COMPRESIVE STRENGTHS AND MODULUS OF ELASTICITY OF STEEL FIBER REINFORCED CONCRETE UNDER DIFFERENT TEMPERATURE CONDITIONS

PUBLICATION ARTICLE

Arranged By:
Mohamed Alfitouri Masoud
S100130013

POSTGRADUATE PROGRAM
DEPARTMENT OF CIVIL ENGINEERING
MUHAMMADIYAH UNIVERSITY SURAKARTA
2015
COMPRESIVE STRENGTHS AND MODULUS OF ELASTICITY OF STEEL FIBER REINFORCED CONCRETE UNDER DIFFERENT TEMPERATURE CONDITIONS

PUBLICATION ARTICLE

Arranged By:
Mohamed Alfitouri Masoud
S100130013

Supervisor 1
Dr. Mohamad Solikin

Supervisor 2
Yenny Nurchasanah, ST, MT
COMPRESIVE STRENGTHS AND MODULUS OF ELASTICITY OF STEEL FIBER REINFORCED CONCRETE UNDER DIFFERENT TEMPERATURE CONDITIONS

Mohamed Alfitouri Masoud 1) Mohamad Solikin 2) Yenny Nurchasanah 3)  
Student, Postgraduate Civil Engineering Program Muhammadiyah University of Surakarta (2014-2015), Jl. A. Yani Tromol Pos I Pabelan Surakarta 57102; Telp. 0271-730772 Indonesia  
Email: mohahmeed85@yahoo.co.uk

Abstract – The aim of this study is to investigate the strength and modulus of elasticity progress of steel fiber reinforced concrete under different temperature condition on difference fibers volume fractions: 1) to analyze the compressive strength and modulus of elasticity of steel fiber reinforced concrete on volume fractions of 1% fiber at three temperature levels of 200°C, 400°C and 600°C; 2) to analyze the compressive strength and modulus of elasticity of steel fiber reinforced concrete on volume fractions of 1.5% fiber at three temperature levels of 200°C, 400°C and 600°C; and 3) to analyze the comparison of the compressive strength and modulus of elasticity at concrete without fibre on the same temperature. This study will compare the compressive strength and modulus elasticity between plain concrete and SFRC containing various volume fraction of steel fiber as reinforcement on elevated temperature heating up to 600°C is subjected to some concrete and SFRC specimen. Material test aims to find out the quality of the material before making the concrete specimen. In this study conduct kinds of test, i.e. 1) Basic Material Test; 2) Compressive Strength; and 3) Modulus of Elasticity. The data analysis was conducted after testing of a specimen by comparing and analyzing the data obtained. The tests was performed compressive test and modulus of elasticity. From the research findings can be concluded that 1) The addition of 1% and 1.5% steel fiber in concrete mix is advantageous for concrete; 2) Overall the compressive strength of concrete was increased as the percentage of steel fiber in concrete increases. Up to 1.5% , Steel fiber reinforced concrete showed a better overall residual strength and better crack resistance than non-fiber concrete; 3) The carbonation process for concrete with steel fiber is a little influenced by temperature compare to concrete without steel fiber; and 4) The concrete with 1.5 % steel fiber demonstrated the highest compressive and modulus of elasticity value, 23.5 and 17172 MPa at 600°C respectively. It is expected that in future concrete having steel fiber will act as a fire protective considerably.

Keyword: Compressive Strengths, modulus of elasticity, steel fiber

I. INTRODUCTION

Concrete is widely used as a primary structural material in construction due to numerous advantages, such as strength, durability, ease of fabrication, and non-combustibility properties, it possesses over other construction materials. Concrete structural members when used in buildings have to satisfy appropriate fire safety requirements specified in building codes (ACI 216.1, ACI-318, EN 1991-1-2, EN, 1992-1-2). This is because fire represents one of the most 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.

Exposure to elevated temperatures which is mainly caused by accidental fire, represents one of the more severe exposure conditions of buildings and structures. The fire resistance and
post heat exposure behavior of structural members depend on thermal and mechanical properties of the materials composing these members. Elasticity is one of the major material properties which play an essential role in the structural behavior of reinforced concrete members both before and after high temperatures exposure (Shallal, 2007).

