endurance**
   - Calculate the standard fire endurance of the specimen under test conditions.

2. **Correct for Additional Factors**
   - Adjust for the effects of additional factors such as:
     - The thickness of the slab.
     - The mass of the slab.
     - The slabs exposed to air.

3. **Adjust for Nonstandard Conditions**
   - Adjust for nonstandard conditions such as:
     - Nonstandard RH conditions.
     - Nonstandard mass conditions.

4. **Apply Adjustment Factors**
   - Apply adjustment factors based on the corrected test conditions.

X4.4 Table X4.1: Factor Characterizing Drying Conditions

<table>
<thead>
<tr>
<th>Conditioning Environment</th>
<th>Middepth RH of Test Specimen, %</th>
<th>Factor A for Portland Cement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal Weight Concrete</td>
<td>Light-Weight Concrete</td>
<td></td>
</tr>
<tr>
<td>60 to 80°F (15.6 to 26.7°C)</td>
<td>80% to 95%</td>
<td>1.0</td>
</tr>
<tr>
<td>70 to 150°F (21.1 to 66.1°C)</td>
<td>80% to 95%</td>
<td>1.0</td>
</tr>
<tr>
<td>120 to 200°F (48.9 to 93.3°C)</td>
<td>80% to 95%</td>
<td>0.7</td>
</tr>
<tr>
<td>190 to 300°F (87.8 to 150.0°C)</td>
<td>80% to 95%</td>
<td>0.45</td>
</tr>
<tr>
<td>260°F (126°C)</td>
<td>80% to 95%</td>
<td>0.0</td>
</tr>
</tbody>
</table>

Note: The table provides factors for adjusting the fire endurance based on the middepth RH of the test specimen.
FIRE RESISTANCE RATINGS - ANSI/UL 263 (BXU) - Continued

Steel Studs

The dimensions and gauge of steel studs are minimums. The hourly ratings apply when the steel studs are of a heavier gauge and/or larger dimensions than specified in a Design. The superimposed load of bearings walls utilizing steel studs shall be based on the capacity of the studs as determined by the 1986 edition of the A.I.S.I. Specification for the Design of Cold Formed Steel Structural Members with the December 11, 1989 Addendum.

Gypsum Board Joint Treatment

The joints in gypsum board applied to wood or steel studs may either be exposed with covered joint tape and joint compound for that portion of the joint above a suspended ceiling which is part of a fire resistive floor-ceiling or roof-ceiling assembly.

Electrical Outlet Boxes

The category of "Outlet Boxes and Fittings Classified for Fire Resistance" (CEPY) includes Classification for nonmetallic outlet and switch boxes for use in wall or partition assemblies. The information provided for each Classification includes the model numbers for the Classified products, a description of the rated assemblies, the spacing limitations for the boxes and the installation details.

Listed single and double gang metallic outlet and switch boxes with metallic or nonmetallic cover plates may be used in bearing and nonbearing wood stud and steel stud walls with ratings not exceeding 2 h. These walls shall have gypsum wallboard facings similar to those shown in Design Nos. U301, U411 and U425.

The surface area of individual metallic outlet or switch boxes shall not exceed 18 sq in. The aggregate surface area of the boxes shall not exceed 100 sq in. per 100 sq ft of wall surface. Boxes located on opposite sides of walls or partitions shall be separated by a minimum horizontal distance of 24 in. Boxes shall not be installed on opposite sides of walls or partitions of staggered stud construction. The minimum separation distance may be reduced when "Wall Opening Protective Material" (WOPM) are installed according to the requirements of their Classification.

The metallic outlet or switch boxes shall be securely fastened to the studs and the opening in the wallboard facing shall be cut so that the clearance between the box and the wallboard does not exceed 1/8 in. During the fire test, the furnace pressure is maintained at a positive pressure level of at least 0.01 in. of water, as measured 0.78 in. (20 mm) from the face exposed to the furnace fire.

COMMENTARY ON DETERMINING CONDITIONS OF
RESTRAINT FOR FLOOR AND ROOF ASSEMBLIES AND
FOR INDIVIDUAL BEAMS

Classifications of floor and roof assemblies and individual beams include restrained and unrestrained ratings. The Standard for Fire Tests of Building Construction and Materials, ANSI/UL 263, and specifically Appendix C, provides general instruction with respect to the concept of these classifications.

Appendix C of Standard ANSI/UL 263 defines restraint in buildings as, "Floor and roof assemblies and individual beams in buildings shall be considered restrained when the surrounding or supporting structure is capable of resisting substantial thermal expansion throughout the range of anticipated elevated temperatures. Constructions not complying with this definition are assumed to be free to rotate and expand and shall be therefore considered as unrestrained".

The restrained condition in fire tests is defined in Appendix C of the Standard as, "one in which expansion at the supports of a load carrying element resulting from the effects of the fire is resisted by forces external to the element". This definition may not be appropriate for conditions of restraint in actual structures. The Standard recognizes that the exercise of engineering judgement is required to determine what constitutes "substantial thermal expansion" when determining the conditions under which the restrained or unrestrained ratings should be used.

Restrained conditions for the fire test assemblies are provided by constructing floor, beam and roof test assemblies within nominal 14 ft by 17 ft frames of composite steel/concrete cross sections having an approximate stiffness (EI/L) of 850,000 kip-in. and 700,000 kip-in. along the 14 ft and 17 ft sides, respectively. The frame stiffness remains constant throughout the fire test because the test frame is insulated from the fire environment.

When applying the published restrained ratings, it is recognized that the individual responsible for the design of the fire-rated construction may ascertain that a different degree of restraint may be provided to the building assembly during a fire condition than was provided to the test sample during the fire test. Under these conditions, the designer may review the Conditions of Acceptance for restrained and unrestrained assemblies and beams in the Standard ANSI/UL 263 for additional guidance when determining whether restrained or unrestrained ratings should be specified.

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