Experimental Study of Hybrid Fiber Reinforcement In Self Compacting Concrete Subjected To Elevated Temperatures

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Abstract- *Concrete, the term and the material is one of the universal material which is widely used across the world. For so many years, the problem was to make concrete durable and increase the strength and environmental friendly without altering cement quantity. To achieve this, it requires proper compaction which in return requires more number of skilled labours. However, there is adequacy of such labours in the industry which affects the quality and durability. In order to fill the gap, the researchers came with new concept by altering the material quantity and found new type of concrete called as Self-compacting concrete (SCC). To increase the strength and resist the cracks, fibers were introduced hence calling it Fiber reinforced self –compacting concrete (FRSCC).*

This FRSCC is mixture of fibers such as steel fibers, glass fibers or Polypropylene fibers and self-compacting concrete where the SCC is prepared by increasing the paste quantity in the concrete mixture. Alternatively, the cement is also replaced by the by-products such as fly ash, GGBS which finds applications in the concrete making it more environmental friendly. Previous studies are lacking in the study of behavior of this hybrid concrete in terms of strength and durability at elevated temperatures. In this study, an attempt is made to fill the gap. The main purpose of this study was to evaluate and understand the strength and durability of the produced concrete at elevated temperatures. To achieve this aim, the concrete of M-40 grade was prepared by replacing the cement with 30% fly ash and GGBS. Nansu method of concrete mix was used to produce the SCC.

To this, steel fibers and PPF were added in percentages of 0.5% respectively making FRSCC. Cubes and cylinders were cast and kept for curing for period of 3, 7, 28 and 56 days at room temperatures. The 28 and 56 days cured specimens were then removed and subjected elevated temperatures of 400 and 600ºC respectively. The specimens were then tested for strength in compression and tensile for 28,400 and 600ºC. Similarly, the specimens were cast for the same grade for ordinary Portland cement concrete with admixtures to measure the above mentioned strength and durability properties.

The experimental results indicate that, the steel fibers in SCC improved the strength factors both in compression and tensile while combination of both SF and PPF didn't make any difference when compared with control specimens. The concrete was not durable at elevated tempertaures making it more stronger in between temperatures of 28ºC to 200ºC. In addition to this, the mixes with GGBS were stronger than the fly ash and OPC mixed specimens proving it to be more durable and environmental friendly.

Keywords- FRSCC, steel fibers, Polypropylene fibers(PPF), fly ash, GGBS, OPC.

I. INTRODUCTION

Concrete, the term and the material is one of the universal material which is widely used across any part of the world. Its type of homogeneous mixture which plays an eminent role in the progression of infrastructure as well as in developing new inception of the structures that helped people to create gigantic monuments. For so many years, the problem was to make the concrete durable as well as increase the strength without altering the quantity of cement and to make it environmental friendly across the world. Many Research works have conducted to make this above properties to happen. In order to create durable concrete, it requires the proper compaction of the concrete in the concrete members. To achieve that more number of skilled labours are required at the construction field. However, there is adequacy in the skilled labours across the globe hence, which directly affects the quality of the concrete making it less durable. Each day, the research have been carried out on how to enhance this performance in many ways for durability criteria. One such progression led to create a self-compacting concrete which requires less skilled labours.

Earlier since 1983, there was problem in Japan country with the same problem of durability of concrete structures. For the improvement in the construction industry, there was necessity of skilled labours for placing and compacting this concrete to obtain the necessary durability, but there was adequacy in the availability of these skilled labours so it was not possible to achieve the required development in the construction industry. Therefore, there was requirement of revolution in the construction industry to achieve this goal. In this regard, Nan Su et.al. in the year 2001 introduced the methodology for SCC.

This developed SCC was derived using required quantity of coarse aggregate which are examined and paste of the cement is mixed with those so that the concrete develops the character of compactaility, flowability and other properties of SCC. To check these properties, the concrete was forced to undergo different tests to concrete in fresh state & strength in compression and tension etc. for concrete in hard state and the results collected indicated that the approach gave highly positive results for the SCC.

The research did not restrict to the production of SCC, there was adequacy to develop the concrete which should possess more hardness, toughness, strength in flexure, tension and compression and ductility. In order to attain these characters, the research was carried out to increase these property of the concrete keeping in mind the durability of it. Hence, the technology developed to embed the fibers into the concrete to achieve the above said properties which led to the invention of the one more type of concrete i.e. Fiber reinforced concrete. It is that concrete where the fibers are spread through the dimension of the concrete matrix. These fibers improve the stress distribution and also the toughness, crack width of the produced concrete.

Fiber reinforced Self-compacting concrete (FRSCC):

Cement, mineral admixture, chemical admixture, various sizes of coarse aggregates and use of fibers to produce the FRSCC. The concrete can be defined as, the one in which fibers are oriented and dispersed randomly in matrix of concrete. Concrete which is brittle in nature when subjected to tensile load can be improvised by the use of these oriented discrete fibers which help in controlling the brittleness and controlling of the continuation of cracked surface. The introduction of such material definitely aid in the improvisation of many properties like toughness, resistance to fatigue, reducing the spalling, improvisation of resistance to abrasion, shear and flexural strength. The aspect ratio, configuration, fiber type and volume fraction becomes the governing properties of fibers in establishing the more durable and mechanically stable concrete.

