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Mechanical behavior of TRC Fine Grained Concrete with short PP fiber exposed to high temperatures.

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ABSTRACT: *This research is based on the mechanical behavior of TRC fine grained concrete with short PP fiber when exposed to high temperature. Textile reinforced concrete (TRC) is a type of composite material with great potential in lightweight and thin-walled structural components bearing high capacity. Textiles can significantly improve the mechanical behavior of cement matrices under static and dynamic conditions, and give superior tensile strength, toughness, ductility, energy absorption and protection against environmental degrading influences. This paper aims to have an in-depth look at treatment of the fabric, methods for production of the composite, the micro-mechanics with special attention to the role of bonding and micro structure, behavior*

under static and dynamic loading, sustainability, design, and the applications of TRC composites.

KEYWORDS: *Textile reinforced concrete(TRC), yarn, PP fibers, Flexural strength, Compressive strength, Mass loss, Temperature.*

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I. INTRODUCTION

Concrete is one of the most significant if not the most key construction material. Concrete, is very strong in compression only retains a tenth of that strength when subjected to tensile force. Basically two materials, with different properties were working together as one unit, forming what we now call as composite structures [1] .

A recent innovative attempt to improve the sustainability of reinforced concrete is the development of textile reinforced concrete(TRC) comprising of fine grained concrete matrix reinforced by multi-axial non-corrosive textile fibers. Reinforced concrete which is complementary to tension and compression is composite material being used in construction industry according to its structural materially, durable advantage. Textile is made up as bundle of carbon, glass, alkali glass fibers As steel is substituted by textile ,general mixing proportions ratios cannot be used[2]. The research about effect of fine grained aggregate on concrete strength is studied by changing amounts of fine aggregates and size of aggregates . Recently, textile reinforced concrete (TRC) in which steel is replaced with Glass fiber or Alkali matrix, it gives the valuable option in consumption of concrete and weight of the structures. Furthermore, TRC offers the state of arts and give the freedom of design and size [3]. Additionally, recent researches, shows that TRC can made tailor also in the choice of binders and the textile as per our application.

1.2 General definition of Textile Reinforced Concrete (TRC)

Textile reinforced concrete or TRC is a relatively new high performance building material. TRC is based on the idea to combine concrete with textile grids made of non-corrosive endless filaments with a very high tensile strength instead of corrodible reinforcing steel that is usually used in reinforced concrete [4][5].

1.3 Applications of Textile Reinforced Concrete

TRC is a composite material consisting of high-performance filament yarns made of alkali-resistant glass or carbon and a fine-grained concrete matrix. The main features of TRC are its high tensile strength and ductile behavior accompanied by high deformations. This material can be used both for new structures and for the strengthening or repair of existing structural elements made of reinforced concrete or other traditional materials [6]. TRC basics as well as examples of TRC use in structural repair and strengthening and also in prefabrication of structural elements, demonstrating the wide range of possible TRC applications. As examples for strengthening applications, the repairs of a steel-reinforced concrete hyper-shell and of a barrel-shaped roof are presented. In the case of the hyper-shell a sufficient strengthening could be attained by applying three layers of textile sheets on the top side of this shell, with the total thickness of the TRC layer of only 15 mm. In the case of the barrel-shaped roof a more complicated arrangement of TRC layers both on the top side and on the bottom side was necessary for the structural retrofitting. As prefabrication applications, two examples are presented: a facade panel and a hybrid pipe system with an inner plastic layer. In the case of the facade panel, a decrease in weight by a factor greater than could be achieved via utilization of TRC instead of the traditional steel-reinforced concrete.

