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# COMPARISON OF PERFORMANCE OF TRC AND PCC EXPOSED TO VARYING TEMPERATURES AND ITS APPLICATION

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**Abstract -** *This paper compares the performance of Textile Reinforced Concrete (TRC) and Plain Cement Concrete (PCC) when exposed to varying temperatures. Concrete is a widely used construction material. It possesses good strength, but poor when involves tension. So as to extend the durability of the Concrete, it's being reinforced with steel, which unfortunately also has the disadvantage of being liable to corrosion and fatigue. It'll further increase the upkeep and repair cost of the structure. An innovative concept to eliminate these drawbacks is that the textile reinforcement of concrete. For past a few years leading scientists are working with the thought of improving the planet of concrete by using high performance fibres, developing so called "Textile concrete (TRC)". Concrete elements exposed to fireside undergo temperature gradients and as a result, undergo physical changes. However, the varying temperature resistance of those materials has not been studied to an excellent extent. We expose the TRC and PCC specimens to varying temperatures and their properties are analysed. Post-Earthquake Fire analysis of beam-column joint with TRC and without TRC also are analysed as a structural application.*

***Key Words***: Textile Reinforced Concrete, Plain Cement Concrete, Varying Temperature, Post Earthquake Fire

## 1. INTRODUCTION

Concrete is widely used in construction because of its numerous advantages, like strength, durability, ease of fabrication etc. Seismic deterioration of the buildings is principally because of irregularity problem, low quality of material, reinforcement insufficiency etc. Concrete structural members when used in buildings must satisfy appropriate fire safety requirements specified in building codes. Fire represents one amongst the foremost severe environmental conditions to which structures may be subjected; therefore, provision of appropriate Fire safety measures for structural members is an important aspect of building design. The extensive knowledge of mechanical properties of TRC and PCC exposed to elevated temperature seems to be decisive for a wider utilization of the material. The elevated temperature resistance of these materials has not been studied to a great extent. A comparison between the performance of TRC and PCC exposed to elevated temperatures is analysed and specimens are to be tested for various properties.

### 1.1 Textile Reinforced Concrete

Textile Reinforced Concrete (TRC) is otherwise known as textile reinforced mortars (TRM) or fabric reinforced cementitious matrix (FRCM). Textile Reinforced Concrete is a composite material which constitutes a novel structural system with enormous potential in construction. The main difference of this system with traditional steel reinforced concrete is that the bulky steel reinforcement has been replaced by lightweight textiles, usually product of glass or carbon fibres. This offers the chance to manufacture thin (thus lightweight) structural elements with a high structural performance. Textile fibers may be of several types, like carbon, basalt, glass and synthetic fibers. The different types of fibers are shown in Figure 1.


**Fig -1**: Types of Textile Fibers

### 1.2 Post Earthquake Fire

Post-earthquake fire (PEF) is considered as one of the most problematic potentially possible disasters in urban areas, because it may end in a conflagration. Most standards and criteria, however, ignore the chance of fireside after earthquake and thus, majority of conventional buildings are not designed to resist thermal loading after an earthquake. Thus, there's high likelihood of rapid collapse for those buildings damaged partially after an earthquake, which are subjected immediately to a following fire.

Concrete has a low thermal conductivity. This slows the transmission of heat to the core of the cross-section and thus concrete acts as a kind of insulation. Although the reinforcing bars have high thermal conductivity, they're generally well protected by the concrete cover. However, after an earthquake, there is a high probability of the cover being damaged, leading to direct exposure of the steel reinforcement to fire. This leads to a rapid reduction of its fire resistance. According to performance-based codes, the extent of damage to the concrete cover can be correlated with the performance level, for which the building was designed for. In buildings designed for Immediate Occupancy (IO) performance level, only minor damage would be sustained by the structural elements when subjected to the design earthquake. Post-Earthquake fire analysis of beam-column joint is analysed using software.

