"Experimental analysis for improvement in capacity of RC column against fire By using diamond shape stirrups and ferrocement Cover"

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ABSTRACT

In last few years we have observed many cases of fire outbreak around the world which results in damage to multi-storey RCC buildings. During the outbreak of fire mainly load bearing element i.e column gets easily affected and it plays important role in failure or collapse of RCC structure. According to National Crime Records Bureau (NCRB) Fire-related accidents have, on average, killed 35 people every day in the five years between 2016 and 2020.It have been observed that most of the fire extinguished withing 2 hours of its outbreak. The ties in RCC Column are mostly provided either circular or rectangular depending on guidelines given in IS codes and Shape of Structure. In an atmospheric temperature it is beneficial to provide lower tie spacing because it helps to improve movement capacity of section and it also provides better confinement. From previous researches it observed that specific heat capacity of Ferrocement is higher than specific heat capacity of concrete hence we can use ferrocement as fire protection material. From this experiment our Aim is to improve fire resistance capacity of RCC column by using different tie shapes and different spacing and providing ferrocement cover of different thickness over RCC column .

Key Words - Casting, Diamond Ring & Ties, Rebound hammer &Ultrasonic Pulse velocity test, NDT, Compression Test, Fire Resistance, Mix Design

1. INTRODUCTION

Outbreak of fire is one of the most important issue which can create risk to the building. Most structural materials which are weakened when exposed to high temperatures cause buildings to collapse. Therefore it's become necessary to adopt a use of fire resisting material in construction of building to mitigate the damage causes due to fire. Recently there are many types of fire protection materials were developed to protect the structural members against fire. The mainly cementitious, intumescent, fibrous and composite Types of materials are used. Ferrocement is cementitious composite material. It consist of cement mortar which is reinforced with close spaced layers of continuous and relatively small sized wire mesh. This wire mesh can reduce spalling of surface and mortar is good insulator , consequently using ferrocement jacketing for strengthening of structural components like reinforced concrete, prestressed concrete, or steel could enhance the fire resistance of the composite elements

From recent studies it has been proved that ferrocement jacket can perform satisfactory against fire mainly because of its structural fire integrity as compared to conventional mortar

We need to understand use of ferrocement as fire protection material and not only of the structural fire integrity but also the insulation property of this material. The specific heat capacity is one of important value for determining the insulation property. The specific heat of a material is the amount of heat required to heat up 1 g of the material by one degree Celsius or Kelvin. A high specific heat means high ability for retaining heats—an ability that is desirable for energy absorption in fire protection materials. It has been previously reported that a use of silica fume and fiber reinforcement increase the specific heat of cement paste.

2. MATERIALS

Materials

Cement

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 ferrocement. When ferrocement 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 fineaggregate used was natural sand.

Ferrocement

Ferrocement is a system of construction using reinforced mortar or plaster (lime or cement, sand, and water) applied over an "armature" of metal mesh, woven, expanded metal, or metal-fibers, and closely spaced thin steel rods such as rebar. The metal commonly used is iron or some type of steel, and the mesh is made with wire with a diameter between 0.5 mm and 1 mm. The cement is typically a very rich mix of sand and cement in a 3:1 ratio; when used for making boards, no gravel is used, so that the material is not concrete.

Diamond shape wire mesh :- Diamond shape wire mesh performs the similar function as reinforcement does in concrete. It has specific properties for plastering use. Diamond wire mesh is formed by twisting two adjacent wires at least four times, forming a strong honeycomb mesh structure. So, it has a high strength and durability.

Diamond Tie

Diamond shape stirrups are used to improve fire resisting strength of ferroconcrete

Reinforcement

Deformed bars 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.

Fire resistance: It is the fire protection behavior of a material or arrangement pattern. As a construction unit, fire resistance is measured by the ability to restrict a fire or to continue to conduct a special structural function or both.

Fire rating: It is the time required, (in hours), for a construction unit in building to perform its special fire-resistance behavior. The desired fire rating for many construction units of building can be obtained from model codes.

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 m^3

Mix Proportion by Volume

Cement = 315 kg/m^3 Water = 157.6 Liter/m^3

Fine aggregate = 802.36 kg/m^3

Coarse aggregate 20 mm = 1110 x 60 %= 666kg/m^3

Coarse aggregate 10 mm = 1110 x 40 %= 444 kg/m^3Water-cement ratio = 0.5

3 Literature review

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. Testvariables considered in the study include the amount of transverse steel and the tie configuration

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 toelongate, 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 whythe 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.