1.4 Advantages of Textile Reinforced Concrete (TRC)

some advantages which has been shown by textile reinforced concrete such that, no concrete cover is necessary to protect the reinforcement from corrosion since the reinforcing materials used do not corrode under normal environmental conditions. Considering that no concrete cover is needed, very thin strengthening layers can be produced. Carbon textile reinforcements have a much larger surface area than traditional steel-bar reinforcements. Thus, very high bond forces can be introduced into the concrete. This, in practice, is evidenced by both the ability to use short anchoring lengths and the presence of very dense crack patterns. TRC produced from PP fibers possess distinctly higher strength than standard steel-bar reinforcements. The current generation of textile reinforcements has reached strengths well over 1,500 N/mm². In addition to increasing the ultimate loading capacity of reinforced concrete, TRC is also suitable for other repair applications. The use of additional TRC strengthening layers in RC structures has proved to have a positive influence on subsequent concrete cracking [7][3].

1.5 Problems to be Solved

Textile reinforced concrete element are thin walled compared to the convectional steel reinforced element and concrete cover is relatively small. If such textile reinforced concrete elements were exposed to combustion, it’s obvious that the textile has to withstand very high temperatures due to the thin walled structure as well as the small concrete cover. Therefore, especially the fire behavior of the textile material itself is of relevance to the overall load bearing capacity of such an element. If high temperatures were considered, mainly tensile strength and the coefficient of thermal expansion becomes of interest. Such mentioned problems are to solved in order to have a strong and durable textile reinforced concrete to be used in modern industry of constructions.

II. MATERIALS

The choice of fiber material for use in TRC is based on various factors such as materials properties, corrosion and temperature resistance, bond quality, demand/production cost and even environmental impact. The reinforcement ratio and placement of the textile reinforcement will also have a great impact on the composite behavior of a TRC member. Fiber materials which have generally been used and explored in TRC include, but are not limited to: alkali- resistant glass (AR-glass), carbon, basalt, aramid, polyvinyl-alcohol (PVA) with polyvinyl chloride (PVC) coating. In this thesis, it is primarily of interest to explore the use of fly-ash, silica fume, sand ,and PP fibers .

