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EXPERIMENTAL STUDY ON HIGH TEMPERATURE MESH CONFINED CONCRETE

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Abstract:

This paper presents a fire accidents are happening in most of the buildings which causes heavy damage to the buildings and result in loss of durability. In order to avoid the consequences an experimental investigation is carried out using mesh confinement concrete. Concrete is a non-combustible material and has a slow rate of heat transfer. High temperature can cause the formation of cracks. These cracks resembles like any other cracks propagation may eventually cause loss of structural collapse and shorting of span life. One mighty problem which occurs when concrete is exposed to fire is spalling. This is the phenomenon in which explosion ejection of chunks in concrete from the surface of the material, In order to reduce early cover spalling, a new idea has been investigated. This is implemented by installing relatively cheap materials such as glass mesh, nylon mesh, GI weld mesh and wire mesh in cylindrical specimens with a length of 300mm and 150mm diameter. It has been understood from the literature to reduce the spalling in concrete and strength can be improved by mesh confinement. Hence an experimental investigation will be done to study the performance of mesh confinement concrete subjected to fire. In this project work the four types of meshes such as glass, wire, nylon and GI weld type were used as confinement materials in the cylinders.

Key Words: Durability, Noncombustible, Spalling & Confinement Concrete

1. Introduction:

Concrete is a composite having properties that change with time. Durability of concrete depends on many factors including its physical and chemical properties; the Plain concrete is strong in compression while weak in tension. The idea of reinforcing concrete with steel bars gave rise to a new composite called Reinforced Concrete which is capable of withstanding both compression and tension simultaneously. Thus reinforced concrete has become the most commonly used construction material. Concrete is well known for its capacity to endure high temperatures and fires, owing to its low thermal conductivity and high specific heat. Once a fire starts and the contents and/or materials in a building are burning, then the fire spreads via radiation, convection or conduction with flames reaching temperatures of between 300°C and 1200°C. High temperature can cause the development of cracks. It should be noted that, in some circumstances, a concrete structure may be considerably weakened after a fire, even if there is no visible damage. The performance of concrete can be measured by the change of its stiffness, strength, or some other property that would affect its main function in service. The spalling damage occurs due to the high vapor pressure of moisture inside the concrete, adding fiber is a very efficient method of preventing spalling because it provides an escape path for the vapor pressure. In order to reduce early cover spalling, cheap materials such as glass mesh, nylon mesh, GI weld mesh and wire mesh are installed in the cylinder specimens. Therefore to resist the fire or spalling, the most commonly used materials are Portland blast furnace slag cement, calcined material aggregate, carbonate aggregate, fiber-cement, and concrete masonry, polypropylene fiber and also mesh confinement in concrete. The main aim of this project work is to resist the spalling of concrete under high temperature and to reduce the loss of strength at high temperature

2. General:

The first step in this study was review the literature and collects the materials for experimental work. Here the four types of meshes such as glass, wire, GI weld and nylon type were used as confinement materials in the cylindrical specimens. In this study a normal strength concrete (NSC) of M20 was considered and a total of 45 numbers of NSC cylinders with and without mesh confinement were cast. After 28 days of curing the specimens were exposed to a temperature of about 300°C.After the fire testing, the specimens were cooled for 24 hours in air-drying method and another method by quenching and allowed to dry for one day and these specimens were tested for finding the mechanical properties.

3. Properties of Materials:

Properties of various materials used in concrete are tested

Table 1: Properties Test

S.No	Description	OPC 53	Sand	Coarse Aggregate
1	Specific Gravity	3.1	2.7	2.78
2	Initial Setting Time	120	-	-
3	Final Setting Time	400	-	-
4	Standard Consistency	33%	-	-
5	Fineness	4.95	2.37	8.27

Table 2: Properties of Mesh

S.No	Parameters	Description			
1	Types	Glass	Wire	nylon	GI weld
2	Diameter of Mesh(mm)	0.2	0.3	0.3	1

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3	Density (kg/m^3)	0.160	7850	0.271	7850
4	Melting point	600^o	800^o	160^o	900^o

4. Mix Design:

The mix design methods being followed in different countries are mostly based on empirical relationships, charts and investigations. The various methods available are ACI mix design method, USBR mix design method, British mix design method and Indian Standard method. In this study mix design was done as per Indian Standard guidelines in IS: 10262-2009.

