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Improvement of Fire Resistance Capacity of Existing Column by Using Diamond Tie Configuration

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ABSTRACT: recent fires around the world have caused significant damage to multi-story reinforced concrete frame structures. The ties in reinforced concrete columns are provided either rectangular or circular according to Indian codal guidelines, depending on the shape of the column. During a fire, the load-bearing elements of a structure, such as columns, become weak links. The failure of columns has been seen to cause the majority of the structural damage. In India alone, an average building fire kills around 2000-3000 people each year, according to statistics. Preventive fire measures, post-fire repairs, and retrofitting are required for the structures. However, most structures have been seen to be irreparably damaged due to the lack of fire-control mechanisms. This results in significant losses in terms of infrastructure economics. Given that most fires can be extinguished within the first to second hour of their occurrence, the goal is to improve the fire resistance requirements of buildings, particularly columns, so that the structures can be used even after a fire. At ambient temperatures, a decrease in tie spacing is beneficial because it increases the moment capacity of the section, resulting in better confinement. However, in the event of a fire, the positive effects of reducing tie spacing beyond 100 mm were not observed.

KEYWORDS: Casting, Diamond Ring & Ties, Rebound hammer & Ultrasonic Pulse velocity test, NDT, Compression Test, Fire Resistance, Mix Design

I. INTRODUCTION

Definition of Fire Resistance

“The property of a building element, component or assembly that prevents or retards the passage of excessive heat, hot gases or flames under conditions of use”

Fire Resistance Period:

Duration of time determined by a fire test or method based on a fire test that a building element, component or assembly maintains the ability to confine a fire, continues to perform a given structural function or both.

The toughness of the RC Framed column is overestimated because the role of loss in confinement behaviour is not taken into account when determining fire resistance. An experimental study focusing

on determining the fire resistance experimentally for 18 Pre-stressed Concrete columns with variable spalling scenarios, reinforcement detailing, and load eccentricities is presented here. Reinforced concrete (RC) is a popular building material all over the world. However, RC deteriorates like other materials, and fire exposure is a more rapid form of deterioration of RC Structures. Early research focused on the good fire resistance of concrete due to its properties of 'incombustibility' and 'low thermal diffusivity'.

Axial forces and force induced moments are the most common loads on RC Columns. The physical-mechanical properties of concrete change dramatically during a fire, resulting in time dependent creep strain and temperature-induced transient strain. Even at static axial loads, this causes greater deformability in the RC Column during fire. As a result, the stiffness of the RC Column decreases over time, as does its resistance to fire loads

Factors Influencing RC Column Fire Resistance

The fire resistance of RC Columns is affected by material, mechanical, structural, loading, and constructional parameters. The limiting behaviour caused by spalling is critical to the fire resistance of RC Columns.

Aggregates

The type of aggregate has a significant impact on the fire resistance of concrete. Carbonate aggregate columns have ten times the fire resistance of siliceous aggregate columns due to the absence of other microscopic reactions in the former. This is because carbonate aggregate has a higher specific heat above 600°C than siliceous aggregate and crystalline material has a higher thermal conductivity than amorphous material.

Primarily, siliceous aggregate causes increased spalling with wider cracks, and the effects of cover spalling are more prevalent in HSC columns due to higher free moisture content in HSC columns with mostly predominant light-weight aggregate and due to low concrete permeability.



Fig1.1: Column of Compression and Tension Face

Concrete structures are well-known for their fire resistance. There haven't been many reported cases of severe structural failure caused by the collapse of individual walls, beams, or columns. However, as buildings are designed with lower safety margins and higher strength concretes, this may change. When a fire breaks out in a building, the walls must be reinforced to limit the spread of fire and maintain structural adequacy.

Materials

Cement

Type I Portland cement, a general purpose cement for construction of reinforced concrete structures, was used for constructing the reinforced concrete columns.

Aggregates

The columns were fabricated with carbonate aggregate concrete. When concrete is made with coarse aggregate consisting mainly of calcium carbonate or a combination of calcium and magnesium carbonate it is referred to as carbonate aggregate concrete. The fine aggregate used was natural sand.

