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CONCRETE'S RESISTANCE TO FIRE

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ABSTRACT

The world's most popular building material is concrete. A civil engineer can accomplish heights they never thought possible.when this concrete is made into reinforced cement concrete by adding steel bars. However, reinforced concrete is vulnerable to the good powers of nature, specifically "FIRE," just like every other material on Mother Earth.This essay discusses how fire and reinforced concrete interact.What does "Fire Rating" signify in terms of the procedure is explained. How exactly are Fire Ratings obtained? R.C.C. members have a natural fire resistance. the physical and chemical processes a R.C.C. member experiences as a result of being around fires and their high temperatures. This paper finishes with recommendations for improving structural concrete's fire resistance as well as information on the rules set forth by IS 456:2000 for ensuring a specific level of fire resistance in concrete.

INTRODUCTION

Concrete is the most widely used building material in the world. In the last century, concrete has actually made it possible to build tall buildings. The pervasive use of concrete is demonstrated by the fact that contemporary cities are referred to as the "Concrete Jungle."

The performance of concrete in the event of a fire has recently come back into focus in light of recent extreme events, such as accidents, arsons, and terrorism, despite the fact that it has been used in civil engineering for more than 100 years and is widely regarded as a well-understood building material. We are all aware of the harm that a fire may do, such as the destruction of homes, the displacement of people, and the loss of livelihood. It is necessary to look more closely at structural concrete's fire-resistance qualities because it is being used in urban structures more and more.

Accidents, energy sources, and natural disasters can all start fires, but human mistake is the main reason why most fires in buildings start. When a fire begins and the inside materials of a structure begin to burn, With flame temperatures rising to between 700° and 1250°C, the fire spreads by radiation, convection, or conduction. The structural integrity and load carrying capacity of a structure can be seriously compromised by the exposure of concrete to high temperatures. When all previous attempts to put out a fire have failed, structural integrity is maybe one of the most serious circumstances faced over the life of a structure.

We will examine the effects of "Fire on Concrete" and "Fire Performance of Concrete Structures" in this study.

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Rating for Fire: 1.1

The IBC-2000 defines "fire resistance rating" as the duration for which a building component may hold back a fire, continue to carry out a particular structural function, or both, as established by the tests described in Section 703. The recognised fire test, ASTM E 119, "Fire Testing for Building Construction Materials," is used for walls, floors, roofs, columns, and beams. The specimen must meet that standard's requirements, unless the actual size is smaller than the minimum given, in order to be tested.

Once an "end point" has been reached, the test is continued. To constitute a "flame passage" termination point in walls, floors, or roofs, a hole or crack must be sufficiently large to permit hot fire gases to pass through to the other side. The example collapses, which is regarded as a "structural end point." When the temperature in any area hits 325°F or when the average temperature of the surface not exposed to fire rises by 250°F, walls, floors, and roofs begin to approach the "heat transmission" end point. Since concrete specimens rarely have structural or flame passage termination points, the latter requirement is always true.

How do fire ratings get done? 1.2

It should be evident how to do this—fire test a specific building component. Calculations performed in line with the code's procedures or predefined designs listed in the code are both acceptable alternatives. Although the code's "calculations" section contains a few formulas, the majority of the data is presented as based on data from common (ASTM E119) fire tests and tabulated in an easy-to-use format. The information about the minimum thickness of precast walls for various fire resistance ratings is included. The numbers are based on the end-point criterion for heat transfers, hence the figures are equal to the minimum thickness of floor slabs.

The following traits affect fire resistance: 1.3

The type of aggregate, moisture content, density, permeability, and thickness of concrete all affect its fire resistance. Because they are composed of either calcium carbonates or magnesium carbonates, or a combination of both, limestone, dolomites, and lime rock are referred to as "carbonate" aggregates.

These aggregates calcine when exposed to fire; calcium oxide replaces the carbon dioxide that was removed. Since heat is necessary for calcining, the reaction starts at the surfaces that are exposed to the fire and gradually moves to the opposite face. As a result, carbonate aggregates behave in fires a little bit better than standard weight aggregates.