A Practical Method For the Calculation of Fire Resistance ofReinforced 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 concretecolumns, which does not need the sophisticated computer aid, hasbeen introduced

Fire Resistance of concrete, Aqeel Shams SGI, Sikar, IJETSR, March 2016,

This paper deals with the interaction of fire with Reinforced concretet. 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.

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 ferrocement 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 calculatinga fire resistance rating.

Fire Safety Engineering of concrete-Filled Steel Tubular Column without Fire Protection, Kenichi Ikeda1 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.

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

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 theconstitutive relationships and mechanical properties to predict structural behaviour.

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

A Model For Evaluating The Fire Resistance Of HighPerformance 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 thermaland structural analysis, for the calculation of fire resistance ofcolumns 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, ferrocement strength, aggregate type, and fiber reinforcement.

4 Methodology

Test specimen of column having size 250x250x700 with different tie configuration and ferrocement cover is prepared for test. Total 18 columns are casted. 28 days curing with gunny bag. After 28 days of casting Fire test is conducted on Panels or all face of Panels. Then Study of the spalling area. Study crack pattern and NDT Test and Rebound hammer tests are carried out for checking the strength of Panels. After fire test is conducted on all columns they are checked for buckling.

Casting of column

Tie Type	Tie Spacing	Ferrocement Cover
Rectangular Ties	100 mm c/c	15 mm, 20mm, 25mm
Rectangular Ties	150 mm c/c	15 mm, 20mm, 25mm
Rectangular Ties	200 mm c/c	15 mm, 20mm, 25mm
Diamond Ties	100 mm c/c	15 mm, 20mm, 25mm
Diamond Ties	150 mm c/c	15 mm, 20mm, 25mm
Diamond Ties	200 mm c/c	15 mm, 20mm, 25mm

Aim

"To study a combination of Diamond Tie Configuration And Ferrocement cover to Improve Fire Resistance Capacity of RC Column by using ferrocement cover"

Objectives

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

Investigate RC column subjected to fire for different tiesystem with different spacing and ferrocement cover

Comparison of RC column subjected to fire for Rectangularand Diamond ties

Comparison of RC column subjected to fire for differentferrocement 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 ferrocement covers that have been exposed to fire

Research Work

Preliminary Investigation – Preliminary investigation- In first phase Physical properties of ingredient of ferrocement. In second phase concrete mix design carried out for grade M20.

- **Test of Ferrocement for Fire Test**
- Test specimen of size 250x250x700 is prepared for Firetest.
- Longitudinal Reinforcement 6@120mm &TransverseReinforcement of 8@100mm , 8@150mm, 8@200mm.
- ferrocement cover is 15mm, 20mm, 25mm.Total 18 columns are casted.
- 28 days curing with gunny bags.
- After 28 days of casting Fire test will be conducted oncolumn 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 is conducted

Ultrasonic Pulse Velocity

- The ultrasonic pulse velocity method could be used toestablish:
- The homogeneity of the Ferroconcrete The presence of cracks, voids and other imperfections, Changes in the
- structure of the Ferroconcrete which may occur with time,
- The quality of the Ferroconcrete in relation to standardrequirements,
- The quality of one element of Ferroconcrete in relation toanother and the values of the Ferroconcrete

Rebound Hammer

The rebound hammer method could be used for:

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

Fire test

After curing all specimens for 28 days all specimens were exposed to fire in blast furnace situated in steel manufacturing factory at temperature of 250^0C for 3 hours and constant load was applied on columns after fire test in a mechanism available in factory in order to check buckling strength of specimens

CASTING OF SPECIMEN

Results

Rebound Hammer Test

Column no	Age of ferroconcrete	Avg Rebound No	Indicative strength (N/SQmm)
C1	**28**	**28.1**	**29.0**
C2	**28**	**29.4**	**31.0**
C3	**28**	**31.2**	**33.2**
C4	**28**	**32.5**	**35.6**
C5	**28**	**30.4**	**32.5**
C6	**28**	**30.1**	**31.6**
C7	**28**	**29.6**	**31.0**
C8	**28**	**30.6**	**32.6**
C9	**28**	**30.2**	**32.0**
C10	**28**	**30.3**	**31.8**
C11	**28**	**30.6**	**32.5**
C12	**28**	**31**	**32.8**
C13	**28**	**32.4**	**34.1**
C14	**28**	**31.4**	**31.9**
C15	**28**	**30.8**	**32.1**
C16	**28**	**31.3**	**31.5**
C17	**28**	**30.9**	**31.9**
C18	**28**	**31.4**	**32.4**