Table 3: Design Mix Ratio

S.No	Water	Cement	Sand	Coarse Aggregate
1	191.06kg	383kg	547kg	1209kg
2	0.5	1	1.43	3.1

Using IS code method and the following mix arrived at proportions for M_{20} grades concrete. The mix proportions were adopted by weight batching. The water cement ratio was kept constant as 0.5.

M_{20} -1: 1.43: 3.1: 0.5

5. Casting of Specimen:

Steel moulds were used for casting the cylinders. Before casting, machine oil was applied on all the surfaces of moulds. For mesh confinement concrete the meshes were installed in the mould before casting. To prevent the mesh from loosening the mesh was tied with steel wire at a spacing of 100mm through the whole length and the concrete was mixed thoroughly and was poured into the moulds in layers. Each layer of concrete was compacted using a table vibrator. After 24 hours of casting, the specimens were removed from the moulds and cured under water for 28 days. After curing, the cylinders were taken out of the curing tank and air dried for a period of 24 hours in a well-ventilated shed at ambient atmospheric conditions.

6. Heating the Specimen in Oven:

An oven designed for a maximum temperature of 300^o C was used. The oven was heated by means of exposed heating elements laid on the refractory wall of the inside chamber, which was approximately 300 x 300 x 400 mm inside dimension. The test specimens were stacked with sufficient space between two adjacent specimens to obtain a uniform heating in each specimen. The test specimens were heated in batches due to limited capacity of the furnace. Extreme care was taken when handling the heated concrete specimens.

Figure 6.1: Oven


Figure 6.2: Cylinders

7. Methods of Cooling:

- ✓ **Air-Drying Method:** After curing, the cubes were taken out of the curing tank and air dried for a period of 24 hours in a well-ventilated shed at ambient atmospheric conditions. Air-dried cylinders were exposed to 300°C temperature in an oven. After the heat treatment, the cylinders were allowed to naturally cool to the ambient temperature in this method.
- ✓ **Quenching Method:** The heating process carried out as described in Air-drying method. After the heating process, the cylinders were immediately removed from the oven after the heating duration and quenched in a water tank to provide the maximum thermal shock due to sudden cooling.

8. Testing of Specimen:

Weight Loss: The following procedure was adopted to find the weight loss of the test specimens After 28 days curing the weight of the test specimens was taken at 1day. Let it be W_1 (kg)

- ✓ The test specimens were exposed to the particular temperature. After exposed to the particular temperature, the weight of the test specimens is taken at 1 day. Let it be W_2 (kg).
- ✓ The weight loss of the test specimens is equal to (W_2 - W_1) kg.

Compression Behavior: For finding the compressive strength and other mechanical properties a universal-testing machine with compress meter or dial gauge with specimen was used. The under mentioned procedure was followed to test cylinder specimen for compressive strength and other mechanical properties

- ✓ After fire test, the cylindrical specimens were cooled by the above two process. The specimens were allowed to dry for one day.
- ✓ This specimen was fixed with dial-gauge and then placed in 1000kN capacity of Universal Testing Machine (UTM).
- ✓ The load was applied to the upper most surface of the specimen. The axis of the specimen was aligned carefully with the axis of the loading device. The load was applied without shock and increased continuously at a uniform rate 5kN/min until the specimen fails.