## 2. METHODOLOGY

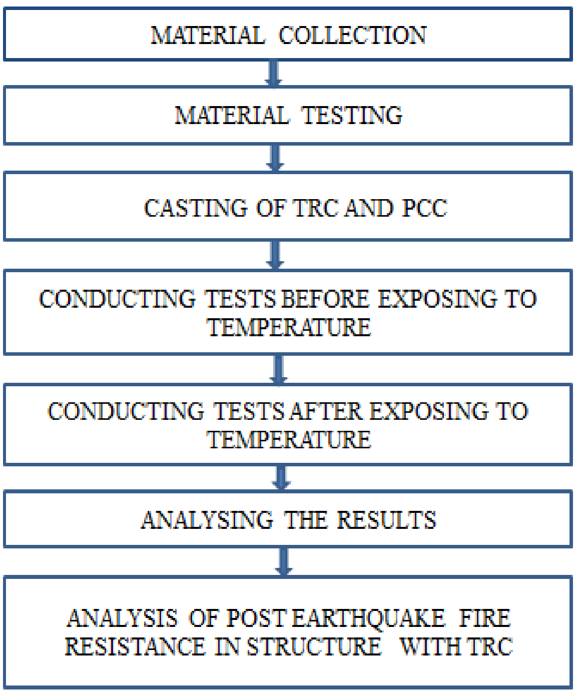


**Fig -2:** Methodology

## 3. MATERIALS USED AND THEIR PROPERTIES

### 3.1 Cement

Ordinary Portland Cement of 53 grade is used. The properties of cement are shown in table 1.

**Table -1:** Properties of Cement

| Sl No. | Properties | Result |
|---|---|---|
| 1. | Fineness | 8.90% |
| 2. | Specific Gravity | 3.17 |
| 3. | Standard Consistancy | 32.15 |
| 4. | Initial Setting Time | 55 min |

### 3.2 Fine Aggregate

M Sand is used as fine aggregate. Properties are shown in table 2.

**Table -2:** Properties of Fine Aggregate

| Sl No. | Properties | Result |
|---|---|---|
| 1. | Fineness modulus | 2.87 |
| 2. | Specific gravity | 2.55 |
| 3. | Bulking of fine aggregate | 18.75% |
| 4. | Bulk density | 1.41g/cc |
| 5. | Void ratio | 0.42 |
| 6. | Porosity | 29.87% |

### 3.3 Coarse Aggregate

Coarse aggregate of nominal size are used. Properties are shown in table 3.

**Table -3:** Properties of Coarse Aggregate

| Sl. NO. | Properties | Result |
|---|---|---|
| 1. | Fineness modulus | 2.87 |
| 2. | Specific gravity | 2.74 |
| 3. | Water absorption | 0.3% |
| 4. | Bulk density | 1.49g/cc |
| 5. | Void ratio | 0.75 |
| 6. | Porosity | 42.92% |

### 3.4 Textile Glass Fiber

Alkali-Resistant Glass Fiber Mesh of 145 GSM (Gram perSquare Metre), Size of 140mm×50m is used in this project. AR-Glass Fibres are manufactured from a specially formulated glass composition with an optimum level of Zirconium (ZrO2) to be suitable for use in Concrete. The higher the Zirconium content in the fibre the better the resistance to Alkali attack. The Fibres add Strength and Flexibility to the concrete resulting in a strong yet light weight, high mechanical strength and excellent tensile strength. The Glass Fiber products are able to bear high loads without significant deformation. It reduces shrinkage in the Concrete. It exhibits excellent Workability characteristics.

### 3.5 Fly Ash

Fly Ash is used as a Cementitious material, to provide enough bonding to the concrete.

### 3.6 Water

Water fit for drinking is generally considered for making Concrete. Water should be free from acid, oils, alkalis and other organic compounds.

### 4. MIX DESIGN

Mix Design is the process of selecting suitable materials to attain the various properties of Concrete such as Workability, Durability and Strength. Mix proportion for PCC and TRC are shown in Table 4 and Table 5.

