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STRENGTHENING OF FIRE DAMAGED CONCRETE COLUMN USING GLASS FIBRES

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ABSTRACT— *Extensive research has shown that glass fibre reinforced polymer (GFRP) wraps are effective for strengthening concrete columns for increased load capacity and deformability, and this technique is now widely used. This project extends the implication of Glass Fibre Reinforced Polymer(GFRP) confinement technique to strengthen fire damaged concrete columns. An experimental program was undertaken to study the compressive strength and stress strain behaviour of both unconfined and Glass fibre confined concrete columns after being heated to elevated temperatures for up to four hours and cooled to room temperature. The results show that GFRP confinement is highly effective for enhancing the load carrying capacity of even severely fire damaged concrete columns.Various results are carried out to test both fire damaged and glass fibre wrapped columns. Tests on compressive strength,Flextural strength and thermal radiation were carried out for three sets of concrete columns namely ordinary column,fire damaged column,fire damaged column wrapped with glass fibres.The results shows that strengthening is effective for columns affected by fire, which could effectively restore the strength and stiffness in fire damaged columns*

Keywords:Glass Fibres,Fibre damaged concrete column,Compressive strength,Flextural strength,Thermal radiation

1. INTRODUCTION

Externally bonded glass fibre reinforced polymer (GFRP) circumferential wraps are a method of choice for reinstating or enhancing the strength and deformation capacity for M30 grade of concrete columns are prepared and used.A wealth of experimental evidence exists to support such applications of GFRPs,and many analytical models are available for use in designing GFRP strengthening schemes for both circular and rectangular concrete columns at ambient temperatures. An increasing body of work has also examined the performance during fire of reinforced concrete columns which have been strengthened with GFRP wraps. However, a potentially useful application of GFRP confinement of concrete which has received only limited attention to date is for strengthening fire-damaged concrete columns; i.e. columns which have been exposed to elevated temperatures or which have experienced heat-induced reduction in the mechanical properties of their constituents.This paper presents the results of an experimental program conducted to study the effectiveness of GFRP confinement for enhancing the strength and axial/lateral stress-strain response of fire damaged concrete columns. Various levels of heat-induced damage to the concrete are examined, covering the full range of relevant fire exposure temperatures.

At present concrete structures are vulnerable to fire due to combustible materials and unavoidable accidents. Retrofitting of fire damaged structural components using glass fiber sheet and cement based composite binders is the recent effective technique. This technique does not increase the deadweight of the members.

The effect of restrained degree, loading level and heating rates on the performance of concrete columns were studied under elevated temperatures and found that use of polypropylene fibers prevent explosive.Studies shows that under restraint condition normal strength concrete showed more spalling compared to high strength concrete. It was decided that explosive spalling occurred after 45min of heating. Minor spallings were followed by severe spallings.For flexural components, increasing the cover concrete would not increase the fire resistance.

OBJECTIVE

- To observe the impact of unstressed heating on the residual strength and axial/lateral stress versus strain response of short, plain concrete cylinders loaded in uniaxial compression;
- To demonstrate and quantify the effectiveness of externally bonded GFRP hoop wraps (i.e. GFRP confinement) for reinstating or increasing the strength of fire-damaged circular concrete compressive elements;
- To (indirectly) investigate the impacts of varying the unconfined concrete compressive strength on the performance of GFRP confinement of concrete (i.e. fire-damaged concrete will have virtually identical grain structure to the undamaged concrete but will have reduced strength and considerable pre-existing micro-cracks in the cement paste,etc); and
- To verify the ability (or lack thereof) of a widely used currently available GFRP confinement model, developed for strengthening unheated concrete, to predict the response of GFRP confined fire-damaged concrete; thus providing quantified design guidance for use by practicing engineers.
- To determine Strength loss of wrapped columns subjected to expansive forces, due to freezing and thawing.
- To Increase strength of concrete due to confinement provided by wraps.

MATERIAL USED

The below materials are used for preparing concrete:

Cement

All through the experimental study, Ordinary Portland Cement conforming to IS: 8112 -1989 was used. The physical properties of the cement are Fineness is 2946 cm2/gm, Normal Consistency is 30%, Initial and final setting time is 64 and 192 minutes, Specific gravity is 3.15. Physical properties of Cement are characterised by:

- Setting Time
- Soundness
- Fineness
- Strength

Aggregates

Locally available river sand of specific gravity 2.64, fineness modulus 2.91, and conforming to Zone II was used as fine aggregate. The crushed granite stone with a maximum size of 12 mm, and specific gravity 2.65 was used as coarse aggregate. Both fine aggregate and coarse aggregate used conform to IS: 383-1970.

Fine aggregate

The material which passes through BIS test sieve number 4 (4.75mm) is termed as fine aggregate usually natural sand is used as a fine aggregate at places where natural sand is not available crushed stone is used as fine aggregates. In our region fine aggregate can be found from bed of Krishna River. It conforms to IS 383 1970 comes under zone II.