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- ✓ The deformation is noted at each stage of loading with the help of dial gauge. The maximum load at failure and deformation was noted. From this load and deformation values the energy absorption capacity and stiffness is also to be determined. The test set up was shown in Figure 8.1

Figure 8.1: Testing of Cylindrical Specimen

9. Failure Pattern of Specimens:

The specimens are tested in UTM up to maximum load according to specimen the load caring capacity vary from each sample, the failure pattern are shown in following figure

Figure 9.1: Glass Mesh

Figure 9.2: Wire Mesh

Figure 9.3: GI Mesh

Figure 9.4: Nylon Mesh

10. Result and Discussion:

Test results were obtained for the compressive strength and loss in weight and strength loss of cylindrical specimens are presented in Table 6.1, 6.2 & 6.3 and illustrated through Figure 6.1, Figure 6.2 and Figure 6.3. The load deformation behaviors for four types of meshes were also discussed.

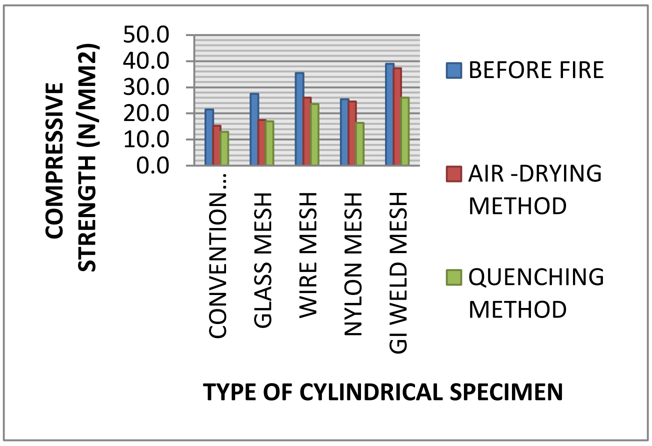

Figure 10.1: Compressive Strength of Specimen

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Table 4: Compressive Strength

Types of Specimen	Compressive strength N/mm^2		
	At Room temperature	After 300°C of heat	
		Air -Drying Method	Quenching Method
Conventional	21.5	15.27	13.01
Glass Mesh	27.45	17.54	16.97
Wire Mesh	35.42	26.03	23.54
Nylon Mesh	25.47	24.62	16.41

Table 5: Loss in weight of cylindrical specimens

Type of Cylinder	Weight Loss After 300°c of heat (Kg)	
	Air Drying	Quenching Method
conventional	0.55	0.17
Glass mesh	0.615	0.17
Wire mesh	0.495	0.13
GI mesh	0.66	0.105
Nylon mesh	0.675	0.03

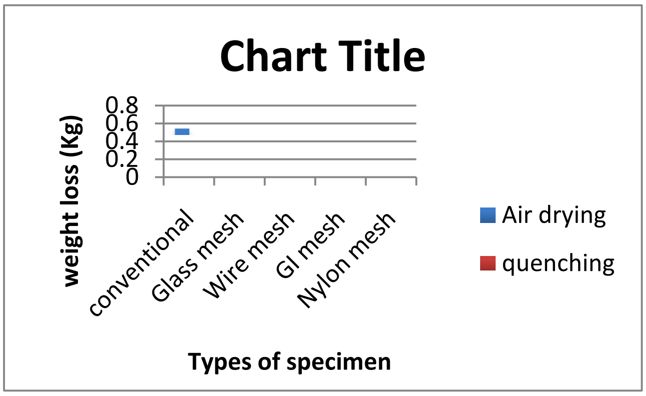

Figure 10.2: Weight Loss of Specimen

Table 6: Loss in Strength of cylindrical specimens

Type of Cylinder	Strength Loss After 300°c of heat %	
	Air Drying	Quenching Method
conventional	28.9	39.5
Glass mesh	36.1	38.2
Wire mesh	26.5	33.5
GI mesh	4.4	33.3
Nylon mesh	5	2