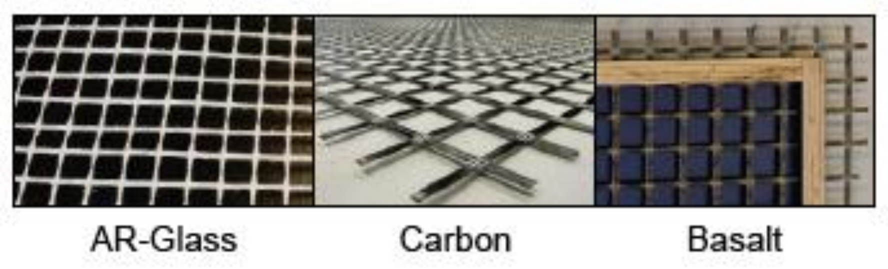

Figure 1. AR-glass, carbon and basalt fiber meshes

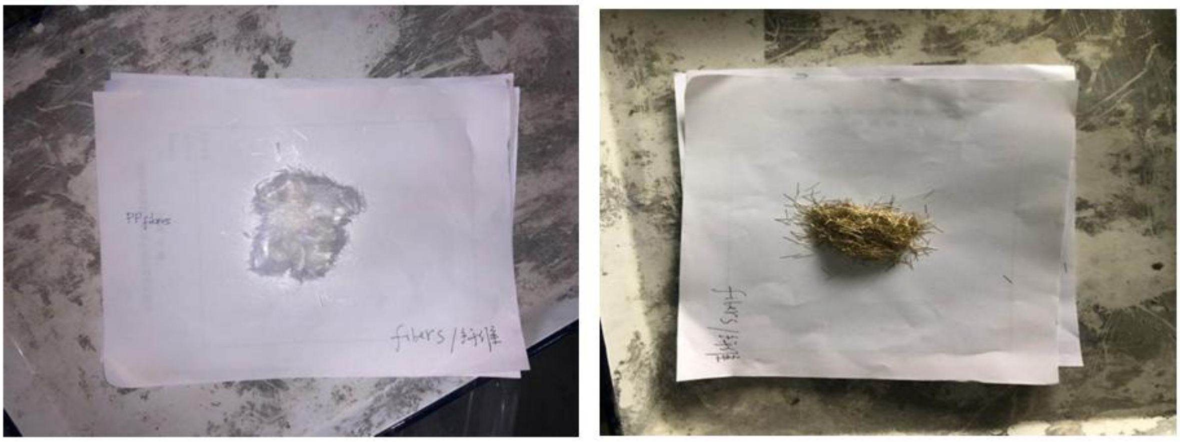

Figure 2 (a) PP fibers (b)Steer fibers

2.2 Durability of Textile Reinforced concrete

TRC is presumed to eliminate the issue of corrosion within reinforced concrete, but what other deterioration mechanisms could potentially arise over time using this composite material. The mechanical behavior of ordinary concrete is complex as it varies over time and is dependent on the fiber- matrix combination. A similar complexity is thought to exist for TRC, and as such the durability of different types of novel textile reinforcements need to be studied and quantified. To date, there exists no long-term performance information about TRC in the field but several accelerated material tests and durability models have been explored.

2.3 Bonding Behavior

The bond behavior between TRC is of crucial importance as it helps understanding the complex mechanism of transferring forces from the textile reinforcement to the surrounding matrix and eventually to the concrete substrate .It is also a fundamental step towards the development of design models to be used in strengthening applications. The yarn structure embedded in a matrix along with these above mentioned associated is conceptualized[8] .After the pre-stress was applied to the epoxy impregnated textiles ,its leads to a high increase of bond strength. We should suggest that for a practical use of textile reinforcement concrete ,the epoxy impregnation and pre-stressing are necessary.

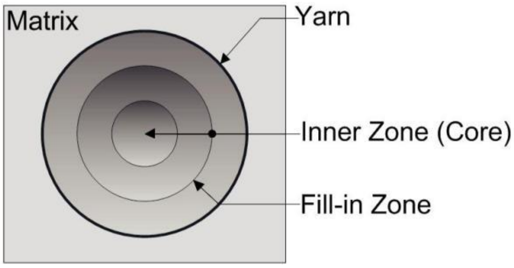

Figure 3 Conceptualized yarn structure

2.4 Sustainability

Textile-reinforced concrete is generally thinner than traditional steel-reinforced concrete. Typical steel-reinforced construction is 100 to 300 mm thick, while a TRC structure is generally 50 mm thick. Since TRC can be used to extend the life of existing structures, it cuts down on the cost of materials and man power needed to tear down these existing structures, in order to create new ones. Instead of replacing old structures, they can now be repaired to add years of service to the lives of their construction.

2.5 Exposure to elevated temperatures

The high-temperature behavior of textile- reinforced concrete (TRC) has not been very investigated so far. Therefore, present applications are limited to members without requirements on the fire-behavior. Exposure to fire or any extreme heat source can have adverse effects on concrete’s mechanical properties. For plain concrete for example, changes can occur in the pore structures, resulting in cracking and spalling, the destruction of the bond between cement paste, aggregates and textile [9]. At present, research into fire resistance performance of fiber reinforced cement-based composite materials concerns two major areas- cementitious composites reinforced with fibers and TRC. It has been reported that the addition of fibers could prevent the explosive spalling of reactive powder concrete (RPC) and significantly increase its compressive and tensile strengths at elevated temperatures [10].

3.1 Arrangement and Instrumentation for load tests

Two tests were carried out; flexural and compressive load tests. Experiment specification and arrangement were being as shown in table

Table 1 Experiment specification and arrangement

Temperature	Dimensions of specimens(mm)	PP fiber content (%)
Room Temperature	**40 ×40 ×160**	**0.05**
	40 ×40 ×160	**0.1**
	40 ×40 ×160	**0.15**
(200^{0}c)	**40 ×40 ×160**	**0.05**
	40 ×40 ×160	**0.1**
	40 ×40 ×160	**0.15**
(400^{0}c)	**40 ×40 ×160**	**0.05**
	40 ×40 ×160	**0.1**
	40 ×40 ×160	**0.15**

Three specimens are used for each fiber content, so as to take an average thus taking the most accurate recording for analysis.

i. After 24 hours, the specimen was removed from the molds

ii. And placed in the curing room at 20°C and 90% RH until an age of 28d.Reasons for curing include;

1) Concrete strength gain- concrete strength increases with age as moisture and favorable temperature is present for hydration of cement.