Concrete is available in various forms and it is often grouped under different categories based on weight (as normal weight and light weight concrete), strength (as normal strength, high strength, and ultrahigh strength concrete), presence of fibers (as plain and fiber-reinforced concrete), and performance (as conventional and high performance concrete). Fire safety practitioners further subdivide normal-weight concretes into silicate (siliceous) and carbonate (limestone) aggregate concrete, according to the composition of the principal aggregate. Also, when a small amount of discontinuous fibers (steel or polypropylene) is added to a concrete batch mix to improve performance, this concrete is referred to as fiber-reinforced concrete (FRC). In this section, the various properties of concrete are mainly discussed for conventional concrete. The effect of strength, weight, and fibers on properties of concrete at elevated temperatures is highlighted (Kodur, 2014).

Traditionally, the compressive strength of concrete used to be around 20 to 50 MPa, which is classified as normal-strength concrete (NSC). In recent years, concrete with a compressive strength in the range of 50 to 120 MPa has become widely available and is referred to as high-strength concrete (HSC). When compressive strength exceeds 120 MPa, it is often referred to as ultrahigh performance concrete (UHP). The strength of concrete degrades with temperature and the rate of strength degradation is highly influenced by the compressive strength of concrete (Kodur, 2014).

Fiber reinforced concrete (FRC) may be defined as a composite materials made with Portland cement, aggregate, and incorporating discrete discontinuous fibers. Now, why would we wish to add such fibers to concrete? Plain, unreinforced concrete is a brittle material, with a low tensile strength and a low strain capacity. The role of randomly distributes discontinuous fibers is to bridge across the cracks that develop provides some post-cracking “ductility”. If the fibers are sufficiently strong, sufficiently bonded to material, and permit the FRC to carry significant stresses over a relatively large strain capacity in the post-cracking stage (Chan).

As with any other type of concrete, the mix proportions for SFRC depend upon the requirements for a particular job, in terms of strength, workability, and so on. Several procedures for proportioning SFRC mixes are available, which emphasize the workability of the resulting mix. However, there are some considerations that are particular to SFRC. In general, SFRC mixes contain higher cement contents and higher ratios of fine to coarse aggregate than do ordinary concretes, and so the mix design procedures the apply to conventional concrete may not
be entirely applicable to SFRC. Commonly, to reduce the quantity of cement, up to 35% of the cement may be replaced with fly ash. In addition, to improve the workability of higher fiber volume mixes, water reducing admixtures and, in particular, superplasticizers are often used, in conjunction with air entrainment (Chan).

The use of spread steel fiber wires can be considered as a solution to control cracking and to increase the strength and ductility of concrete. Since the exposure to high temperature causes different changes in concrete, which lead to the initiation and opening of many cracks, this study was directed to investigate the influence of steel fibers on the elastic modulus of concrete after high temperature exposure (Shallal, 2007).

II. LITERATURE REVIEW

Concrete is a construction material composed of cement as well as other cementations materials such as fly ash and slag content, aggregate (generally a coarse aggregate such as gravel, limestone, or granite, plus a fine aggregate such as river sand), water, and chemical admixtures.

In the development, many found new of concrete modified, such as lightweight concrete, fiber concrete, high strength concrete, self-compacted concrete, etc. Recently, concrete is a building material that is most widely used in the world. Some advantages of concrete are: 1) Able to withstand the compressive force well and resistant to corrosion; 2) Fresh concrete can be casted as desired; 3) Resistant to disintegration and high temperature; and 3) Low maintenance cost.

Since ancient times the fiber increases the physical properties of a reference. For example, in ancient times the fiber is made of straw or horsehair that serves to improve the properties of the bricks on the building. Initially steel fiber was mostly used as a substitute for secondary reinforcement or for crack control in less critical parts of construction. Expected fibers as reinforcement in concrete can be used as a partial replacement for reinforcement on the details of specific structural elements, retaining dynamic loads such as earthquakes, vibrations in the structure of the transport, machinery foundations, as well as fluctuations in wave loads on offshore structure.

Concrete fiber is a concrete that is made by adding fibers on the mixture. The purpose of adding fibers is to increase the tensile strength of concrete, so the concrete can resist to tensile strength due to the weather, climate change and temperatures which typically occur in concrete with an extensive surface. The type of fiber that can be used in concrete fibers can be natural fibers or artificial fibers.

As mentioned before, the concrete is a strong material for concrete compressive load on normal, especially where relatively low strength of cement paste on to the aggregate strength.
Concrete structures may be exposed to high temperatures at which deterioration of concrete occurs. Exposing concrete to high temperature causes strength deterioration, increase in drying shrinkage, reduction in bond strength with reinforcement and increase in the risk of reinforcement corrosion due to high permeability and cracks.