EXPERIMENTAL PROGRAM HEAT TRANSFER ANALYSIS

The heat transfer analysis is important for the prediction of temperature distribution within the cross section of the structural member.There are three approaches. First is to use the charts for temperature distributions in dense concrete elements based on standard fire tests . Secondly to use simple formulae proposed by Wickstrom. The third one, which is considered a more realistic approach, is to estimate temperature time distributions within the cross-section of structural members using finite element methods for heat transfer analysis. In the present work to validate the heat transfer analysis finite element model, twelve reinforced concrete square columns were constructed and heated within the Structural Engineering

Laboratory. The experimental programme and the finite element analysis for heat transfer are discussed in the following sections.

CONSTRUCTION OF RC SQUARE COLUMNS

Two sets of Four reinforced concrete square columns were constructed within the structural engineering laboratory.All square columns were cast in a horizontal position using steel moulds for the formwork. The steel moulds were properly oiled on the inner sides for easy removal of the specimens at the time of demoulding. The cage of reinforcement consisting of 10mm longitudinal bars and 6mm diameter deformed bars were used as a link bars spaced at 100mm centres. The prepared cage of reinforcement was kept in the moulds carefully. Concrete spacers of 25mm size were used to maintain 25mm concrete cover to the main reinforcement using binding wire. The concrete was poured in three layers and compaction of each layer was carried out using a tamping rod. In order to record the temperature at the time of heating, two type K-thermocouples were embedded in each column. One was placed at mid height in the centre of the column, whereas the second K-thermocouple was attached to the longitudinal reinforcement.After 24 hours of casting, the specimens were cured using moist sacking.To prevent the loss of moisture, the specimens were covered with plastic sheet and curing was continued for twenty one days. The specimens were then kept in the laboratory environment until the day of heating and testing.

HEATING OF RC SQUARE COLUMNS

Four reinforced concrete square columns were heated in an electric furnace. The arrangement of post-heated square reinforced concrete columns in an electric furnace . A maximum of four columns were heated at a time with the average heating rate used in the experiment was 150°C/hour. The square columns were heated to a uniform temperature of 500°C. The temperatures within the furnace were controlled with the help of two type-K thermocouples attached at mid height and at the top of the electric furnace.

FIG. ARRANGEMENT OF POST-HEATED SQUARE REINFORCED CONCRETE COLUMNS IN FURNACE

When the average furnace temperature reached 500°C, the furnace temperature was kept constant until the temperature at the centre of columns reached the same temperature. The

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duration of heating of columns to achieve the point of uniformity of temperature inside the furnace and at the centre of columns was eight hours. After achieving the point of uniformity of temperature inside the furnace and at the centre of columns, the furnace was switched off and all the columns were cooled down naturally within the boundary of furnace.

EXPERIMENTAL DESIGN

The experimental program consist of uniaxial compressive tests on 3 plain or FRP wrapped specimens.

Test parameters included: (1) the presence of FRP confinement, (2) the target exposure temperature, and (3) the total heating duration. All tests were performed in triplicate to verify the repeatability of the results, and all other factors which are known to influence the residual properties of concrete were carefully controlled to avoid experimental uncertainties, as described below. Each group of specimens is represented by a designation consisting of a letter (U for unwrapped and W for FRP wrapped), followed by the target temperature and then the exposure duration.

The columns were either unwrapped or wrapped in the hoop direction with a single layer of the SikaWrap Hex unidirectional glass fibre/epoxy FRP strengthening system. This system is typical of the various systems marketed in the UK and Europe for strengthening concrete structures. The manufacturer specified properties for this FRP strengthening system state an ultimate tensile strength of 3400 MPa at a tensile strain of 1.7% with a nominal thickness of 0.12mm. The FRP was applied using a hand lay-up procedure.The cylinder exposure temperatures were selected so as to cover a reasonable range of temperatures being sufficiently high to cause noticeable deterioration in the residual mechanical properties of the concrete (i.e. above about 300ºC), while not being so high as to make repair of the concrete indefensible in practice (i.e. remaining below about 600-700ºC . The default total duration of heating was taken as 120 minutes.

The specific FRP strengthening system used is stated purely for the purposes of factual accuracy. Temperature for a minimum of three weeks before testing. Immediately prior to testing each column was capped with rapid-set mortar to ensure a smooth, level contact surface. Finally, both unwrapped and FRP wrapped columns were painted with a high contrast texturing effect using black paint with a random white speckle pattern;To prevent explosive concrete cover spalling during heating, which would damage the furnace, all specimens in the group were conditioned in a drying oven for two days at 90ºC before being placed in the furnace.

HEATING REGIMES

The specimens were heated in groups of three specimens per exposure inside an electric furnace with internal dimensions of 230mm × 230mm × 510 mm. For a given exposure temperature (i.e. 300ºC, 500ºC, or 686ºC) the furnace was programmed to heat as quickly as possible up to the desired temperature and then to hold that temperature for the required duration of *total* heating (120 or 240 minutes). The furnace was then switched off and allowed to cool slowly to ambient. Typical heating profiles for the various thermal exposures are given. These profiles include the intended furnace control temperatures as well as temperatures recorded at TC1 within the specimen. It should be noted that 120 minutes was insufficient to reach the original target temperature of 700ºC, and the actual furnace temperature achieved for the 700ºC soak temperature specimens was 686ºC in all cases. The approximate heating rate was in the range of 5-15ºC/minute.