2) Improved durability of concrete- the durability of concrete is affected by a number of factors including its permeability, porosity and absorptive.

3) Enhanced serviceability - Concrete that is allowed to dry out quickly undergoes considerable early age shrinkage.

4) Improved micro-structure - Material properties are directly related to their micro-structure.

3.2 The effect of PP Fiber Content on Flexural Strength at Room Temperature

Before exposure to high temperature, the flexural strength of the specimen was measured using a flexural testing machine under three-point bending test. The table below shows the flexural strength of the different specimen containing different volumes of PP-fiber for each of the specimens. The table shows the flexural strength of one of each different specimens all containing 0.05%, 0.1% or 0.15%PP- fiber.

The Figure 4 below shows the flexural strength of different specimens all containing 0.05%, 0.1% and 0.15% PP fiber at room temperature of 30^{0}c

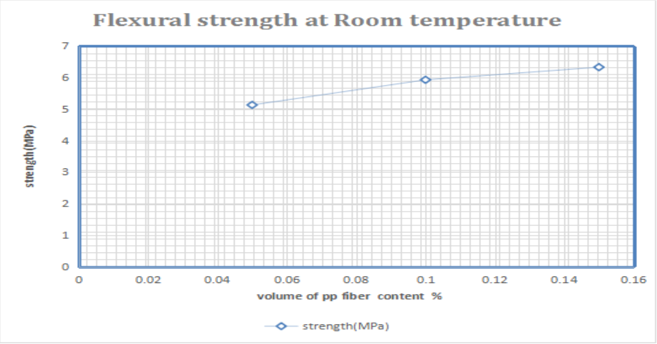

Figure 4 Flexural Strength test at room temperature

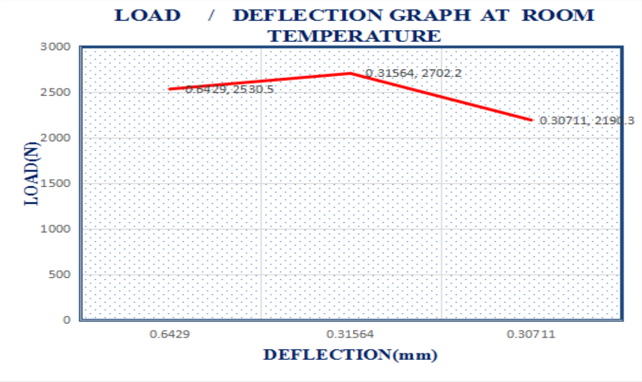

Figure 5 Load/Deflection at room temperature

3.3 The effect of PP Fiber content on Flexural Strength after exposure to high temperatures (200^{0}c)

figures show the bending tests results for the Specimens with 0.05%, 0.1% and 0.15%PP fiber content after they were heated for an hour, comparing heated for 0 minute.For the different fiber contents, it can be seen clearly that for the specimen with PP fiber the flexural strength increases when exposed to high temperature at 200^{0}c. After being exposed to high temperatures for an hour there was an increase in flexural strength for all the three specimens containing different PP fiber.

After the specimens were heated to 200^{0}c, it was seen clearly that specimen with 0.15% fiber content exhibited an increase in flexural strength compare to the specimen at room temperature with the same fiber content. The same property was experienced with other specimens after being exposed to 200^{0}c.The Figure illustrates the flexural strength for the three specimens.

