Study on Hybridlength Steel Fiber Reinforced Concrete Subjected to Elevated Temperatures

Deepthy.S.Nair
P.G Scholar
Department of civil Engg.
M.A College of Engg. Kothamangalam
Kerala, India

Dr. Mathews. M. Paul
Professor
Department of Civil Engg.
M.A College of Engg. Kothamangalam
Kerala, India

***Abstract*— Concrete is a composite material likely exposed to high range of temperatures during its service life. The relative properties of concrete after such an exposure are of great importance in terms of the durability of buildings. The constituents of concrete have different properties and also depends on moisture and porosity. A complete understanding of the behavior of concrete under elevated temperature after a thermal excursion is essential for reliable design evaluations and assessments. The properties of concrete changes with respect to time and the environment to which it is exposed, an assessment of the effects of concrete is also important in performing safety evaluations.**

Keywords— Concrete, Temperature, Compressive strength, Split tensile strength.

I. INTRODUCTION

Exposure of concrete to elevated temperature affects its mechanical and physical properties. Temperature affects produce dimensional changes, loss of structural integrity, release of moisture and gases resulting from the migration of free water could adversely affect plant operations and safety. Exposure of reinforced concrete buildings to an accidental fire may result in cracking and loss in the bearing capacity of their major components, such as columns, beams, and slabs, producing extensive surface cracks that penetrate across depth, producing possible spalling, upward cambering of surface and plastic deformation of reinforcing steel. It is a challenge for structural engineers to develop efficient rehabilitation techniques to restore their structural integrity, after being exposed to intense fires for a long period of time. Steel fibres are relatively short and closely spaced as compared with countinuous reinforcing bars of wires. Steel offers many advantages when used as a primary structural framing material in buildings as well as under temperature variations. The study focuses on the effect of temperature on fiber reinforced concrete by incoperating two different length hooked steel fibers.

A. Behaviour of concrete subjected to temperature

The influence of temperature on different properties of concrete is considerable. Increase in temperature cause increases initial strength and reduces the long term strength of the concrete. Fire is one of the most severe risks to buildings and structures. Exposure to fire is the most destructive process that a concrete structure can be subjected to during its service life. Under high temperature effect, chemical composition, physical structure and moisture content of concrete changes. These changes are primarily observed at the cement paste and then the aggregates. Heating to high temperatures causes the dehydration of hardened cement paste and conversion of calcium hydroxide into calcium oxide in which chemically bound water is gradually released to become free water. As a result the bond become weak and sudden crack occurs and affect the concrete to fail.

B. Properties of steel fibers on concrete

Fibre is a small piece of reinforcing material possessing certain properties. It can be circular, triangular or flat in cross-section. The fibers is often described by a convenient parameter called Aspect ratio. The aspect ratio of the fibre is the ratio of its length to its diameter. The principle reason for incorporating fibres into a cement matrix is to increase the toughness and tensile strength and improve the cracking deformation of the concrete. Steel fibres reduce the permeability and water migration in concrete, which ensures protection of concrete due to the ill effects of moisture. When concrete subjected to high temperature Steel fibers are effective in reducing plastic shrinkage cracking and reduce the spalling and increase the post craking strength.

II. LITERATURE REVIEW

Balazs and Lubloy [1] investigated the properties of concrete may be considerably influenced by high temperatures. These properties are depends on the maximum temperature and the composition of the concrete. Water-cement ratio (W/C), type of cement, type of aggregate and porosity are also influenced by the temperatrure. The deterioration of concrete at high temperatures is manifested as deterioration of the material itself and the deterioration of the structural performance. *Bangi and Horiguchi* [2] investigated on effect of fibre type and geometry on maximum pore pressures in fibre-reinforced high strength concrete at elevated temperatures. Fibre type and geometry, significantly contributes towards pore pressure.. *Haddad et al*. [3] studied the effect of elevated

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temperature on bond between steel reinforcement and fiber reinforced concrete. Steel fibers like hooked steel fiber attained the highest bond resistance against elevated temperatures ranging 400 to 600°C. *Lau and Anson* [4] studied on effect of high temperatures on high performance steel fibre reinforced concrete. After being subjected to different elevated heating temperatures ranging between 105°C and 1200°C the compressive strength, flexural strength, elastic modulus and porosity of concrete reinforced with 1% steel fibre increases *Peng et al.* [5] studied effect of thermal shock due to rapid cooling on residual mechanical properties of fiber concrete exposed to high temperatures. The results prove that the rapid cooling regimes such as quenching in water, or water spraying for 30 min or more, caused an action of 'thermal shock' to concrete under elevated temperature. It results a sudden decrease in compressive strength.

Literature survey reveals that there exists a gap area in using hybridlength steel fibers in the concrete when they are subjected to the high temperature. The scope of the study includes to evaluate the effect of varying Percentage of hybridlength steel fibers in the concrete mixture subjected to different temperatures. For this making workable, high strength and durable concrete containing hybridlength steel fibers and study the variation in its compressive strength and split tensile strength when they are subjected to different temperatures.