The standard temperature versus time curve (ISO 834) used for structural fire resistance testing in Europe. It is clear that the furnace used in the current study was unable to achieve rapid heating rates that are representative of the standard fire. However this is not considered critical because the current study is concerned primarily with confinement of concrete within a column’s core (i.e. inside the hoop ties or spirals).Within the core concrete the heating rates and peak temperatures experienced would be moderated by the thermal protection of the cover concrete, and would likely be similar to the exposures reproduced by the heating profiles imposed herein. It should also be noted that the standard fire does not necessarily reflect the actual heating of concrete within a real structure during a real fire.

STRUCTURAL TESTING & OPTICAL STRAIN MEASUREMENT

All specimens were tested under concentric, monotonic, uniaxial compression using a 1000kN structural loading frame.Testing was performed under load control at a rate of approximately 100kN/min. The column bases were rotationally restrained during testing while the tops were effectively pinned (by bearing against a load cell with a spherical seat).The total applied load was monitored during testing.

THERMAL CONDUCTIVITY

Thermal conductivity of concrete were obtained for mixes M-1, M-2, M-3and M-4. Sample analytical fit with measured temperature response data of M-3 specimen 1 & 2 for the time interval between 4 hours 20 minutes ~ 6 hours

Thermal conductivity obtained based on above described method for three Mixes.The variation of thermal conductivity with time can be expressed as nonlinear curve.

The thermal conductivity of OPC concrete follows a unique pattern irrespective of the mix proportions, where it remains constant up to hours and starts to increase up to a maximum value in the range which is fairly in good agreement with values proposed by previous studies for hardened concrete.

The thermal conductivity/radiation test was conducted using fire splinter arc and the test was carried out for both normal concrete column and glass fibre wrapped column.The test results are tabulated as follows

THERMAL CONDUCTIVITY OF NORMAL COLUMN

GRADE	TIME IN "HOUR"	TEMPERATURE
M30	2	23
M30	3	30
M30	4	36
M30	5	44

THERMAL CONDUCTIVITY OF WRAPPED COLUMN

GRADE	TIME IN "HOUR"	TEMPERATURE
M30	2	19
	3	26
	4	32
	5	36

It can be seen clearly that the use of glass fibre wrapping in fire damaged column minimises the impact of fire over the concrete column b

FLEXURAL STRENGTH

Flexural strength, also known as modulus of rupture, bend strength, or fracture strength is a material property, defined as the stress in a material just before it yields in a flexure test. The transverse bending test is most frequently employed, in which a specimen having either a circular or rectangular cross-section is bent until fracture or yielding using a three point test technique. The flexural strength represents the highest stress experienced within the material at its moment of rupture.

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Specimen indication	Deflection in mm	Ultimate load in KN	Flexural strength in N/mm^2
M1	1.02	66	5.86
M2	1.24	78	6.93
M3	1.16	74	6.57

COMPRESSIVE STRENGTH:

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Compressive strength test was carried out on three sets concrete columns namely (i)ordinary column (ii)fire damaged column (iii)fire damaged column wrapped with glass fibres.The test result analysis is as follows

COMPESSIVE STRENGTH OF ORDINARY CONCRETE COLUMN

GRADE	SPECIMEN	COMPRESSIVE STRENGTH(N/mm^2)
M30	M1	39.40
M30	M2	40.1
M30	M3	39.66

COMPRESSIVE STRENGTH OF FIRE DAMAGED COLUMNS

GRADE	SPECIMEN	COMPRESSIVE STRENGTH(N/mm^2)
M30	M1	27.58
M30	M2	28.37
M30	M3	27.76

COMPRESSIVE STRENGTH OF FIBRE REINFORCED COLUMNS

GRADE	SPECIMEN	COMPRESSIVE STRENGTH(N/mm^2)
M30	M1	37.96
M30	M2	41.1
M30	M3	41.6

It was observed that the compressive strength of fire damaged column is only about 70% of initial strength of the concrete.The addition of glass fibres to it has enabled it to increase the strength to about 90-95%

CONCLUSION

The various tests were carried to different sets of concrete columns of M30 grade.First set of columns are ordinary concrete columns,the second set is fire damaged columns and the third sets were fire damaged and fitted with glass fibres.The result analysis gives us an idea that the fire damaged column strength decreased to about 25-30% of initial strength and the addition of glass fibres made up for the loss of strength and substancially increased the strength to pre heated levels.The result analysis of all the three tests were found to be a satisfactory one with the use of glass fibres.The comparison of results clearly shows that the inclusion of glass fibres to fire damaged concrete columns using epoxy resin to be an effective one and cost effective than the carbon fibres

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