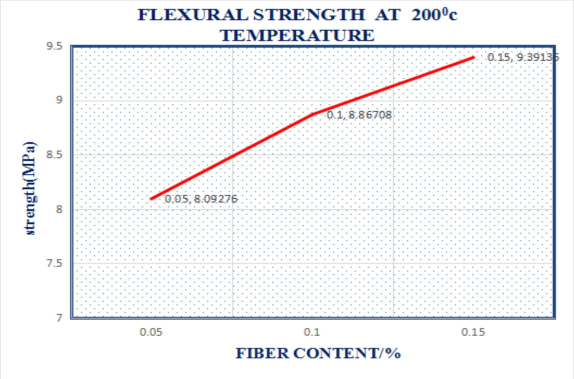

Figure 6 Flexural Strength test at 200^{0}c temperature

With the increase in load there was an increase in deflection which was exhibited in all the three specimens. Comparing the specimens at room temperature and after the specimens where exposed to a temperature of 200^{0}c for all the fiber contents, it was clearly observed that there was an increase in ultimate load with respect with respect to deflection. Specimen with fiber content 0.15% had an increase in load of about 82% and an increase of deflection of about 98% in deflection. The Figure below illustrated the information

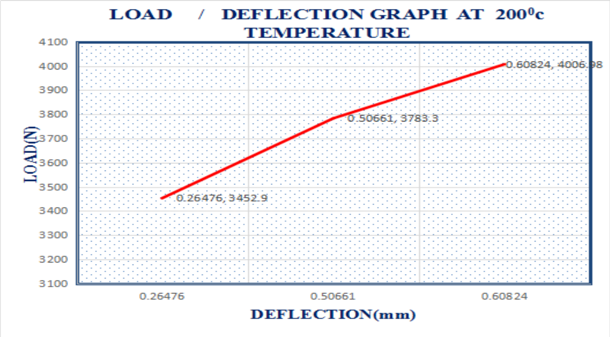

Figure 7 Load/Deflection at200^{0}C temperature

3.4 The effect of high temperatures(400^{0}c) on PP Fiber content on Flexural Strength.

For the specimen that contained only 0.1% PP- fiber, the same property was exhibited. There was significant increase in flexural strength with time as compared to the specimens at room temperature. However, the flexural strengths at each specific interval were much higher in the flexural strength of the specimen with 0.05% PP- fiber content at the same interval. For example, before being exposed to elevated temperatures, the specimen with 0.05% PP fiber tested a much lower flexural strength at room temperature than those that contained 0.1% PP -fiber, where the 0.05% PP fiber content specimen has a flexural strength of 5.13336MPa while the 0.1% PP fiber specimen had a flexural strength of 5.93096 MPa. After being exposed to high temperatures for an hour, the 0.1 % PP fiber content specimen also showed a significant increase in flexural strength as it was compared to room temperature but the flexural strengths were by 22.14% higher than those shown from the specimen with 0.05% PP fiber content at the same time interval. it was also seen that, there was a drop in flexural strength to the specimens at 400^{0}c when compared to specimens at 200^{0}c.This also explains that when exposed to much higher temperature the flexural strength of TRC reduces.