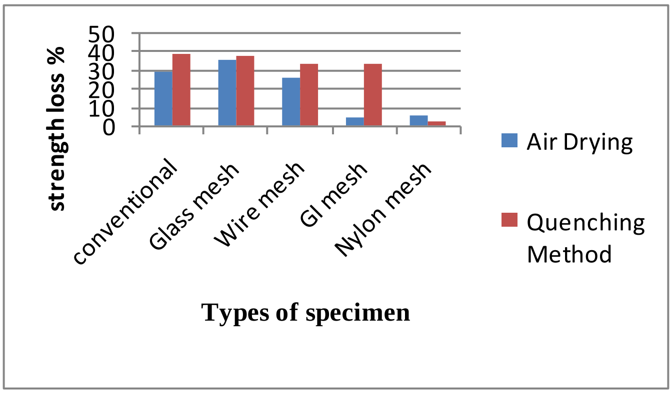

Figure 10.3: Strength Losses Of Specimens

Load Carrying Capacity: The load carrying capacity of conventional cylinder and mesh confinement cylinder was recorded and is shown in the Figure 6.7. The conventional cylinder specimen was loaded upto their ultimate load. It was noted that of cylinders with confinement materials Glass mesh, Wire mesh, GI Weld mesh and Nylon mesh had the higher load carrying capacity compared to the conventional cylinder specimen. The load carrying capacity of the specimen was increased by the mesh confinement materials to the concrete. In before fire cases the conventional cylinder the ultimate failure took place at a load of 380kN. In glass mesh specimen the ultimate load was 430kN, which is lower than conventional specimen, Wire mesh in which

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ultimate load was about 590kN. Similarly, in GI Weld mesh specimen ultimate failure took place at a load of 690kN, which is higher than Nylon mesh specimen in which ultimate load was 290kN

Table 7: Load carrying capacity of cylindrical

Types of Specimen	Load carrying capacity(KN)		
	At Room temperature	After 300°C of heat	
		Air -Drying Method	Quenching Method
Conventional	380	280	230
Glass Mesh	430	360	480
Wire Mesh	590	465	423
GI weld mesh	690	660	460
Nylon Mesh	450	435	290

Energy Absorption Capacity: In general, the energy absorption capacity of a given material can be obtained from the load deflection curve and variation of energy absorption capacity for all the cylinders were presented Here the mesh is used as confinement to concrete, which arrest the crack and resist the spalling. The mesh confinement concrete exhibit an increase in energy absorption capacity with reference to control specimen. In before fire cases, the energy absorption was found to be increased by 8.29% for glass mesh specimen, 73.05% for wire mesh specimen, 73.58% for GI Weld mesh specimen, 47.15% for nylon mesh specimen as that of conventional specimen. In air-drying method the energy absorption was found to be increased by 4.375% for glass mesh specimen, 1.42 times for wire mesh specimen, 1.64 times for GI Weld mesh specimen, 12.5% for nylon mesh specimen with reference to conventional cylinder specimen. In quenching method the energy absorption was found to be increased by 3.45% for glass mesh specimen, 1 time for wire mesh specimen, 1.2 times for GI Weld mesh specimen, 10.34% for nylon mesh specimen with reference to conventional cylindrical specimen. Therfore the air-drying method has higher energy absorption capacity compared to the quenching method and also the GI weld mesh specimen has higher energy absorption capacity compared to the other mesh specimens.

Table 8: Energy absorbtion capacity of cylindrical

Types of Specimen	Energy absorbtion capacity(N.MM) X10^3		
	At Room temperature	After 300°C of heat	
		Air -Drying Method	Quenching Method
Conventional	386	320	290
Glass Mesh	418	334	300
Wire Mesh	668	776	580
GI weld mesh	670	846	638
Nylon Mesh	578	360	320