Reinforcement

Deformed bars meeting the requirements of ASTM A615-80 were used for main longitudinal bars, spirals, and ties. All reinforcement had specified yield strength. The longitudinal reinforcement in the circular columns was comprised of bars, symmetrically placed, with Cover to the spiral reinforcement. The square column had four diameter longitudinal reinforcing bars with cover to the ties. The main reinforcing bars were welded to steel end plates.

Concrete is the most widely used construction material in the world. Literally it's concrete which makes high-rise structures possible in past century; the extensive use of concrete can be shown in the fact that the cities of today are known as the Concrete Jungle. Although presence of concrete in civil engineering is more than 100 years old, concrete is extensively used and is thought to be a well understood construction material, in the light of recent extreme events, including accidents, arsons and terrorism, attention has refocused on the performance of concrete in the vague of fire. We are all aware of the damage that fire can cause in terms of loss of lives, homes and livelihoods. With the increasing use of structural concrete in urbane structures there is a need arise for closer study of the fire resisting properties of structural concrete. Fires are caused by accidents, energy sources or natural means, but the majority of fires in buildings are caused by human errors.

Once a fire starts and the contents in a building starts burning, then the fire starts spreading via radiation, convection or conduction with flames reaching between 600° and 1200°C. The exposure of concrete to high temperature can jeopardize significantly the structural integrity and load bearing capacity of the structure. Fire represents possibly one of the most severe conditions encountered during the life time of a structure and when all other measures for containing a fire have failed, structural integrity represents the last line of defense

Fire Rating:

“Fire resistance rating” means “the period of time a building components maintains the ability to confine a fire or continues to perform a given structural function or both, as determined by the tests prescribed in section 703”. For walls, floors, roofs, columns and beams, tests referred to are the standard fire test, ASTM E 119, “Fire tests for Building Construction Materials”. That standard requires that the specimen to be tested at least a certain size, unless the actual size is smaller than the minimum specified. The test is continued until an “end point” is reached. A „structural” end point occurs if the specimen collapses. A “flame passage” end point occurs in walls, floors or roofs if a hole or crack occurs that is large enough to allow hot gases from the fire to reach the other side. A “heat transmission” end point occurs for walls, floors and roofs if the average temperature of the surface not exposed to fire is increases by 250°F or if the temperature at any point rises at 325°F. For concrete specimens, this later criterion always governs, that is, the structural or flame passage end points, seldom occurs.

This standard specifies acceptable methods for determining the fire resistance of concrete and masonry building assemblies and structural elements such as walls, floor and roof slabs, beams, columns, lintels, and masonry fire protection for structural steel columns. These methods must be used for design and analysis and must be based on the ASTM E 119 fire exposure and applicable end-point criteria. This standard does not apply to floor or roof assemblies made of composite metal deck. This document's primary purpose is to determine the design requirements for concrete and masonry elements to resist fire and provide fire protection. Tolerance compliance with concrete provisions shall be based on information provided in ACI 117.

II. LITERATURE REVIEW

Thermal restraint and fire resistance of columns, Cabrita Neves a, J.C. Valente a , J.P. Correia Rodrigues b,22 May 2020,

A proposal is made, based on the results of a series of tests and calculations, with the aim of being used as a simple method to correct the value of the critical temperature of steel columns free to elongate, in order to take into account the restraint effect of the structure to which they belong in a practical situation. To better illustrate the possible types of behaviour of heated steel columns with elastic restraint to the thermal elongation, and the reasons why the critical temperature of axially loaded slender steel columns with thermal restraint can sometimes be lower than the critical temperature of the same columns free to elongate, a simple model is presented and used in a qualitative analysis.

