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Code Requirements for Determining Fire Resistance of Concrete and Masonry Construction Assemblies

An ACI/TMS Standard

Reported by Joint ACI-TMS Committee 216

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FOREWORD

Fire resistance of building elements is an important consideration in building design. While structural design considerations for concrete and masonry at ambient temperature conditions are addressed by ACI 318 and ACI 530/ASCE 5/TMS 402, respectively, these codes do not consider the impact of fire on concrete and masonry construction. This standard contains design and analytical procedures for determining the fire resistance of concrete and masonry members and building assemblies. Where differences occur in specific design requirements between this standard and the aforementioned codes, as in the case of cover protection of steel reinforcement, the more stringent of the requirements shall apply.

Keywords: beams (supports); columns (supports); compressive strength; concrete slabs, fire endurance; fire ratings; fire resistance; fire tests; masonry walls; modulus of elasticity; prestressed concrete; prestressing steels; reinforced concrete; reinforcing steel; structural design; temperature distribution; thermal properties; walls.

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ACI 216.1-07 supersedes ACI 216.1-97, was adopted March 6, 2007, and published May 2007.

CHAPTER 1—GENERAL

1.1—Scope

This standard describes acceptable methods for determining the fire resistance of concrete building and masonry building assemblies and structural elements, including walls, floor and roof slabs, beams, columns, lintels, and masonry fire protection for structural steel columns. These methods shall be used for design and analysis purposes and shall be based on the fire exposure and applicable end-point criteria of ASTM E 119. This standard does not apply to composite metal deck floor or roof assemblies.

The primary intended use of this document is for determining the design requirements for concrete and masonry elements to resist fire and provide fire protection. Tolerance compliance to the provisions for concrete shall be based on information provided in ACI 117. Consideration for compliance to the provisions for masonry shall be based on the information provided in ACI 530.1/ASCE 6/TMS 602.

1.2—Alternative methods

Methods other than those presented in this standard shall be permitted for use in assessing the fire resistance of concrete and masonry building assemblies and structural elements if the methods are based on the fire exposure and applicable end-point criteria specified in ASTM E 119. Computer models, when used, shall be validated and supported by published material to substantiate their accuracy.

1.3—Definitions

The following definitions apply for this standard:

approved—approved by the building official responsible for enforcing the legally adopted building code of which this standard is a part, or approved by some other authority having jurisdiction.

bar, high-strength alloy steel—steel bars conforming to the requirements of ASTM A 722/A 722M.

barrier element—a building member that performs as a barrier to the spread of fire (for example, walls, floors, and roofs).

beam—a structural member subjected primarily to flexure, but also to axial loads.

blanket, ceramic fiber—mineral wool insulating material made of alumina-silica fibers and having a density of 4 to 8 lb/ft^3.

board, mineral—mineral fiber insulation board complying with ASTM C 726.

building code—a legal document that establishes the minimum requirements necessary for building design and construction to provide for public health and safety.

concrete, carbonate aggregate—concrete made with coarse aggregate consisting mainly of calcium carbonate or a combination of calcium and magnesium carbonate (for example, limestone or dolomite).

concrete, cellular—a low-density product consisting of portland-cement, cement-silica, cement-pozzolan, lime-pozzolan, lime silica pastes, or pastes containing a blend of these ingredients and having a homogeneous void or cell structure, attained with gas-forming chemicals or foaming agents. (For cellular concretes containing binder ingredients other than, or in addition to, portland cement, autoclave curing is usually employed.)

concrete, lightweight-aggregate—concrete made with aggregates conforming to ASTM C 330 or C 331.

concrete, normalweight—concrete made with aggregates conforming to ASTM C 33.

concrete, perlite—nonstructural lightweight insulating concrete having a density of approximately 30 lb/ft^3, made by mixing perlite aggregate complying with ASTM C 332 with portland cement slurry.

concrete, plain—structural concrete with no reinforcement or less reinforcement than the minimum amount specified in ACI 318 for reinforced concrete.

concrete, reinforced—structural concrete reinforced with no less than the minimum amount of prestressing tendons or nonprestressed reinforcement as specified by ACI 318.

concrete, semi-lightweight—Concrete made with a combination of lightweight aggregates (expanded clay, shale, slag, or slate, or sintered fly ash) and normalweight aggregates, having an equilibrium density of 105 to 120 lb/ft^3 in accordance with ASTM C 567.

concrete, siliceous aggregate—normalweight concrete having constituents composed mainly of silica or silicates.

concrete, structural—all concrete used for structural purposes, including plain and reinforced concrete.

concrete, vermiculite—concrete in which the aggregate consists of exfoliated vermiculite.

end-point criteria—conditions of acceptance for an ASTM E 119 fire test.

end-point, heat transmission—An acceptance criterion of ASTM E 119 limiting the temperature rise of the unexposed surface to an average of 250 °F for all measuring points or a maximum of 325 °F at any one point.