Concrete's moisture content affects how it reacts in a fire in a complex way, thus it shouldn't be allowed to dry out completely, especially if the concrete is extremely permeable, such concrete that includes latex or silica fume. Alternatively, if the water to cement ratio is shockingly low. Concrete that is nearly totally dry performs well in general. Concrete that is

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lighter than concrete that is heavier will often perform better in a fire. The thicker or more massive the concrete, the better it reacts to fire.

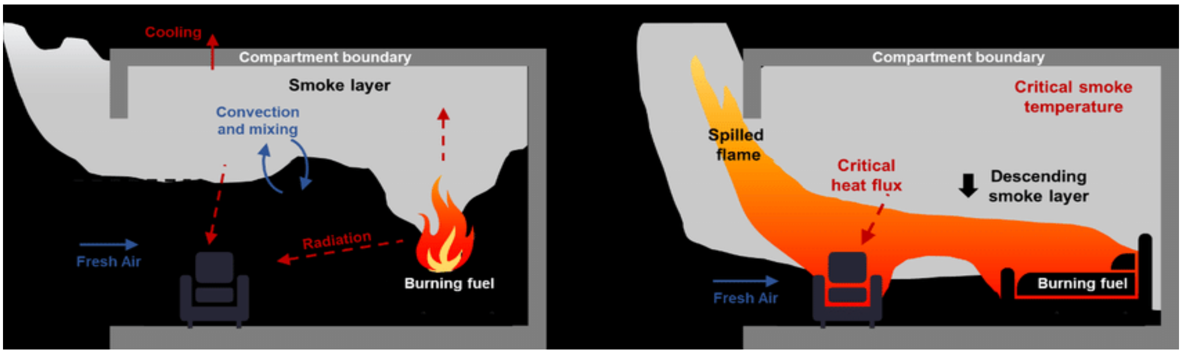
COMPOSITE CONCRETE & FIRE

Burning Concrete: 2.1

Concrete doesn't burn; unlike other building materials, it cannot be "started on fire," and when it is burned, it doesn't release any harmful gases. In addition, it won't produce smoke or leak molten material, which lessens the fire load. Because of these qualities, concrete is regarded as having a high level of fire resistance and is practically "fireproof" in the majority of applications. When the two primary ingredients of concrete, cement and aggregate, are chemically mixed, they produce a substance that is essentially inert and, more significantly for fire safety design, has a relatively low thermal conductivity. This excellent performance is a result of these two main components of concrete. Concrete can serve as an excellent concrete shield because to the conductivity's slow rate of heat transfer. Internal zones of concrete do not attain as high a temperature as a surface exposed to flame because the rate of temperature increase across a concrete cross section is comparatively sluggish.

After one hour of exposure on three sides, A standard ISO 834/BS 476 fire test on beams of concrete measuring 160 mm in width and 300 mm in depth showed that, while a temperature of 600 °C is reached at 16 mm from the surface, this value halves to just 300 °C at 42 mm from the surface — a temperature gradient of 300 °C in roughly an inch of concrete! Even after a considerable amount of time, the temperature of the concrete inside is still quite low; as a dividing element, it may continue to be structurally strong.

When concrete is subjected to the extreme heat of a fire, numerous physical and chemical changes could take place. The chart below relates concrete temperature (not flame temperature) to some inductive changes in its characteristics and displays these changes.



Diagrammatic representation of standard compartment fire

Concrete's fire behaviour is fundamentally related to the material's temperature-dependent characteristics.

Strong temperature gradients are frequently produced within fire-exposed concrete members because the thermal diffusivity is relatively low when compared to steel. This causes the core

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regions to take a long time to heat up due to significant temperature inertia. Therefore, while structural effectiveness is not affected until the bulk of the material reaches the same temperature, compressive strength is rapidly lost at a critical temperature, which is not too far from the equivalent temperature for loss of steel strength. This calls for the full structural element's temperature response.