**Table -4:** Mix proportion of PCC

| | | |
|---|---|---|
| 1. | Water –Cement ratio | 0.4 |
| 2. | Weight of cement | 436 kg |
| 3. | Weight of coarse aggregate | 1144 kg |
| 4. | Weight of fine aggregate | 620 kg |
| 5, | Weight of water | 192 l |

**Table -5:** Mix proportion of TRC

| | | |
|---|---|---|
| 1. | Water –Cement ratio | 0.4 |
| 2. | Weight of cement | 468 kg |
| 3. | Weight of coarse aggregate | 1685 kg |
| 4. | Weight of fine aggregate | 156 kg |
| 5. | Weight of water | 195 l |

### 5. CASTING AND CURING OF SPECIMENS

Specimens of cube, beam and cylinder were casted and are cured (Shown in Figure 3 and Figure 4).

**Fig -3:** Casting of PCC and TRC specimens

**Fig -4:** Curing of specimens

### 6. EXPERIMENT AND OBERVATIONS

Experiment is conducted in three stages. Firstly the PCC and TRC specimens are tested for compressive strength, flexural strength and split tensile strength, for 7 days, 14 days and 28 days, before exposing to temperature. In the second stage the specimens are tested for the said tests for 28 days after exposing to temperature. Then the results are compared. In the third stage, PEF analysis of beam-column joint is done using software.

### 6.1 Test Result before Exposing to Temperature

Test results of specimens exposed to temperature are given below (Table 6, 7, 8 respectively).

**Table -6:** Compressive Strength Test

| | PCC (N/mm2) | TRC (N/mm2) |
|---|---|---|
| 7 days | 27.80 | 29.70 |
| 14 days | 38 | 40.9 |
| 28 days | 48 | 55 |

**Table -7:** Flexural Strength Test

| | PCC (N/mm2) | TRC (N/mm2) |
|---|---|---|
| 7 days | 3.70 | 4.20 |
| 14 days | 4.30 | 4.70 |
| 28 days | 8 | 11.50 |

**Table -8:** Split Tensile Strength Test

| | PCC (N/mm2) | TRC (N/mm2) |
|---|---|---|
| 7 days | 3.30 | 3.70 |
| 14 days | 3.80 | 4.10 |
| 28 days | 4 | 5.43 |

### 6.2 Exposing Specimens to varying temperatures and Testing

To determine the strength after exposed to varying temperatures, the specimens were heated in oven. After exposing to specified temperatures for three hours, these specimens were tested for respective strengths in hot condition immediately after taking out of the oven. The test specimens were subjected to temperatures from 100°C to 300°C at intervals of 100°C each for three hours duration. The specimens were heated to the specified target temperatures. The specimens are then compared and are shown in Table 9, Table 10 and Table11 respectively.

**Table -9:** Comparison of PCC and TRC for Compressive Strength

| Temperature (°C) | 100 | 200 | 300 |
|---|---|---|---|
| PCC | 43.9 | 42 | 39.1 |
| TRC | 49.5 | 48 | 47.9 |

**Table -10:** Comparison of PCC and TRC for Flexural Strength

| Temperature (°C) | 100 | 200 | 300 |
|---|---|---|---|
| PCC | 7.04 | 6.91 | 5.92 |
| TRC | 10.12 | 9.90 | 9.11 |

**Table -11:** Comparison of PCC and TRC for Split Tensile Strength

| Temperature (°C) | 100 | 200 | 300 |
|---|---|---|---|
| PCC | 3.21 | 2.90 | 2.40 |
| TRC | 4.34 | 4.01 | 3.84 |

### 6.3 Post Earthquake Fire analysis

As a structural application, a beam-column joint is analysed for the PEF resistance using ETAB 2015 Software. Firstly the the building (without TRC) is experienced with Earthquake force and then it is loaded with fire loading. On analyzing with the software, the structure with most damage is found out. Then building (with TRC) is made to undergo earthquake load, then with fire load. Here also the structure with most damge is found out and a comparison is made btween the sructures with TRC and without TRC. The obtained results are given below.