Stiffness: Stiffness is defined as the load required causing unit deflection of the cylinder. A tangent is drawn for the curve at load of P= 0.75Pu, where Pu is the maximum load of that cycle. The slope of the tangent, thus drawn, gives the stiffness of the cylinder. The variation of stiffness characteristics for all the cylinders was shown in Figure 6.9. The mesh confinemnt concrete exhibit an increase in stiffness with reference to control specimen. In before fire cases, the stiffness was found to be increased by 38.77% for glass mesh specimen, 164% for wire mesh specimen, 2.44 times for GI Weld mesh specimen, 65% for nylon mesh specimen as that of conventional specimen. In air-drying method the stiffness was found to be increased by 75% for glass mesh specimen, 1.57 times for wire mesh, specimen, 3.32 times for GI Weld mesh specimen, 1 time for nylon mesh specimen with reference to conventional cylinder specimen. In quenching method the stiffness was found to be increased by 14.2% for glass mesh specimen, 1.78 times for wire mesh specimen, 1.96 times for GI Weld mesh specimen, 60.62% for nylon mesh specimen with reference to conventional cylindrical specimen. Therefore the air-drying method has higher stiffness compared to the quenching method and also the GI weld mesh specimen has higher stiffness compared to the other mesh specimens.

Table 9: Stiffness of cylindrical specimen

Types of Specimen	Stiffness in (N/MM) X10^3		
	At Room temperature	After 300°C of heat	
		Air -Drying Method	Quenching Method
Conventional	118.18	133.33	111.54
Glass Mesh	164	233.33	130
Wire Mesh	312	343.75	310
GI weld mesh	406.98	576.92	330.77
Nylon Mesh	195	266.76	179.16

Ductility Factor: Ductility is the ratio between deflections at ultimate load to that at the onset of yielding. In before fire cases, the ductility factor was found to be increased by 5.83% for glass mesh specimen, 12.62% for wire mesh specimen, 21.36% for GI Weld mesh specimen, 8.74% for nylon mesh specimen as that of conventional specimen. In air-drying method the stiffness was found to be increased by 2.94% for glass mesh specimen, 8.82% for wire mesh specimen, 17.65% for GI Weld mesh specimen, 5.88% for nylon mesh specimen with reference to conventional cylinder specimen. In quenching method the stiffness was found to be increased by 4% for glass mesh specimen, 10% for wire mesh specimen, 14% for GI Weld mesh specimen, 6% for nylon mesh specimen with reference to conventional cylindrical specimen. Therefore the air-drying method has higher ductility factor compared to the quenching method and also the GI weld mesh specimen has higher ductility factor compared to the other mesh specimens.

Table 10: Ductility factor of cylindrical specimen

Types of Specimen	Ductility factor		
	At Room temperature	After 300°C of heat	
		Air -Drying Method	Quenching Method
Conventional	1.02	1.03	1
Glass Mesh	1.04	1.09	1.05
Wire Mesh	1.11	1.16	1.10
GI weld mesh	1.2	1.25	1.14
Nylon Mesh	1.07	1.12	1.06

11. Conclusion:

Based on the investigations, the following conclusions were drawn:

- ✓ The compressive strength of GI weld mesh specimen is higher compared to conventional specimen in before and after fire at a temperature of about 300°C.
- ✓ The specimens under air drying cooling method has higher load carrying capacity, energy absorption, compressive strength, ductility factor and stiffness compared to quenching cooling method.
- ✓ The GI weld mesh specimen has less deformation compared to conventional specimen.
- ✓ In air-drying cooling method, the load carrying capacity of GI weld mesh specimen is higher compared to the conventional specimen by the amount of 1.35 times respectively.
- ✓ In air-drying cooling method, the energy absorption and stiffness of GI weld mesh specimen is higher than that of conventional specimen by the amount of 1.64 and 1.96 times respectively.
- ✓ In air-drying cooling method, the ductility factor of GI weld mesh specimen is 17.25% higher than that of conventional specimen.
- ✓ The nylon mesh type specimen has higher weight loss and there is a presence of more cracks.
- ✓ When cylindrical specimens exposed to 300°C temperature, the color of the concrete became light yellow.
- ✓ The air-drying cooling method gives long service life to the structure compared to quenching cooling method

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