Another problem occurs when concrete is subjected to spalling. Concrete pieces are violently ejected off the surface of the material during this occurrence, which is brought on by a reduction in surface tensile strength. It is brought on by the mechanical forces created inside the element as a result of intense heating or cooling, and/or by the concrete's rapid expansion of moisture raising the pore water pressure inside the structure.

Fire's physical and chemical effects: 2.2

When concrete is heated, a variety of physical and chemical changes could take place. After cooling, some of them are reversible, but others are irreversible, which could make the concrete structure significantly weaker in the event of a fire. Most porous concrete has some liquid water in it. This begins to evaporate if the temperature exceeds 100°C, which often leads to an increase in pressure inside the concrete. Cement's calcium hydroxide will begin to dehydrate at a temperature of about 400°C, producing more water vapour and significantly reducing the material's physical strength.

At greater temperatures, aggregate may experience further modifications. For instance, at roughly 575°C, mineral alteration causes quartz-based aggregates to expand in volume, but at 800°C, decomposition of limestone-based aggregates starts. Cracking and spalling may result from differential expansion between the cement matrix and the aggregate. These physical and chemical alterations to concrete will work together to weaken the material's compressive strength. Unlike steel constructions, where cooling will frequently successfully return the material to its former state, changes in the structural characteristics of concrete after a fire do not reverse themselves. It should be emphasised that, in some situations, a concrete structure may be significantly weaker after a fire, even if there is no visible damage, because of the permanent changes in the physical and chemical properties of the cement itself.

CRACKING

It is commonly accepted that the processes that create spalling and cracking are related. Fissures may form in the concrete instead of, or in addition to, explosive spalling due to thermal expansion and dehydration brought on by heating. The reinforcement bars may be directly heated through these cracks, which could result in thermal stress and more cracking. In other cases, the cracks could act as conduits for the spread of fire between adjacent compartments.

An emphasis is placed on the depths to which cracks in a concrete structure that has been subjected to fire. It was discovered that the depth of penetration is correlated with the fire's temperature and that, in general, the cracks penetrated the concrete part rather deeply.

The majority of the damage was contained to the area close to the fire's source, but the nature of the concrete's cracking and discoloration suggested that the area around the reinforcement

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had experienced 700°C of concrete heat. A brief heating and cooling cycle brought on by the fire being put out was blamed for cracks that reach more than 30 millimetres into the depth of the structure.

It's important to recognise the significance of concrete's stress conditions. In order to compact the material and prevent cracks from forming, compressive loads that may result from thermal expansion can be very helpful. As a result, the material's compressive strength and elastic modulus degrade considerably more slowly than they would in specimens receiving decreased loading.

SPALLING

"Explosive spalling" is one of the most complicated and, as a result, least understood behavioural traits in concrete's response to high temperatures or fire. Although it has been recorded at temperatures as low as 200°C and during the early stages of fire, this process is frequently believed to only take place at high temperatures.

Due to the increased heating of the steel reinforcement, severe spalling can negatively affect the strength of reinforced concrete structures. The coating of concrete covering the reinforcement bars may be severely reduced or even eliminated by spalling, exposing the reinforcement to high temperatures and reducing its strength, deteriorating the mechanical qualities of the structure as a whole. Another significant impact that spalling has on a structure's physical strength is that it reduces the stress on the remaining portions of the concrete that can still support the load, increasing the cross-section of concrete that is available to support the imposed load. Spalling is commonly assumed to occur as a result of high thermal strains brought on by rapid heating and/or significant pressure build-up as a result of Moisture evaporating from porous concrete that the concrete's structure can't get rid of. Fractures form and bits of material from the surface layers explode as a result of these activities.

The following types of fire spalling could take place:

I. Aggregate spalling, or crater-formed spalling, is ascribed to the aggregates' mineralogical makeup.

II. Surface Spalling is a violent flaking in the shape of a disc, especially in pressure-stressed walls, and is likely brought on by water wetness.