Fire Resistance of Concrete, Aqeel Shams SGI, Sikar, IJETS, March 2016,

This paper deals with the interaction of fire with Reinforced Concrete. It explains the process that what is the meaning of 'Fire Rating'? How exactly Fire Ratings can be achieved? Inherent fire resistance of R.C.C. members; the physical and chemical processes a R.C.C. member goes through when exposed to high temperature due to fire, its deterioration. Lastly this paper concludes with the suggestions on how to make structural concrete more fire resistant and what are the guidelines provided by IS 456:2000 on securing the certain degree of Fire Resistance in Concrete.

Axial compressive behavior of lightweight aggregate concrete columns confined with transverse steel reinforcement, Tao Wu, Hui Wei, Yu Zhang and Xi Liu, SAGE, 23 February 2018,

This study presents an experimental investigation into the behavior of lightweight aggregate concrete columns confined with transverse steel reinforcement. Twelve reinforced specimens were tested under monotonically increasing axial compressive load. Test variables considered in the study include the amount of transverse steel and the tie configuration

Evaluation of Fire Effects on Reinforced Concrete Columns Using Finite Element Method, Sajjad Sayyar Roudsari and Taher M. Abu-Lebdeh, American Journal of Engineering, 2019,

In this paper, four different Reinforced Concrete (RC) columns are analyzed with Finite Element (FE) ABAQUS software and validated experimentally. One of the RC columns, the control specimen, is subjected to only compressive force applied at both ends of the column, while the other three models were loaded under both compressive force and fire load. The temperature is applied to reach up to 600 Celsius Degree for the period of 10, 15 and 20 min. The load-displacement diagrams were constructed. Results showed good correlations between experimental and FE analysis. Moreover, results showed reduction in load capacity as duration of fire load increases

A Practical Method For the Calculation of Fire Resistance of Reinforced Concrete Columns, Ataman Haksever, ISSN, 2019,

In this paper a practical method for the determination of the fire resistance time of the uniaxial stressed reinforced concrete columns, which does not need the sophisticated computer aid, has been introduced

Studies on the behavior of Reinforced Concrete Short Column subjected to fire, Aneesha Balaji, Muhamed Luquman K, Praveen Nagarajan, T.M. Madhavan Pillai, Alexandria Engineering Journal, Jan 2019

The paper investigates the axial capacity of reinforced columns exposed to fire. The simplified method namely 500 C isotherm method explained in Eurocode 2 is used to assess the capacity of the column. Finite element software ANSYS is used to perform the thermal analysis. A set of numerical studies were carried out to quantify the effect of various parameters on short columns subjected to fire.

Improved confinement of reinforced concrete columns, Ahmed M. El-Kholy a, Hany A. Dahish, Ain Shams Engineering Journal, June 2019,

This paper presents a practical confinement configuration consisting of single Expanded Metal Mesh (EMM) layer in addition to regular tie reinforcement. The EMM layer is warped above ties. The proposed transverse reinforcement, with various volumetric ratios of ties, was investigated in sixteen square short RC column specimens categorized in two groups according to their slenderness ratios.

Multi-objective thermodynamic optimization of an irreversible regenerative Brayton cycle using evolutionary algorithm and decision making, Rajesh Kumar, S.C. Kaushik, Raj Kumar, Ranjana Hans, Ain Shams Engineering Journal, 9 June 2019,

Multi-objective genetic algorithm based on NSGA-II has been applied to simultaneously optimize ecological function, power output and thermal efficiency of an irreversible regenerative Brayton heat engine model.

Fire Resistance of load-Bearing Reinforced Concrete Walls, Andrew H. Buchanan, V. Rad Munukutla, Jan 2020,

This paper describes a numerical method of calculating the fire resistance of loadbearing reinforced concrete walls. Each wall is divided into a number of segments of height and elements of thickness. The calculated temperature profile through the wall gives the temperature in each element which is used with the constitutive relationships and mechanical properties to predict structural behaviour.

A Model For Evaluating The Fire Resistance Of High Performance Concrete Columns, V.K.R Kodur, T.C. Wang, F.P. Cheng and M.A. Sultan, National Research Council, 2017,

A numerical model, in the form of a computer program, for evaluating the fire resistance of high performance concrete (HPC) columns is presented. The three stages, associated with the thermal and structural analysis, for the calculation of fire resistance of columns is explained.