Damage to concrete structural elements during a fire is generally caused by a large cavity filled with air inside the concrete with water vapor or other gas species (which reached 5% - 7.5% of the volume of concrete). Concrete is expanding due to an increase in temperature. Expansion is not balanced by the volume of air voids that exist. This leads to high pressure within the cavity which causes cracks or a burst to drain the water vapor and gases out of the concrete.

III. RESEARCH METHODOLOGY

Material

Steel fibers are usually made of metallic fibers or carbon steel and used as concrete reinforcement to improve the ductility of concrete as well as the form of flexural shear reinforcement. Dramix® steel fibers, from industry specialist Bekaert, have set a new standard for concrete reinforcement with their unique combination of flexibility and cost-efficiency. Dramix RC 80/60 BN is the steel fiber that will be used in this experiment with 60 mm in length, 0.75 mm in diameter and aspect ratio (l/d): 80. The tensile strength is minimum of 1050 N/mm². The fiber will be collected from a factory that is located in Jakarta.

Concrete is primarily consisting of Portland cement, aggregate (fine and coarse), and water. In general it's best to keep it simple, since more ingredients can make it more difficult to control. The cement and water form a paste that coats the aggregate and sand in the mix. The paste hardens and binds the aggregates and sand together. Portland Cement Pozzolan (PPC) was used in this experiment.

Concrete Mixed Design

Three series of concrete mixes will be cast using Portland cement, local sand and local gravel with a maximum size of 20 mm. The mix combination will consist of following ratio: 1 cement (1): sand (1.4): gravel (2.4) by weight, and water/cement ratio of 0.5. The main differentiation between the three series is the volume fraction of steel fiber. Series A, B and C specimens will be cast using fiber (0%, 1% and 1.5%) by volume is added respectively. The used steel fiber is Dramix RC 80/60 BN, and with nominal ultimate strength of 30 MPa.

Fiber reinforced concrete will be mixed according to the fifth mixing procedure of ACI 544. Twenty-four hours after casting, the specimens will be stripped from the mold and placed in water containers to be cured for fourteen days. Then after, the specimens will removed
from the water containers and left in the laboratory environment until the time of heating at the age of twenty-eight days. Cylinders with 150 mm diameter and 300 mm length will be tested for both compressive strength according to ASTM C39-86 and static modulus of elasticity according to ASTM C469-87.

The specimens will be heated to three temperatures of (200°C, 400°C and 600°C). The cylinders will be used for compressive strength and modulus of elasticity test at each temperature from each series. Also, two specimens will be used for each test from each series at room temperature as reference specimens.

To control the temperature a thermocouple will be used. A thermocouple is a sensor for measuring temperature. It consists of two dissimilar metals, joined together at one end. When the junction of the two metals is heated or cooled a voltage is produced that can be correlated back to the temperature. The thermocouple alloys are commonly available as wire. The material requirement for 1 m$^3$ and 1 mixture of 5298.75 cm$^3$ volume shows in table 1.

Table 1 Material requirement for 1 m$^3$ and 1 mixture

<table>
<thead>
<tr>
<th>Volume</th>
<th>Weight (kg)</th>
<th>Water (l)</th>
<th>Cement (kg)</th>
<th>Fine Agg. (kg)</th>
<th>Coarse Agg. (kg)</th>
<th>Steel Fiber (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 m$^3$</td>
<td>2276</td>
<td>177</td>
<td>354</td>
<td>654.375</td>
<td>1099.625</td>
<td>78.5</td>
</tr>
<tr>
<td>1 mixture</td>
<td>12.06</td>
<td>.938</td>
<td>1.876</td>
<td>3.47</td>
<td>5.82</td>
<td>.416</td>
</tr>
<tr>
<td>60</td>
<td>723.6</td>
<td>56.28</td>
<td>112.56</td>
<td>208.2</td>
<td>349.2</td>
<td>24.96</td>
</tr>
</tbody>
</table>

Volume of 1 specimen (cylinder of 150mm x 300mm)

Analysis

The compressive strength of the concrete will be obtained using the procedures in ASTM C39. The modulus of elasticity of the concrete will be achieved using the procedure in ASTM C 469. After the test of compressive strength and modulus of elasticity being conducted the plot of stress and strain will be collected. This data is required for analysis of this research. The analysis of the research will consider with the data that provided or produce from the test. It means that the analysis cannot be done without the data from the test.