III. Corner Spalling - Violent corner spalling that is likely a result of water dampness and temperature strains brought on by bilateral rapid heating up, and

IV. Explosive Spalling: Extremely violent breaking of big, up to 1 m2, fragments into walls. The force causes some fragments to fly 12 metres.

FIRE RESISTANCE IMPROVEMENT

Through the Use of Lightweight Aggregate: 3.1

Lightweight aggregate serves as the coarse aggregate in the majority of modern lightweight high performance concrete mixes, while sand serves as the fine aggregate. Compared to 150

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p.c.f. for ordinary weight concrete, the light weight unit mix weight in this design is roughly 115–120 p.c.f. High freezing and thawing endurance, internal curing, reduced dead load, and good fire resistance are just a few of the benefits of lightweight high-performance concrete, often known as light weight structural concrete. Additionally, it meets with best practises for resource utilisation and environmental considerations.

Making a structure more manageable by using reasonably priced, high-performance light weight concrete is one approach to cut back on surplus material. According to ACI 213, light weight structural concrete is concrete with an air-dry density between 85 and 115 pounds per cubic foot (p.c.f.), with the same project criteria allowing air-dry densities up to 120 p.c.f., and a 28-day compressive strength above 2500 p.c.i. The dead load of light weight structural concrete is considerably lower than that of regular weight concrete, which has a density of about 150 p.c.f. Utilizing light weight aggregates, typically expandable shale, clay, or slate, allows for the weight difference to be obtained.

Structural light weight aggregate concrete's engineering characteristics:

Buildings and exposed structures with weight and durability difficulties can be solved with structural light weight aggregate concrete. Lightweight concrete is just as robust as ordinary concrete, but it is between 25% and 35% lighter. The following are some of the substantial cost advantages and design flexibility that structural light weight concretes offer: The advantages of this design include lower story heights, longer spans, better fire ratings, thinner sections, smaller structural components, less reinforcing steel, and lower foundation costs.

Reduced transportation and installation expenses are provided by lightweight concrete precast elements. Using light weight aggregate to decrease concrete density is a well-established practise where characteristics like improved fire resistance, simplicity of handling and transportation, or less structure dead load are sought. With compressive strengths of up to 5,000 psi, lightweight concrete has been employed often in commercial construction since the beginning (34.5 MPa). However, substantially weaker strength has been defined over the previous 20 years.

The final properties of concrete are greatly influenced by the physical characteristics of the aggregate, which typically makes about 65–75% of a concrete mix. In comparison to low or medium strength concrete, high strength concrete depends more on the quality of the aggregate. Most often, aggregate is utilised as a cheap filler material. The majority of the weight applied on the concrete is supported by the cement paste matrix. The aggregate's capability for carrying load and the interaction between the aggregate and cement paste become the limiting variables in the development of strength when the design load approaches and exceeds the strength restrictions of the cement paste matrix.

This limit looks to be between 15,000 and 16,000 psi, in all actuality (100 to 110 MPa) approximately 80% of this for concrete built using light weight expanded slate aggregate, and perhaps less than 70% of this for concrete made with regular weight expanded clay or shale material. Since the mechanical properties of light weight aggregate are more similar to those of the cement paste matrix than to those of normal weight aggregate, this restriction is more obvious for light weight concrete because variations in aggregate quality will be more

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directly reflected in the characteristics of the concrete. Since the features of the concrete will more obviously reflect this restriction, it is more obvious for low weight concrete.