Bending Test Results for 0.05%,0.1%,0.15% PP- fiber content specimens at 4000c

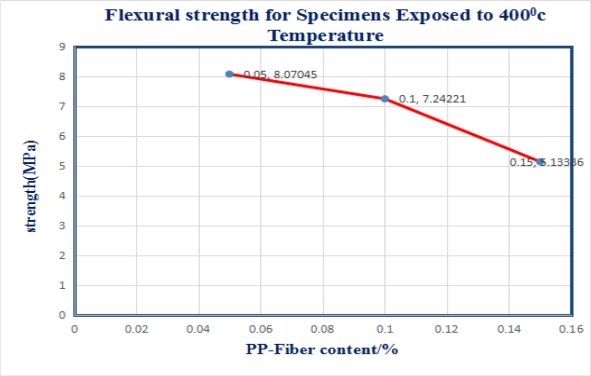

Figure 8 Flexural Strength test at 400^{0}c

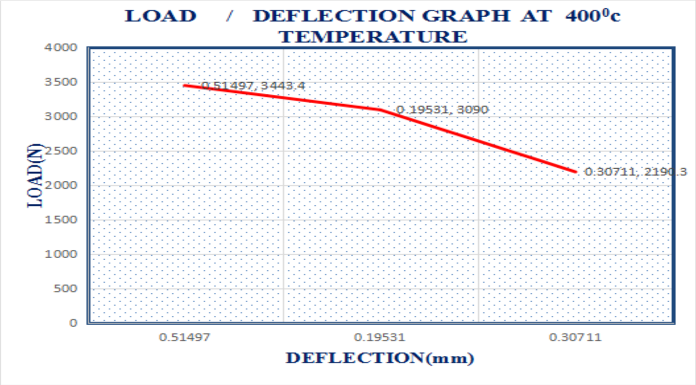

Figure 9 Load/Deflection at 400 ^{o}C temperature

With 0.15%PP fiber content, despite the increase in flexural strength with heating time, the flexural strength was relatively high compared to the specimen with 0.05% and 0.1% PP fiber content. Before heating specimen with 0.15% PP fiber content had a flexural strength that much higher than the specimen with 0.05% and 0.1% PP fiber and a high flexural strength after being exposed to elevated temperatures for an hour. In both three categories of temperature, specimen with 0.15% exhibited much higher flexural strength.

3.6 The effect of Temperature and PP Fiber content on Compressive Strength at Room Temperature.

It can be seen from the table and graph that with increase in PP fiber content there was a negligible increase in compressive strength when the PP fiber content was 0.1% having the highest compressive strength and a followed by that with 0.15%PP fiber content. This suggests that there is little or no contribution made by the PP fiber on the compressive strength of the specimen.

Compressive Strength test Results for specimen containing different volumes of PP fiber(0.05,0.1,0.15) at room temperature

The Figure below illustrates the compressive strength. Specimen with 0.1% showed an increase in strength among the three specimens

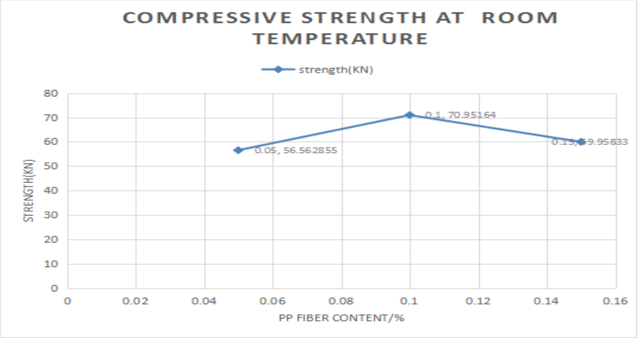

Figure 10Compressive Strength test at Room temperature

3.7 The effect of temperature (200^0C) on PP Fiber content on Compressive Strength

The Compressive strength test results for specimens with 0.05%, 0.1% and 0.15% PP fiber content It is seen that with an increase in the time the specimen with 0.05% PP fiber content are exposed to elevated temperatures, their compressive strength increases by over 20.7045KN which is 36.6% when compared to that specimen at normal temperature and in compressive strength after an hour exposure to high temperatures. And also it is observed that for specimen with 0.1% a drop in strength by 5.25226KN which is 7.9%as compared to one with normal temperature. For specimen with 0.15% PP content, it was seen that there was an increase in strength by 3.30616KN which is 5.5%after being exposed to high temperature at 200^0c.