Data collection will be noted manually by recording the value that shows both on the compressive test machine and modulus elasticity test machine. Values will be recorded in the form of load, stress, elongation etc. After all the data being collected, the data processing will be executed using a formula in accordance with the data obtained.
IV. RESULT AND DISCUSSION

1. Temperature Test

In this test, the specimen was burned until some specified temperature (200°C, 400°C, and 600°C). From this test can be recognized about the period of time that needed to reach the specified temperature. The specimen burning process was executed after making concrete specimen. Specimens were cured 28 days in water form then they burned directly with specified temperature. The compressive strength and modulus of elasticity test are conducted soon after burning process. The temperature influenced the mechanical and physical properties of material. With increasing the temperature, water in the samples evaporated and changed the structure of concrete. The content (vaporization) of concrete resulted and affected the structure of concrete that consist of particle bonding. The physical properties changing were clearly seen on sample color change due to high temperature.

2. Compressive Strength

Concrete specimens consisted of 1.0 %, 1.5 % and 0 % of steel fiber as reinforcement (SFRC). Table 2 is compressive strength test result of experimental sample with and without SFRC at different temperature. The result of compressive strength showed that the 0% SFRC had the lowest compressive strength. It indicated that the more steel fiber the higher compressive strength are obtained.

The specimen of 0% SFRC was able to resist less load than 1.0% and 1.5 % SFRC, its compressive strength recorded 31.3 MPa. However, when this specimen reached the ultimate stress and started to fall down or break, it cannot resist the form or cannot hold up for long periods and directly crushed to pieces. Table 2 shows the result of compressive strength test at various level of temperature.

Table 2 Compressive strength test result of experimental sample with and without SFRC at different temperature

<table>
<thead>
<tr>
<th>SFRC (%)</th>
<th>Compressive Strength (MPa)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Room</td>
</tr>
<tr>
<td>0%</td>
<td>31.3</td>
</tr>
<tr>
<td>1.0%</td>
<td>34.7</td>
</tr>
<tr>
<td>1.5%</td>
<td>39.2</td>
</tr>
</tbody>
</table>
Figure 1 Compressive strength test result of experimental sample with and without SFRC at different temperature

From table 2 it can be seen that with the increasing of temperature the compressive valued was decreased in all cases i.e concrete with and without steel fiber. Nevertheless, the sample containing steel fiber rate of declining was less than the sample without having steel fiber. As a result, overall the value of compressive strength was increased due to the addition of steel fiber.

The result of this study has the similarity with the research carried out by Lau in 2003. He concluded that steel fiber is beneficial to concrete exposed to high temperatures up to 1200°C confirming that 1 percent steel fiber is of no disadvantage if concrete is subjected to a fire. After concrete exposure to high temperature, steel fiber reinforced concrete shows a higher overall residual strength and better crack resistance than non-fiber concrete.

Likewise, the effects of elevated temperatures on the compressive strength stress –strain relationship (stiffness) and energy absorption capacities (toughness) of concretes were presented by Poon et al., 2004. High-performance concretes (HPCs) were prepared in three series, with different cementitious material constitutions using plain ordinary Portland cement (PC), with and without metakaolin (MK) and silica fume (SF) separate replacements. Each series comprised a concrete mix, prepared without any fibers, and concrete mixes reinforced with either or both steel fibers and polypropylene (PP) fibers. Their results showed that after exposure to 600 and 800°C, the concrete mixes retained respectively, 45% and 23% of their compressive strength, on average. The results also show that after the concrete was exposed to the elevated temperatures, the loss of stiffness was much quicker than the loss in compressive strength, but the loss of energy absorption capacity was relatively slower. Steel fibers approximately doubled the energy absorption capacity of the unheated concrete. They were effective in minimizing the degradation
of compressive strength for the concrete after exposure to the elevated temperatures. The steel-fiber-reinforced concretes also showed the highest energy absorption capacity after the high-temperature exposure, although they suffered a quick loss of this capacity.

Shallal in 2007 concluded their result that the compressive strength of both plain and fiber reinforced concretes, decreased in similar fashion after exposure to elevated temperatures. However, the use of 1.0% of steel fibers enhanced the compressive strength at 500°C by about 16.5% compared to plain concrete at the same temperature.