The objectives of the study are:

- Study the effect of steel fibers on compressive strength of concrete
- To predict the performance characteristics of steel fibers with different percentages (0%,0.5%,1%) on concrete with temperatures(Ambient temperature,200°C,400°C)
- To minimize the experimental procedure according to Box-Behnken Design for optimization.

III. MATERIALS AND METHODOLOGY

The materials selected for this experimental study includes normal natural coarse aggregate, Manufactured sand as fine aggregate, cement, superplasticizer, both end hooked steel fiber and portable drinking water. Potable clean drinking water available in the water supply system was used for casting as well as for curing of the test specimens. Hooked end Steel fibers of two different diameters 0.55mm with 35mm length and 0.75mm diameter with 60mm and aspect ratio of 63.63 and 80 were used. The manufracturer is Stewols private limited,Nagpur. The super plasticizer used was MASTER RHEOBUILD 918 a product of BASF India Pvt. Ltd, Ernakulam.The physical and chemical properties of each ingredient has considerable role in the desirable properties of concrete like strength and workability. The cement used for this project work is ordinary portland cement of Zuari 53 grade. Manufacturer's sand has been used for the present investigation ,it is also called M sand. Coarse Aggregate used are of two sizes 20 mm maximum size and 12.5 mm maximum size. The several tests were conducted on both fine and coarse aggregates as per relevant Indian Standared codes [6].

A. *Mix Design*

The mix design is carried out as per relevant Indian standard Code Specification [7]. Mix designing is carried out to arrive at the quantities required for 1 m^3 of concrete and mix designation as shown in Table I.

TABLE I. QUANTITY REQUIRED FOR 1M^3 MIX

W/C	Proportion of Steel Fiber	Water (Kg)	Cement (Kg)	F_a (Kg)	C_a (Kg)	Steel Fiber (Kg)
0.35	0	160	460	660	1240	0
	0.5	159	457	656	1233	39
	1	158	455	653	1237	78
0.4	0	160	400	700	1260	0
	0.5	159	398	696	1253	39
	1	158	396	693	124	78
0.45	0	160	360	730	1260	0
	0.5	159	358.2	726	1253	39
	1	158	356.4	722	1247	78

B. *Box -Benhken Design*

Box– Behnken designs are experimental designs for Response Surface Methodology, devised by George E.P.Box and Donald Behnken in 1960 [8]. Response Surface Methodology (RSM) is an empirical optimization technique for evaluating the relationship between experimental outputs (or responses) and factors called x_1, x_2, and x_3. Box–Behnken is a spherical, revolving design. In this study Box-Behnken design with three variable and three-level factor to reduce the numbers of experiment adopted. Three control factors, namely, water-cement ratio, steel fiber percentage, and temperature are used in this experimental work. In the present investigation 3 set of factors are involved and hence we require a 3^3 set that is requiring 27 replications and a 3^3 full factorial design. But according to Box–Behnken designs it can be reduced to 13 sets and the design points reside in the middle of the sides and at the corner points of a cube. Figure I. Shows the model for Box–Behnken design. The model is designed using the equation:(1)

$$y = ß_0 + ß_1x_1 + ß_2x_2 + ß_3x_3 + ß_{11}x_1^2 + ß_{22}x_2^2 + ß_{33}x_3^2 + ß_{12}x_1x_2 + ß_{13}x_1x_3 + ß_{23}x_2x_3 \quad (1)$$

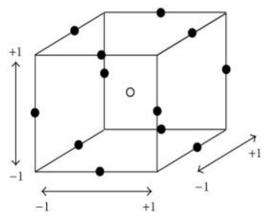

Figure I.
Box Behnken Design For Three Factors

C. Details of the specimen

To study the effect of elevated temperature on concrete cubes of size 150mm x150mmx150mm were tested in order to determine the compressive strength of the concrete. Three different temperatures were choosen are ambient temperature, 200°C and 400 °C and denoted by T_0, T_{200}, T_{400}. Specimen with fiber percentage 0%, 0.5%, 1% are represented by S_0, $S_{0.5}$, $S_{1.0}$ respectively. Specimen with W/C ratio 0.35, 0.4 and 0.45 are considered and represented by $R_{0.35}$, $R_{0.4}$, $R_{0.45}$.

D. Test on fresh properties of concrete – Slump test

It is used to study the workability of prepared concrete during the progress of work and to check the uniformity of concrete.
The details of mixes corresponds to slump are shown in Table II.