end-point, integrity—an acceptance criterion of ASTM E 119 prohibiting the passage of flame or gases hot enough to ignite cotton waste before the end of the desired fire-endurance period. The term also applies to the hose-stream test of a fire-exposed wall.

end-point, steel temperature—an acceptance criterion of ASTM E 119 defining the limiting steel temperatures for unrestrained assembly classifications.

end-point, structural—ASTM E 119 criteria that specify the conditions of acceptance for structural performance of a tested assembly.

endurance, fire—a measure of the elapsed time during which a material or assembly continues to exhibit fire resistance. As applied to elements of buildings with respect to this standard, it shall be measured by the methods and criteria contained in ASTM E 119.

fiberboard, glass—fibrous glass insulation board complying with ASTM C 612.

fiber, sprayed mineral—a blend of refined mineral fibers and inorganic binders.

fire resistance—the property of a material or assembly to withstand fire or provide protection from it. As applied to elements of buildings, it is characterized by the ability to confine a fire or, when exposed to fire, to continue to perform a given structural function, or both.

fire-resistance rating (sometimes called fire rating, fire-resistance classification, or hourly rating)—a legal term defined in building codes, usually based on fire endurance; fire-resistance ratings are assigned by building codes for various types of construction and occupancies, and are usually given in half-hour or hourly increments.

fire test—see **standard fire test**.

joist—a comparatively narrow beam, used in closely spaced arrangements to support floor or roof slabs (that require no reinforcement except that required for temperature and shrinkage stresses); also a horizontal structural member such as that which supports deck form sheathing.

masonry, plain—masonry in which the tensile resistance of masonry is taken into consideration and the resistance of the reinforcing steel, if present, is neglected.

masonry, reinforced—a material in which the masonry tensile strength is neglected and the effects of stress in embedded reinforcement are included in the design.

masonry unit, clay—solid or hollow unit (brick or tile) composed of clay, shale, or similar naturally occurring earthen substances shaped into prismatic units and subjected to heat treatment at elevated temperature (firing), meeting requirements of ASTM C 34, C 56, C 62, C 126, C 212, C 216, C 652, or C 1088.

masonry unit, concrete—hollow or solid unit (block) made from cementitious materials, water, and aggregates, with or without the inclusion of other materials, meeting the requirements of ASTM C 55, C 73, C 90, C 129, or C 744.

mastic, intumescent—spray-applied coating that reacts to heat at approximately 300 °F by foaming to a multicellular structure having 10 to 15 times its initial thickness.

material, cementitious—cements and pozzolans used in concrete and masonry construction.

material, vermiculite cementitious—cementitious material containing mill-mixed vermiculite to which water is added to form a mixture suitable for spraying.

reinforcement, cold-drawn wire—steel wire made from rods that have been rolled from billets, cold-drawn through a die; for concrete reinforcement of a diameter not less than 0.08 in. nor greater than 0.625 in.

standard fire exposure—the time-temperature relationship defined by ASTM E 119.

standard fire test—the test prescribed by ASTM E 119.

steel, hot-rolled—steel used for reinforcing bars or structural steel members.

strand—a prestressing tendon composed of a number of wires twisted about a center wire or core.

temperature, critical—temperature of reinforcing steel in unrestrained flexural members during fire exposure at which the nominal flexural strength of a member is reduced to the moment produced by application of service loads to that member.

tendon—a steel element such as strand, bar, wire, or a bundle of such elements, primarily used in tension to impart compressive stress to concrete.

wallboard, gypsum type "X"—mill-fabricated product, complying with ASTM C 36/C 36M, Type X, made of a gypsum core containing special minerals and encased in a smooth, finished paper on the face side and liner paper on the back.

1.4—Notation

A_1, A_2, and A_n = air factor for each continuous air space having a distance of 1/2 to 3-1/2 in. (13 to 89 mm) between wythes (nondimensional)

A_{ps} = cross-sectional area of prestressing tendons, in.^{2}

A_s = cross-sectional area of non-prestressed longitudinal tension reinforcement, in.^{2}

A_{st} = cross-sectional area of the steel column, in.^{2}

a = depth of equivalent rectangular concrete compressive stress block at nominal flexural strength, in.

a_θ = depth of equivalent concrete rectangular stress block at elevated temperature, in.

B = least dimension of rectangular concrete column, in.

b = width of concrete slab or beam, in.

b_f = width of flange, in.

c_c = ambient temperature specific heat of concrete, Btu/(lb/°F)

D_c = oven-dried density of concrete, lb/ft^3

d = effective depth, distance from centroid of tension reinforcement to extreme compressive fiber or depth of steel column, in.

d_{ef} = distance from centroid of tension reinforcement to most extreme concrete compressive fiber at which point temperature does not exceed 1400 °F, in.

d_ℓ = thickness of fire-exposed concrete layer, in.

d_{st} = column dimension, in.

ºF = degrees Fahrenheit

f_c = measured compressive strength of concrete test cylinders at ambient temperature, psi

f'_c = specified compressive strength of concrete, psi

$f'_{c\theta}$ = reduced compressive strength of concrete at elevated temperature, psi