Type	Dry Loose Unit Weight (pcf)	(Kg/m^3)	Bulk Specific Gravity (Kg/m^3)	1 Hour Water Absorption (% Weight)	24 Hour Water Absorption (% Weight)
Expanded Clay	37	600	1300	25	30
Expanded Clay	47	750	1300	8	11
Expanded Clay	50	800	1450	8	11
Expanded Clay	45	700	1250	7	not available
Expanded Clay	50	800	1500	7	10
Expanded Clay	50	800	1500	12	20
Expanded Shale	45	700	1400	9	10
Expanded Slate	47	750	1500	4	5

An overview of a few light weight aggregates:

Pumice Aggregate

Pumice, which can also be formed in a less acidic form, is essentially made of solidified foamy lava, which is often rhyolitic in composition. The strength of an aggregate can be very porous and weak, or it can be stronger and less porous. The porosity and size of aggregates have a significant impact on the specific properties of absorption, which is often high. Pumice must have a low density and a relatively high strength in order to be deemed an acceptable aggregate for use in structural light weight concrete. The amount of voids, which depends on the kind of deposit from which the pumice is derived, determines the density.

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Expanded Slate Aggregate

Argillite slate is present in a geological formation known as the Tillite Formation. It is made up of elastic rock fragments and is a fine-grained, thinly laminated grey siltstone. Volcanic ash was occasionally deposited into the same deposition basin together with an ash flow or gravity mud flow. Within the system, further layers of volcanic tuff with significant amounts of calcite formed. The alternating layers of material faulted and folded over the course of subsequent millions of years of geological activity, disorganizing the previously orderly, layered system.

IS 456:2000 RECOMMENDATIONS

According to Bureau of Indian Standards, IS 456. The fire resistance of constructions made of reinforced concrete is covered in A. A structure's or a structural component's design should be sufficiently fire resistant against heat transmission, flame penetration, and failure. Concrete resists flames.

Element depends on member size information, cover details for the steel reinforcement, and aggregate details. on concrete; applied. The reinforcing details should account for the shifting structural section pattern and ensure that there are enough supports, links, bonding, and anchors for both the structure as a whole and each individual piece. If the nominal cover required is greater than 40 mm for beams and 35 mm for slabs, additional precautions, such as the application of fire-resistant finishes, the provision of fire-resistant false ceilings, and the use of sacrificial steel in the tensile zone, should be taken to provide protection against spalling.

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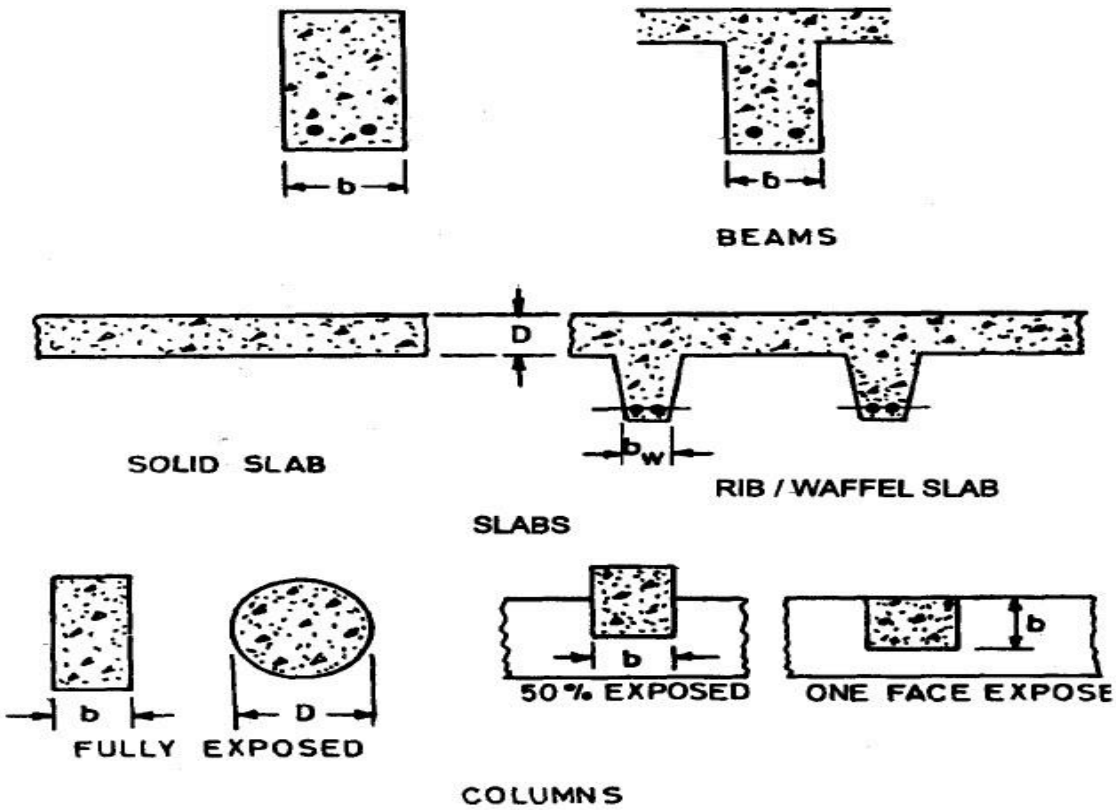