Predicting the fire resistance behaviour of high strength concrete columns, Kodur, V.K.R.; Wang, T.C.; Cheng, F.P. NRCC-43379, Feb 2020,

The validity of the numerical model used in the program is established by comparing the predictions from the computer program with results from full-scale fire resistance tests. Details of fire resistance experiments carried out on HPC columns, together with results, are presented. The computer program can be used to predict the fire resistance of HPC columns for any value of the significant parameters, such as load, section dimensions, fiber reinforcement, column length, concrete strength, aggregate type, and fiber reinforcement.

Fire resistance of reinforced concrete columns: A systematic review, S.H. Buch & U.K. Sharma, Applications of Fire Engineering, September 2019,

This review studies the equivalence of fire resistance of RC Columns from various analytical methods with the experimental results. The experimental results for determining fire resistance are co-related with each other to determine the deviation from general results. The reasons for variation in experimental results and

indications for modification in theoretical methods are finally discussed.

Fire resistance design guidelines for high strength concrete columns, Kodur, V.K.R. , NRCC-46116 ,October 2018,

An overview of the research program, aimed at developing fire resistance design guidelines for high strength concrete (HSC) columns, is outlined. A comparison is made of the fire resistance performance of HSC column with that of normal strength concrete column.

Fire Resistance of Brick Masonry, Centennial Park Drive, Reston, Virginia, March 2018,

This Technical Note presents information about the fire resistance of brick masonry assemblies in loadbearing and veneer applications. Fire resistance ratings of several brick masonry wall assemblies tested using ASTM E119 procedures are listed. For untested wall assemblies, procedures are presented for calculating a fire resistance rating.

Fire Safety Engineering of Concrete-Filled Steel Tubular Column without Fire Protection, Kenichi Ikeda and Yoshifumi Ohmiya, Fire Science and Technology ,2019,

This report presents modeling of the member and frame, based on fire tests and previous research, thermal analysis of the frame during fire, and consideration of on-site planning and execution, as designed by the authors in 47 buildings.

Validation of Indian standard code provisions for fire resistance of flexural elements, Aneesha Balaji*, Praveen Nagarajan, and Madhavan Pillai, Songklanakarin J. Sci. Technol, Mar.-Apr. 2018,

The aim of this paper is to familiarize the simplified method, i.e., 500°C isotherm method. The procedure is customized for Indian conditions and a parametric study is done to determine the fire rating for flexural elements. Fire ratings recommended in IS 456:2000 is compared with strength criteria by using the 500°C isotherm method. It is also compared by thermal criteria obtained by heat transfer analysis of finite element model

Fire Resistance of Axially Loaded Slender Concrete Filled Steel Tubular Columns, A. Espinós, A. Hospitaler, M. L. Romero, Acta Polytechnica , 1/2019,.

In a fire, the degradation of the material properties will cause CFT columns to become highly nonlinear and inelastic, which makes it quite difficult to predict their failure. In fact, it is still not possible for analytical methods to predict with enough accuracy the behaviour of columns of this kind when exposed to fire. Numerical models are therefore widely sought. Many numerical simulations have been carried out worldwide, without obtaining satisfactory results. This work proposes a three-dimensional numerical model for studying the actual fire behaviour of columns of this kind.

III. RESEARCH METHODOLOGY

Aim

“To study a Diamond Tie Configuration to Improve Fire Resistance Capacity of Existing Column”

Objectives

To study the improvement of fire resistance of reinforced column by rectangular and diamond tie;

- Investigate RC column subjected to fire for different tie system with different spacing and cover
- Comparison of RC column subjected to fire for Rectangular and Diamond ties.
- Comparison of RC column subjected to fire for different concrete cover.