### 3. Modulus Elasticity

The function of Steel fiber function is to hold up or to resist the load and transfer the energy to the entire surface. It was showed by the number of modulus elasticity. When the specimen were suffered by the load and reached the ultimate stress, the concrete experienced the crack or fracture for some period before crushed to pieces. This is due to the steel fiber resist once in concrete and there is a good bonding between matrix and reinforcement that lead crush occurred slowly. The Table 3 shows the result of modulus elasticity test.

<table>
<thead>
<tr>
<th>SFRC (%)</th>
<th>Modulus Elasticity (MPa)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Room</td>
</tr>
<tr>
<td>0%</td>
<td>27094</td>
</tr>
<tr>
<td>1%</td>
<td>30103</td>
</tr>
<tr>
<td>1.5%</td>
<td>32954</td>
</tr>
</tbody>
</table>

Table 3 Modulus elasticity of experimental sample with and without SFRC at various temperature

![Figure 2](image_url) Modulus elasticity of experimental sample with and without SFRC at various temperature
From the table 3 and figure 2 it can be reported that the effect of modulus of elasticity of concrete is almost as same as compressive strength for concrete with and without steel fiber. As temperature increases, the modulus of elasticity becomes reduced. However, the sample with steel fiber still higher than the sample without having steel fiber. Consequently, overall the value of modulus of elasticity was increased due to the addition of steel fiber. The highest modulus elasticity was found at 1.5% SFRC in case of all specimens.

Shallal in 2007 found that modulus of elasticity of concrete decreases as temperature increases. The test results of this study completely confirm this result. The use of steel fibers, improved the elastic modulus of concrete at normal temperature. The modulus of elasticity increased by about 29% when 1.0% of fiber was used. Besides, the modulus of elasticity of both plain and fiber reinforced concrete decreased as temperature increase by amounts depending on temperature level at 150 °C and 350 °C. The percentage residual modulus of elasticity of fiber reinforced concrete is little higher than of plain concrete.

According to Lau in 2006 it can be noted that fiber reinforcing concrete has higher strength and better performance in fracture or crack resistance after exposure to high temperature while high performance concrete can tolerate high temperature, below 600°C, than the normal strength concrete without spalling. Besides he also reported that the behavior of concrete structure is often dependent on the modulus of the elasticity of the concrete, and his experimental result showed that this modulus is strongly affected by exposure temperature. The reduction of static modulus of elasticity progressed sharply between maximum exposure of 300 and 800°C.

The research carried out by Swamy in 1992 showed that in the temperature range of 25°C to 400°C, the loss in strength of concrete decreased slightly. At temperature between 400°C to 600°C the strengths of concrete declined sharply and reached their lower limits. These researchers further concluded that fiber reinforced concrete has better performance in resisting high temperature than plain concrete.

The research was also reported that a fiber content higher than 1.5% by volume of concrete, the improvement in mechanical properties may be insignificant or reduced. It was found that the reduction in mechanical properties of plain concrete due to exposure high temperature is higher than concrete specimen incorporated with fibers. A distinct loss in mechanical properties was reported after heating to 600°C. The report showed that SFRC beams exhibited higher flexural rigidity, initial cracking loads and ultimate loads than those without steel fibers. It was found that the color of the concrete darkened after exposure to a temperature of 400°C for 4 to 6 hours duration time.

Hannant in 1978 remarked that although steel fiber may not offer any obvious advantage from a fire-endurance points of view, however results have shown that steel fibers can delay the
occurrence of cracking due to strong bond strength and hence potentially improve the performance of concrete after exposure to high temperatures.

By all the test result can be concluded that the highest concrete strength (compressive strength) and the highest modulus elasticity was found in concrete with 1.5% of steel fiber. This is caused by the ability of steel fiber that can transfer and distribute the load well. As a result, the concrete component can resist more of destruction energy. On the other hand, burning or giving the temperature more on concrete will decrease the properties and ability of concrete especially on mechanical properties of concrete.

4. Carbonation test

Carbonation of concrete is a chemical reaction where atmospheric CO$_2$ diffuses into the pore system of concrete through the pores of concrete and causes changes into the chemical composition of concrete. In carbonation the carbon dioxide reacts principally with calcium hydroxide to form calcium carbonate. The calcium hydroxide is not the only substance that reacts with CO$_2$, the other hydration products and even the residual unhydrated cement compounds also take part into carbonation reactions. Due to carbonation, the alkalinity of the pore fluid drops from a pH value exceeding 12.6 to a value about of 8.0 (Varjonen, 2004).