Compressive Strength Test Results for 200^0C PP fiber content specimens

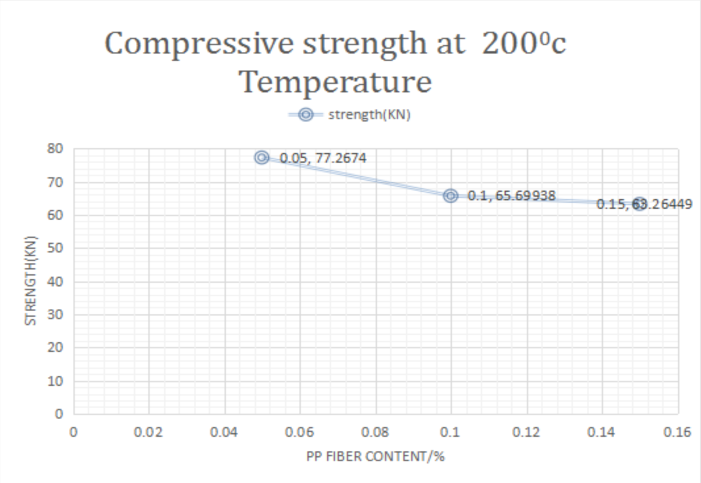

Figure 11 Compressive Strength test at 200^0c temperature

3.8 The effect of PP Fiber content on Compressive Strength after exposure to high temperatures at(400^0C)

Compressive Strength Test Results for 400^0C PP fiber content specimens

Comparing the three specimens which had been tested before being exposed to high temperature, it was observed that there was an increase in compressive strength with all three specimens after being exposed to high temperature. The chart below illustrates the changes in strength.

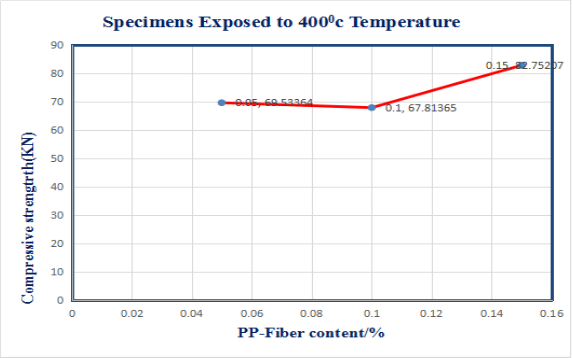

Figure 12 Specimens exposed to 400^0c

IV. CONCLUSION

This study shows the Mechanical behavior of TRC Fine Grained Concrete with short PP fiber exposed to high temperatures. The conclusions drawn from this study are as follows:

i. An increase in PP- fiber content increases ultimate load at 200^0c and 400^0c

ii. All specimens showed an increase in flexural strength relatively after exposure to high temperatures except for specimen at 400^0c with 0.15% PP fiber.

iii. However, flexural strength at each time interval was much higher with increase in PP fiber content. It was evident therefore that an increase in PP fiber content contributes to the increase in flexural strength of TRC fine grained concrete with short PP fiber under exposure to elevated temperatures.

iv. The compressive strengths of the specimens increase under temperatures with or without fiber addition.

v. When compared, the specimen with higher PP fiber content showed minimal increase in compressive strength with time. For example, in an hour or 60 minutes’ time interval, specimens with 0.05%PP fiber showed an increase in compressive strength. In the same time interval, specimen with 0.1% and 0.15% PP fiber content experienced a n increase in compressive strength of both respectively for both 200^0c and 400^0c when compared to room temperature.

vi. An increase in temperature increases the matrix. Since PP fiber is more resistance compared to the matrix, this causes continuity in turn increasing the compressive

vii. According to the micro structural observations, the incline in bearing capacity of the TRC after exposure to high temperatures is mainly caused by the degraded filaments, the reduced pore size of the matrix and the increased bonding between pp fiber and matrix which are correlated to the rise in temperature. The higher the temperature the more induced to PP fibers.

V. SUGGESTIONS FOR FURTHER RESEARCH

Textile Reinforced Concrete (TRC) being a relatively new composite material in the construction industry, thereby still has several areas that need further clarity in order to develop complete, safe and robust structures. Therefore, for the many years to come further research has to be done.

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