Problem Statement

For RC columns that have been exposed to fire, look into alternate tie systems with different spacing and coverings. In an RC column that has been exposed to fire, rectangular and diamond ties are compared and comparison of RC columns with various concrete covers that have been exposed to fire

Research Work

- **Preliminary Investigation**—Preliminary investigation- In first phase Physical properties of ingredient of concrete. In second phase Concrete mix design carried out for grade M20.
- **Test of Concrete for Fire Test**
 - Test specimen of size 230x230x750 is prepared for Fire test.
 - Longitudinal Reinforcement 6#12 & Transverse Reinforcement of 8@100mm, 8@150mm, 8@200mm.
 - Cover for concrete is 25mm, 35mm, 45mm.
 - Total 18 columns are casted.
 - 28 days curing with gunny bags or curing pond.
 - After 90 days of casting Fire test will be conducted on column on one face of column or all face of column.
 - Study the spalling area.
 - Study crack pattern.
 - Finding buckling load of column.
 - NDT Test are carried of checking the strength of column
 - Rebound hammer & Ultrasonic Pulse velocity test

Ultrasonic Pulse Velocity

- The ultrasonic pulse velocity method could be used to establish:
- The homogeneity of the Ferrocete,
- The presence of cracks, voids and other imperfections,
- Changes in the structure of the Ferrocete which may occur with time,
- The quality of the Ferrocete in relation to standard requirements,
- The quality of one element of Ferrocete in relation to another and the values of the Ferrocete.

Rebound Hammer

The rebound hammer method could be used for:

- Assessing the likely compressive strength of Ferrocete with the help of suitable correlations between rebound index and compressive strength.
- Assessing the uniformity of Ferrocete,
- Assessing the quality of the Ferrocete in relation to standard requirements

Casting of Column

Table1.1: Casting Details

Tie Type	Tie Spacing	Concrete Cover
Rectangular Ties	100 mm c/c	25 mm, 35mm, 45mm
Rectangular Ties	150 mm c/c	25 mm, 35mm, 45mm
Rectangular Ties	200 mm c/c	25 mm, 35mm, 45mm
Tie Type	Tie Spacing	Concrete Cover
Diamond Ties	100 mm c/c	25 mm, 35mm, 45mm
Diamond Ties	150 mm c/c	25 mm, 35mm, 45mm
Diamond Ties	200 mm c/c	25 mm, 35mm, 45mm

Testing Apparatus



Figure1.2: Testing Apparatus

IV. EXPERIMENTAL STUDY

M20 MIX DESIGN IS 10262:2019:

- Step-1** Calculate Target Mean Strength of Concrete
- Step-2** Selection of Water-Cement Ratio
- Step-3** Estimation of Air Content
- Step-4** Selections of Water Content and Admixture Content
- Step-5** Estimation of Cement Content
- Step-6** Estimation of Coarse Aggregate Proportion
- Step-7** Mix Calculation for 1 m³

Mix Proportion by Volume

Cement = 318 kg/m³

Water = 197.15 Liter/m³

Fine aggregate = 802.36 kg/m³

Coarse aggregate 20 mm = 1162.16 x 60 %= 697.29 kg/m³

Coarse aggregate 10 mm = 1162.16 x 40 %= 464.86 kg/m³

Water-cement ratio = 0.62

Weight of Materials for 1 Bag (50 kg) Bag of Cement

We know that volume of 50 kg bag of cement is 0.035 m³. so if we divide the weight of cement by the volume of 1 bag of cement we will get a number of bags of cement required for making 1 cubic meter of concrete.

Cement = 318 kg / 0.035 = 11.13 Nos. of Bags

Now divide all other quantities by 11.13 to get materials quantity for 50 kg or 1 bag of cement

Fine Aggregate (Sand) = 802.36 / 11.13 = 72.08 kg

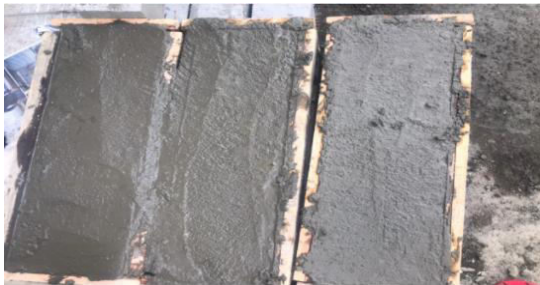
Coarse Aggregate (20 mm) = 697.29 / 11.13 = 62.64 kg

Fine Aggregate (10 mm) = 464.86 / 11.13 = 41.76 kg

Water = 197.15 / 11.13 = 17.71 liter.