Ultrasonic pulse velocity Test

Column No	Transmission Type	Age of concrete	distance	Time (in micro sec)	Upv (km/sec)
C1	Direct	28	250	60.9	4.10
C2	Direct	28	250	59.4	4.20
C3	Direct	28	250	59.5	4.20
C4	Direct	28	250	56.6	4.41
C5	Direct	28	250	59.1	4.23
C6	Direct	28	250	58.4	4.28
C7	Direct	28	250	57.7	4.33
C8	Direct	28	250	57.2	4.37
C9	Direct	28	250	58.1	4.30
C10	Direct	28	250	57.8	4.32
C11	Direct	28	250	60.1	4.16
C12	Direct	28	250	57.5	4.34
C13	Direct	28	250	56.4	4.43
C14	Direct	28	250	57	4.38
C15	Direct	28	250	56.5	4.42
C16	Direct	28	250	57.6	4.34
C17	Direct	28	250	56.9	4.39
C18	Direct	28	250	56.6	4.41

Fire resistance test

Column No	Axial Load KN	DETAILS OF COLUMN	Type of Stirrups
C1	**590.40**	longitudnal reinforcement 6@12 transverse Rf 8@100 ferro cover15mm	**square**
C2	**582.60**	longitudnal reinforcement 6@12 transverse Rf 8@100 ferro cover15mm	**square**
C3	**542.20**	longitudnal reinforcement 6@12 transverse Rf 8@100 ferro cover20mm	**square**
C4	**533.17**	longitudnal reinforcement 6@12 transverse Rf 8@150 ferro cover20mm	**square**
C5	**492.22**	longitudnal reinforcement 6@12 transverse Rf 8@150 ferro cover25mm	**square**
C6	**486.20**	longitudnal reinforcement 6@12 transverse Rf 8@150 ferro cover25mm	**square**
C7	**667.34**	longitudnal reinforcement 6@12 transverse Rf 8@200 ferro cover15mm	**square**
C8	**655.29**	longitudnal reinforcement 6@12 transverse Rf 8@200 ferro cover15mm	**square**
C9	**634.60**	longitudnal reinforcement 6@12 transverse Rf 8@200 ferro cover20mm	**square**
C10	**644.35**	longitudnal reinforcement 6@12 transverse Rf 8@100 ferro cover20mm	**Diamond**
C11	**610.50**	longitudnal reinforcement 6@12 transverse Rf 8@100 ferro cover25mm	**Diamond**
C12	**592.41**	longitudnal reinforcement 6@12 transverse Rf 8@100ferro cover25mm	**Diamond**
C13	**714.64**	longitudnal reinforcement 6@12 transverse Rf 8@150 ferro cover15mm	**Diamond**
C14	**722.74**	longitudnal reinforcement 6@12 transverse Rf 8@150 ferro cover15mm	**Diamond**
C15	**687.60**	longitudnal reinforcement 6@12 transverse Rf 8@150 ferro cover20mm	**Diamond**
C16	**695.65**	longitudnal reinforcement 6@12 transverse Rf 8@200 ferro cover20mm	**Diamond**
C17	**645.80**	longitudnal reinforcement 6@12 transverse Rf 8@200 ferro cover25mm	**Diamond**
C18	**625.50**	longitudnal reinforcement 6@12 transverse Rf 8@200 ferro cover25mm	**Diamond**

CONCLUSION

1. UPV results with direct methods Shows readings are below 4.5 km/sec.

2 according to upv result ferroconcrete has cracks and voids

3 fire resistant strength i.e axial load is maximum at longitudnal reinforcement 6@12 transverse Rf 8@150mm ferro cover15mm with diamond ties And fire resistant strength slightly reduces after increasing spacing more than 150mm and ferrocement cover more than 15 mm

4. it shows Diamond tie will improve fire resistance significantly with increase in buckling strength

5. it shows Spalling Area on the specimen of diamond tie will be less.

6. it shows Higher ferrocement Cover will provide more protection from Fire.

7. indicative strength obtained after rebound hammer test was maximum 35.6

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