Minimum Reinforced Concrete Members Dimensions for Fire Resistance

Fire Resis-tance *h*	Minimum Beam Width *b*	Rib Width of Slabs b_w	Minimum Thickness of Floors *D*	Column Dimension (b or D)			Minimum Wall Thickness		
				Fully Exposed	50% Exposed	One Face Exposed	$p<0.4\%$	$0.4\%\leq p\leq 1\%$	$p>1\%$
	mm	mm	mm	mm	mm	mm	mm	mm	mm
0.5	200	125	75	150	125	100	150	100	100
1	200	125	95	200	160	120	150	120	100
1.5	200	125	110	250	200	140	175	140	100
2	200	125	125	300	200	160	–	160	100
3	240	150	150	400	300	200	–	200	150
4	280	175	170	450	350	240	–	240	180

SYNOPSIS AND CONCLUSION

SYNOPSIS

1. The amount of time a building component can contain a fire is known as its fire rating.

2. The type of aggregate, moisture content, density, permeability, and thickness of a concrete all affect its fire resistance.

3. Cracking - The dehydration and thermal expansion of the concrete brought on by heating may result in cracks, creating pathways for the reinforcement bars to be heated directly, leading to thermal strains and additional cracking.

4. Spalling results from a significant build-up of pressure brought on by moisture evaporation within porous concrete, which the structure of concrete is unable to discharge

5. Although it has been recorded at temperatures as low as 200° C and during the early stages of fire, this process is frequently believed to only take place at high temperatures.

6. The type of aggregate, the presence of free moisture, and the ability of the material to expand are all factors that can affect the occurrence of fire spalling.

7. According to the theory that moisture clogs, when heated, the steam pressure in the pores rises nearly to the surface.

8. The pressure gradient causes moisture to move not just away from the specimen but also in the direction of the interior, cool areas.

9. Steam will condense when it comes into contact with the inner, cooler layer. Up until the creation of a fully saturated region of "substantial thickness," this process will continue, going further into the cross section. The "Moisture Clog" is the name of this area.

10. According to the hydraulic spalling theory, spalling results from water expanding hydraulically until it fills the surrounding porous skeleton to a greater volume than is physically possible.

CONCLUSION

Concrete has been used as a principal building material for more than a century, and it has shown to be a robust, long-lasting material with built-in fire resistance. However, as a result of industrialization, conflict, and terrorism, new fire risks have emerged in the new century.

The time is right to conduct fresh, in-depth research and studies to strengthen concrete's fire resistance in order to prepare it for brand-new threats like industrial fires and explosions. This is because of these recent changes in the world around us.

The work in this study's presentation aims to highlight the consequences of fire on reinforced concrete structures. Spalling and cracking in particular.

The current work demonstrates that adding reinforcement with PP-fibers and lightweight aggregates is recommended to boost and improve concrete's ability to resist fire as a building material.

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