CASTING OF SPECIMEN





V. TESTING SPECIMEN

Pulse Velocity of Ultrasonic

An ultrasonic pulse velocity (UPV) test is a non-destructive, in-situ examination of the quality of concrete and natural rocks. The velocity of an ultrasonic pulse passing through a concrete structure or natural rock formation is measured in this test to determine the strength and quality of concrete or rock.

Ultrasonic Pulse Velocity (UPV) testing determines the integrity and quality of structural concrete or stone (up to 6 feet thick) by measuring the speed and attenuation of an ultrasonic wave as it passes through the element being tested.

An ultrasonic pulse velocity (UPV) test is a non-destructive, in-situ examination of the quality of concrete and natural rocks. The strength and quality of concrete or rock are evaluated in this test.



This test is conducted by passing a pulse of ultrasonic through concrete to be tested and measuring the time taken by pulse to get through the structure. Higher velocities indicate good quality and continuity of the material, while slower velocities may indicate concrete with many cracks or voids.

Ultrasonic testing equipment includes a pulse generation circuit, consisting of electronic circuit for generating pulses and a transducer for transforming electronic pulse into mechanical pulse having an oscillation frequency in range of 40 kHz to 50 kHz, and a pulse reception circuit that receives the signal

Hammer Rebound Test

The hammer measures the rebound of a spring-loaded mass striking a sample's surface. The test hammer strikes the concrete with a predetermined amount of force. The rebound of the concrete is determined by the hardness of the concrete and is measured by the test equipment. The rebound value can be used to calculate the compressive strength of concrete using a conversion chart. When performing the test, hold the hammer at right angles to the surface, which should be flat and smooth. The rebound reading will be influenced by the hammer's orientation:

Gravity will increase the rebound distance of the mass when used oriented upward (for example, on the underside of a suspended slab), and vice versa for a test conducted on a floor slab.

The test is also sensitive to the following factors:

- Variation in the sample at the local level. To reduce this, it is best to take a number of readings and average or median the results.
- The sample's water content; a saturated material will produce different results than a dry one.

The Schmidt hammer should be calibrated prior to testing using a calibration test anvil supplied by the manufacturer. Take twelve readings, removing the highest and lowest, and then taking the average of the ten remaining. This method of testing is classified as indirect because it does not provide a direct measurement of the material's strength. It simply provides an indication based on surface properties and, as such, is only useful for comparing samples.

ASTM C805 governs this concrete testing method.

Rebound Hammer Test



Table1.1: Rebound Hammer Test

Concrete member	ID mark	Grade of concrete	Date of casting	Date of Testing	Age of concrete (days)	Direction of Impact	Corrected Avg Rebound No	Indicative Strength (N/sq mm)
COLU MN	C1	M-20	06-10-2021	10-01-2022	90	HORIZONTAL	28.3	29.2
COLU MN	C2	M-20	06-10-2021	10-01-2022	90	HORIZONTAL	29.7	31.1
COLU MN	C3	M-20	06-10-2021	10-01-2022	90	HORIZONTAL	31.3	33.5
COLU MN	C4	M-20	06-10-2021	10-01-2022	90	HORIZONTAL	32.7	35.3
COLU MN	C5	M-20	07-10-2021	10-01-2022	90	HORIZONTAL	30.7	32.5
COLU MN	C6	M-20	07-10-2021	10-01-2022	90	HORIZONTAL	30.2	31.8
COLU MN	C7	M-20	07-10-2021	10-01-2022	90	HORIZONTAL	29.8	31.3
COLU MN	C8	M-20	08-10-2021	10-01-2022	90	HORIZONTAL	30.5	32.3
COLU MN	C9	M-20	08-10-2021	10-01-2022	90	HORIZONTAL	30.2	31.8
COLU MN	C10	M-20	08-10-2021	10-01-2022	90	HORIZONTAL	30.3	32
COLU MN	C11	M-20	09-10-2021	10-01-2022	90	HORIZONTAL	30.5	32.3
COLU MN	C12	M-20	08-10-2021	10-01-2022	90	HORIZONTAL	31	32.6
COLU MN	C13	M-20	09-10-2021	10-01-2022	90	HORIZONTAL	32.6	32.9
COLU MN	C14	M-20	10-10-2021	10-01-2022	90	HORIZONTAL	31.4	32
COLU MN	C15	M-20	10-10-2021	10-01-2022	90	HORIZONTAL	30.9	32.2
COLU MN	C16	M-20	10-10-2021	10-01-2022	90	HORIZONTAL	31.2	31.7
COLU MN	C17	M-20	10-10-2021	10-01-2022	90	HORIZONTAL	30.9	32.2
COLU MN	C18	M-20	10-10-2021	10-01-2022	90	HORIZONTAL	31.2	32.7