TABLE II.
DETAILS OF MIXES CORRESPONDS TO SLUMP

Mix Designation	W/C ratio	Superplastizer (% of cement)	Slump Obtained (mm)
R0.35	0.35	0.5	66
R0.4	0.4	0.5	80
R0.45	0.45	0.5	95

E. Heating of the specimens

The study includes the effect of temperature on the concrete. The specimens were heated in the electric oven. After attaining desired temperature, one hour is provided to the specimen to maintained in that level for reaching steady state condition. After that the oven was swithched off and allow the specimen to cool off. It is observed that the mass of the specimen decreases after subjected to temperature and the loss in concrete mass is considerably less in steel fiber reinforced specimen compared to the control mix specimen.

IV. RESULT AND DISCUSSIONS

A. Result analysis by Box-behnken design using regression technique

Experiments were performed using the Box–Behnken experimental design. Box–Behnken experimental design is a type of response surface methodology. Response surface methodology is an empirical optimization technique for evaluating the relationship between the experimental outputs and factors called x_1, x_2, and x_3. For obtaining the results for Box-Behnken design, analysis of variance has been calculated to analyze the accessibility of the model and was carried in Microsoft Office Excel 2007.
Box–Behnken Regression was done and the values were compared with the obtained value. The coefficient of determination (R^2) is defined as the ratio of the explained variation to the total variation, and is a measure of the degree of fit. A good model fit should yield an $R^2$of at least 0.8. The coefficient of determination (R^2) is defined as the ratio of the explained variation to the total variation. The test result of the experimental specimen and by using Box–Behnken design as shown in the Table. III and Table. IV

TABLE III.
TEST RESULTS

Designation	Temperature (°C)	Steel fiber (%)	Average Compressive Strength (N/mm²)	Average Split Tensile Strength (N/mm²)
$R_{0.35}$ S_0 T_{200}	200	0	43.4	3.0
$R_{0.35}$ $S_{0.5}$ T_0	27	0.5	53.2	4.8
$R_{0.35}$ $S_{0.5}$ T_{400}	400	0.5	50.5	3.4
$R_{0.35}$ $S_{1.0}$ T_{200}	200	1	55.5	5.6
$R_{0.4}$ S_0 T_0	27	0	40.2	3.3
$R_{0.4}$ S_0 T_{400}	400	0	35.4	2.3
$R_{0.4}$ S_0.5 T_{200}	200	0.5	41.2	3.4
$R_{0.4}$ $S_{1.0}$ T_{400}	400	1	43.0	4.0
$R_{0.4}$ $S_{1.0}$ T_0	27	1	44..5	4.8
$R_{0.45}$ $S_{1.0}$ T_{200}	200	1	45.4	4.4
$R_{0.45}$ $S_{0.5}$ T_0	27	0.5	42.3	3.9
$R_{0.45}$ $S_{0.5}$ T_{400}	400	0.5	40.5	3.2
$R_{0.45}$ S_0 T_{200}	200	0	35.6	2.2

TABLE IV.
BOX–BEHNKEN DESIGN RESULTS

Designation	Temperature (°C)	Steel fiber (%)	Predicted Compressive Strength (N/mm²)	Predicted Split Tensile Strength (N/mm²)
$R_{0.35}$ S_0 T_{200}	200	0	45.05	3.09
$R_{0.35}$ $S_{0.5}$ T_0	27	0.5	53.01	4.87
$R_{0.35}$ $S_{0.5}$ T_{400}	400	0.5	49.92	3.53
$R_{0.35}$ $S_{1.0}$ T_{200}	200	1	54.60	5.29
$R_{0.4}$ S_0 T_0	27	0	38.60	3.12
$R_{0.4}$ S_0 T_{400}	400	0	34.44	2.07
$R_{0.4}$ S_0.5 T_{200}	200	0.5	41.20	3.40
$R_{0.4}$ $S_{1.0}$ T_{400}	400	1	44.40	4.14
$R_{0.4}$ $S_{1.0}$ T_0	27	1	45.64	5.05
$R_{0.45}$ $S_{1.0}$ T_{200}	200	1	43.74	4.30
$R_{0.45}$ $S_{0.5}$ T_0	27	0.5	42.93	3.74
$R_{0.45}$ $S_{0.5}$ T_{400}	400	0.5	40.62	3.13
$R_{0.45}$ S_0 T_{200}	200	0	36.49	2.50

Box-Behnken design was successfully adopted and the experiments were designed choosing the input parameters for the levels selected. Response surface methodology using Box-Behnken design proved very effective and time saving model for studying the influence of process parameters on response factor by significantly reducing the number of experiments and hence facilitating the optimum conditions. The predicted values and experimental values are approximately same and hence the model is fit. The conclusions obtained from the test results are:

- The compressive strength and split tensile strength increases with the increase in the % of steel fibers.
- As temperature increases the strength decreases in the case of 0% steel fiber mixes.
- It is found that increase in temperature the compressive strength reduction is very small in steel fiber containing specimen.
- As in the case of 1% steel fiber the tensile strength is very much higher compared to the control mix specimen.
- Reduction in compressive strength appears to be decrease in a systematic manner with increase in steel fibers.

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