Table 4 Effect of temperature on the depth of Carbonation

<table>
<thead>
<tr>
<th>SFRC (%)</th>
<th>Length of Carbonation (cm)</th>
<th>200°C</th>
<th>400°C</th>
<th>600°C</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td></td>
<td>1.5</td>
<td>2.5</td>
<td>3</td>
</tr>
<tr>
<td>1</td>
<td></td>
<td>1.2</td>
<td>2</td>
<td>2.5</td>
</tr>
<tr>
<td>1.5</td>
<td></td>
<td>1</td>
<td>1.5</td>
<td>2</td>
</tr>
</tbody>
</table>
From Table 4 and Figure 3, it can be seen that as temperature goes up, the depth of carbonation becomes increased. It is more prominent for concrete without steel fiber compared to concrete with steel fiber. The effect of temperature on carbonation can be explained from the compressive strength point of view. With the decreasing of compressive strength, the length of carbonation has been increased in case of both normal and SFRC or vice-versa. As earlier in this research, it was found that as temperature increases, the compressive strength was reduced at normal as well as SFRC conditions.

The carbonation test result of this research has the similarity with previous carbonation test result. Chi and co-workers in 2002 carried out an experimental investigation to study the effect of carbonation on mechanical properties and durability of concrete, where they found the depth of carbonation decreases with an increase in compressive strength. According to their opinion, this approach appears to be very logical, since both carbonation and compressive strength are significantly controlled by the pore structure of concrete.

Wang in 2014 used the mixing amount of steel fiber (0, 0.5, 1.0, 1.5, and 2.0%) to influence the carbonation depth of concrete. The results demonstrated that appropriate amount of steel fiber can impede the speed of concrete carbonation; the concrete carbonation speed is the slowest when the fiber content is 1.5%, and the carbonation speed is accelerated when the fiber content is increased to 2%.

Likewise, Fattuhi in 1986 and Wierig in 1984 pointed out that the depth of carbonation decreases with increasing compressive strength for all types of concrete, but these relations depend on the type of cement and curing.

Indeed, carbonation is one of the major factors to cause structure deterioration. The basic factor influencing carbonation is the diffusivity of the hardened cement paste. Carbonation rate is controlled by the ingress of CO₂ into concrete pore system by diffusion with a concentration gradient of CO₂ acting as the driving force. Factors affecting diffusion rate include the type and
amount of cement, porosity of the material, time of curing, type and quantity of pozzolanic additions. Moreover, several mechanical properties of concrete such as compressive strength, surface hardness and resistance to aggressive agents may change due to carbonation (Chi et al., 2002).

V. CONCLUSION AND SUGGESTION

1. Conclusion

The research findings of this study is concluded that
1. The addition of 1% and 1.5% steel fiber in concrete mix is advantageous for concrete.
2. Overall the compressive strength of concrete was increased as the percentage of steel fiber in concrete increases. Up to 1.5%, Steel fiber reinforced concrete showed a better overall residual strength and better crack resistance than non-fiber concrete.
3. The carbonation process for concrete with steel fiber is a little influenced by temperature compare to concrete without steel fiber.
4. The concrete with 1.5% steel fiber demonstrated the highest compressive and modulus of elasticity value, 23.5 and 17172 MPa at 600°C respectively. It is expected that in future concrete having steel fiber will act as a fire protective considerably.

2. Suggestion

To continue this study with better output, this research need to some more consideration that can included following ways
1. Special care is required in translating observations on laboratory – made concrete specimens into useful information on full structures. For instance, the behavior of elements of concrete in a real fire is highly complicated and the inner section of a heavy member differently affected from outer areas.
2. To further understand the microstructure of concrete after exposure to high temperature it is suggested to study also the decomposition changes due to heating before and after the sintering process. To investigate the cracking situation, Scanning Electron Microscopy (SEM) or X-ray Diffraction (XRD) tests are required.
3. The usage of steel fiber with shorter dimension so that the load may be spread all over the structure and the bond between mortars become stronger.

REFERENCES


ACI-318, Building Code Requirements For ReinForced Concrete and Commentary, American Concrete Institute, Farmington Hills, Mich, USA, 2008.


Wang, Y., Experimental Study on Carbonation of Steel Fiber Reinforced Concrete, 4th International Conference on the Durability of Concrete Structures, Purdue University, West Lafayette, IN, USA, 24–26 July 2014.