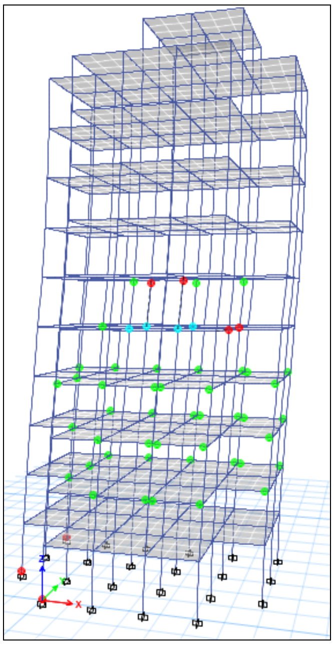

**Fig -5**: Analysis using Software

- Pushover Analysis is used to access plastic hinges in the building.
- Red colour hinges represent maximum damage.
- Temperature loads are applied to portions of maximum earthquake damages.
- 1400Mega Joules per square meter temperature load is used for the Fire Analysis.

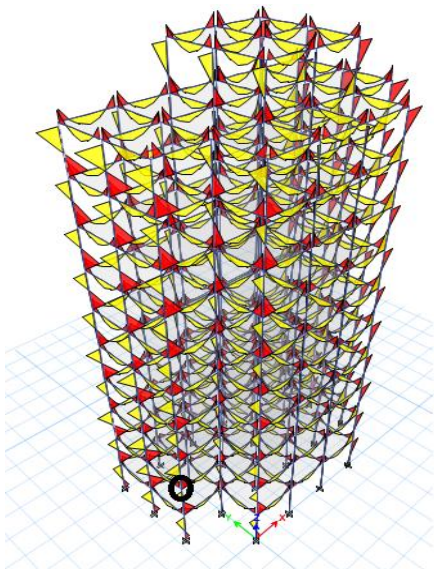

**Fig -6**: Selected beam-column joint

The figure (fig.6) above shows the selected beam column joint. The table 12 shows the analysed results.

**Table -12:** Software analysis of normal concrete and TRC

| | NORMAL CONCRETE | TR CONCRETE |
|---|---|---|
| JOINT DIPLACEMENT | 375.9 | 110.7 |
| COLUMN MOMENT | 330.0 | 213.8 |
| COLUMN AXIAL FORCE | 2669.3 | 2700.5 |
| BEAM MOMENT | 365.4 | 228.7 |
| BEAM AXIAL FORCE | 2112.8 | 2744.0 |
| MAXIMUM DISPLACEMENT | 381.4 | 110.8 |
| STOREY DRIFT | 0.018 | 0.006 |
| BASE REACTION | 23915.7 | 40716.1 |
| OVERTURNING MOMENT | 119081.4 | 202680.5 |
| JOINT REACTION | 1836.1 | 2718.2 |
| FUNDAMENTAL PERIOD | 3.4 | 2.6 |
| STOREY STIFFNESS | 100504.7 | 279342.0 |
| MCR | 1.64 | 1.61 |

## 7. CONCLUSIONS

As the temperature increases, there is a decrease in strength of both PCC and TRC specimens. But when we a comparison is made between PCC and TRC, we can conclude, in both the experiments (laboratory experiment and software analysis) we have conducted, the structure with TRC exhibit more strength than the structure without TRC. The following were the conclusions made,

- TRC structures have more strength than PCC before exposing to temperature and after exposing to temperature.
- Textile Reinforced concrete is found to exhibit more compressive strength, split tensile strength and flexural strength than the Plain Cement concrete at all temperatures.
- The difference between compressive strength, flexural strength and split tensile strength of Textile Reinforced Concrete and Plain Cement Concrete varies in the range of 9-10, 0-12, 0-20 percentage respectively.
- The joint displacement and maximum storey displacement are less for structure with textile reinforcement because its higher tensile strength resists pulling apart forces.
- Addition of Fibre results in higher compressive strength, axial force is directly proportional to compressive strength.
- Higher flexural strength help to resist bending in sections, so column moments and beam moments are less.
- Higher MCR indicates higher beam to column connection ductility.

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