NDT-StructuralMembers- Ultrasonic Test Results

Table1.2: NDT-StructuralMembers- Ultrasonic Test Results

ID mark	Concrete member	Location	Date of casting	Date of Testing	Age of concrete (days)	Grade of concrete	Method by Probe direction	Distance (m)	Time (micro seconds)	Ultrasonic pulse velocity (UPV) (km/sec)	Concrete Quality Grade
DIRECT	COLUMN	Center	06-10-2021	10-01-2022	20	M-20	HORIZO	250	60.9	4.11	"Good"
DIRECT	COLUMN	Center	06-10-2021	10-01-2022	20	M-20	HORIZO	250	59.4	4.21	"Good"
DIRECT	COLUMN	Center	07-10-2021	10-01-2022	20	M-20	HORIZO	250	59.5	4.2	"Good"
DIRECT	COLUMN	Center	07-10-2021	10-01-2022	20	M-20	HORIZO	250	56.6	4.42	"Good"
DIRECT	COLUMN	Center	08-10-2021	10-01-2022	20	M-20	HORIZO	250	59.1	4.23	"Good"
DIRECT	COLUMN	Center	06-10-2021	10-01-2022	20	M-20	HORIZO	250	58.4	4.28	"Good"
DIRECT	COLUMN	Center	06-10-2021	10-01-2022	20	M-20	HORIZO	250	57.7	4.33	"Good"
DIRECT	COLUMN	Center	07-10-2021	10-01-2022	20	M-20	HORIZO	250	57.2	4.37	"Good"
DIRECT	COLUMN	Center	07-10-2021	10-01-2022	20	M-20	HORIZO	250	58.1	4.3	"Good"
DIRECT	COLUMN	Center	08-10-2021	10-01-2022	20	M-20	HORIZO	250	57.8	4.33	"Good"
DIRECT	COLUMN	Center	06-10-2021	10-01-2022	20	M-20	HORIZO	250	60.1	4.16	"Good"
DIRECT	COLUMN	Center	06-10-2021	10-01-2022	20	M-20	HORIZO	250	57.5	4.25	"Good"
DIRECT	COLUMN	Center	07-10-2021	10-01-2022	20	M-20	HORIZO	250	56.4	4.2	"Good"
DIRECT	COLUMN	Center	07-10-2021	10-01-2022	20	M-20	HORIZO	250	57	4.3	"Good"
DIRECT	COLUMN	Center	08-10-2021	10-01-2022	20	M-20	HORIZO	250	56.5	4.45	"Good"
DIRECT	COLUMN	Center	08-10-2021	10-01-2022	20	M-20	HORIZO	250	57.6	4.3	"Good"



Fire Resistance test

Grade of concrete	M20
temp	200 C
time	2 hrs

Table1.3: Fire Resistance test

SrNo	ColNo	Axial Load	Description	SPACING	CLEAR COVER
1	C1	581.45	Longitudinal Reinforcement #12 & Transverse Reinforcement of 8@100mm, Cover for concrete is 25mm	100	25MM
2	C2	575.65	Longitudinal Reinforcement #12 & Transverse Reinforcement of 8@100mm, Cover for concrete is 25mm	100	25MM
3	C3	535.45	Longitudinal Reinforcement #12 & Transverse Reinforcement of 8@150mm, Cover for concrete is 25mm	150	25MM
4	C4	525.21	Longitudinal Reinforcement #12 & Transverse Reinforcement of 8@150mm, Cover for concrete is 25mm	150	25MM
5	C5	485.23	Longitudinal Reinforcement #12 & Transverse Reinforcement of 8@200mm, Cover for concrete is 25mm	200	25MM
6	C6	479.2	Longitudinal Reinforcement #12 & Transverse Reinforcement of 8@200mm, Cover for concrete is 25mm	200	25MM
7	C7	659.245	Longitudinal Reinforcement #12 & Transverse Reinforcement of 8@100mm, Cover for concrete is 35mm	100	35MM
8	C8	645.28	Longitudinal Reinforcement #12 & Transverse Reinforcement of 8@100mm, Cover for concrete is 35mm	100	35MM
9	C9	627.87	Longitudinal Reinforcement #12 & Transverse Reinforcement of 8@150mm, Cover for concrete is 35mm	150	35MM
10	C10	635.45	Longitudinal Reinforcement #12 & Transverse Reinforcement of 8@150mm, Cover for concrete is 35mm	150	35MM
11	C11	598.62	Longitudinal Reinforcement #12 & Transverse Reinforcement of 8@200mm, Cover for concrete is 35mm	200	35MM
12	C12	580.45	Longitudinal Reinforcement #12 & Transverse Reinforcement of 8@200mm, Cover for concrete is 35mm	200	35MM
13	C13	705.45	Longitudinal Reinforcement #12 & Transverse Reinforcement of 8@100mm, Cover for concrete is 45mm	100	45MM
14	C14	715.7	Longitudinal Reinforcement #12 & Transverse Reinforcement of 8@100mm, Cover for concrete is 45mm	100	45MM
15	C15	675.2	Longitudinal Reinforcement #12 & Transverse Reinforcement of 8@150mm, Cover for concrete is 45mm	150	45MM
16	C16	685.25	Longitudinal Reinforcement #12 & Transverse Reinforcement of 8@150mm, Cover for concrete is 45mm	150	45MM
17	C17	630.75	Longitudinal Reinforcement #12 & Transverse Reinforcement of 8@200mm, Cover for concrete is 45mm	200	45MM
18	C18	615.45	Longitudinal Reinforcement #12 & Transverse Reinforcement of 8@200mm, Cover for concrete is 45mm	200	45MM

CONCLUSION

From above results,

1. UPV results with direct, semi direct, and indirect methods indicates that readings are below 3.5 km/sec.
2. Indirect velocity gives the less pulse velocity than direct method generally by 1km/sec.
3. AS per UPV results it is observed that concrete shows presence of cracks, voids and honeycombing in concrete
4. Reinforcement replacement and repair
5. Epoxy grouting and micro concrete
6. Injection grouting for concrete
7. Diamond tie will improve fire resistance significantly with increase in buckling strength
8. Spalling Area on the specimen of diamond tie will be less.
9. Higher Concrete Cover will provide more protection from Fire.

RECOMMENDATIONS

- PP fibres in concrete columns are recommended because they help to improve the axial load capacity of reinforced concrete columns.
- When the temperature is high the thickness of the concrete cover helps to resist increased temperatures.
- It also protects reinforcement steel from high temperatures. It's

- Concrete coverings of at least 3 cm are recommended. 3- There is a need for more research in the field of "Increasing the fire resistance of reinforced concrete pillars ", because of its significance and seriousness in terms of safeguarding properties and people's lives
- Any structure used to store combustible resources (gas, fuel, wood, etc.) must be designed to withstand the loads imposed by high temperatures.
- Electrical furnaces and compression should be available at local testing laboratories

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