Advantages Of FRSCC:

The advantages of FRSCC are listed below:

- The concrete with these fibers increase the flexural strength, improves the abrasion, resistance of impact load, spalling making it concrete more durable.
- Use of these fibers helps in reduction of nominal reinforcement in the concrete which further helps in reduction of section, leads to some of the productivity related improvements.
- They help in delivering cost effective concrete which helps in cost savings of the project, rapid construction and reduced costs for labour.
- The crack free accommodation stress happens inside the matrix of the concrete. Therefore, the micro cracks are stopped before they are going to develop and help in good performance.

Disadvantages Of FRSCC:

- Use of some of the fibers makes the concrete little heavy than normal concrete which in turns increase the specific gravity.
- The cost of raw material is high hence the concrete production becomes high.
- Right quantity of fibers has to be used i.e. proportioning of the fibers. If this is not satisfied then there will be more changes in the strength of the concrete.
- In case of steel fibers, there is a little problem associated with rusting of fibers which reduces the higher performance level of the concrete.

Applications Of FRSCC:

Following are the some of the applications of the FRSCC

- It finds its application in construction of highway pavements, airport runways, bridge deck overlays, spillways.
- It can be used to construct spillways, dams and many other precast products.
- This concrete can be used to construct the factories, warehouses, hangers of aircraft.
- It can also be used in the construction of residential and commercial slab and beams, parking areas and tunnels.

II. METHODODLOGY

The current chapter deals with the ingredients, their chemical and physical properties, extraction and the tests conducted on them. Additionally. It deals with the specimen preparation, concrete mixing, and casting into different specimens, curing of the specimens, subjecting them to higher temperatures and then testing them under different conditions.

MATERIALS:

The subsequent different materials that are used to prepare the sample and conduct the experiment for the proposed objectives:

- Ordinary Portland Cement (OPC)
- Fine aggregate
- Coarse aggregate
- Mineral Admixture
  - Fly ash: The fly ash used belongs to class F type of fly ash where it is having lime content less than 5%. Its specific gravity is 1.85 and fineness is 8.5%.
  - GGBS: The GGBS used is obtained from RMC plant having its specific gravity 2.55 and fineness 1.8%.
- Fibers reinforced
  - Steel fibers: The steel fibers were ASTM A820 type-I 50mm in length, 0.75mm thickness having aspect ratio of 50 and tensile strength 1000MPa.
  - Polypropylene Fibers:
- Chemical Admixture: For the Present study, Conplast SP 430 is used as superplasticizers which is SulphonatedNaphthanene Polymers. The color is brown and has an immense property that is very easily dispersible in the water. Nearly a 30% of reduction in the water is achieved without any loss in the concrete workability.
- Water: The normal potable water is used for the preparation of fresh concrete mix and then later for the process of curing of specimens.

MIX DESIGN:

Table 1 – Obtained values of mix and comparison with EFNARC standards

Contents	EFNARC Ranges	Obtained Values	Remarks
Powder	380-600	508.70	OK
Fine Aggregate	48-55% of Total Aggregate	964	OK
Coarse Aggregate	750-1000	766	OK
Water	150-230	223.73	OK

Table 2 – Mix proportions of the produced SCC of M-40 Grade

W/C	Powder Content (Cement+Fly ash)	Coarse Aggregate	Fine Aggregate
0.45	508.70	766	964
0.45	1	1.51	1.90

SPECIMEN PREPARATION:

No. of Specimens: The optimum content for the reinforcing fibers also found out by some journal paper reference and conducting the trail tests. Considering all these material specification 150X150X150mm size cubes and 150mm Ǿ and 300 mm in height cylinders are casted for the following mentioned mixes:

- Control Specimens (CS):

Mix 1: OPC 100% – CS1
Mix 2: OPC 70% + Fly ash 30% – CS2
Mix 3: OPC 70% + GGBS 30% – CS3

- With reinforced Steel Fibers (SF):

Mix 1: OPC 100% + 0.5% SF – S1
Mix 2: OPC 70% + Fly ash 30% + 0.5% SF – S2
Mix 3: OPC 70% + GGBS 30% + 0.5% SF – S3

- With both reinforced Steel Fibers (SF) and polypropylene fibers (PPF):

Mix 1: OPC 100% + 0.5% SF – P1
Mix 2: OPC 70% + Fly ash 30% + 0.5% SF + 0.5% PPF – P2

Mix 3: OPC 70% + GGBS 30% + 0.5% SF + 0.5% PPF – P3

Mixing and Concrete Casting:

Before casting the concrete all the moulds should be dust free and free from any moisture content the surface of the moulds should be applied with one coat of caster oil. The following steps are followed to mix the concrete:

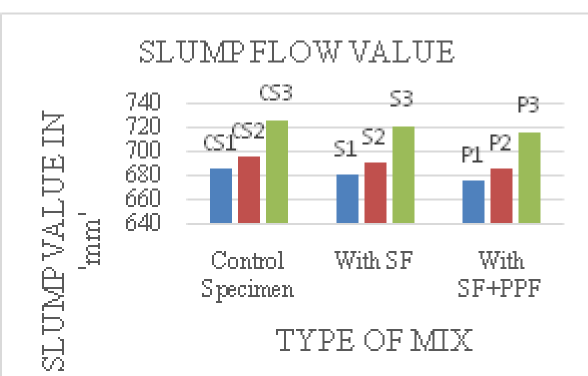
- The FRSCC can be produced just like the normal OPC concrete. Same technique can be utilized here in mixing
- The mixing can be done by hand mixing.
- The binders, fine aggregate, coarse aggregate are well mixed for about 3+ minutes. On the mixture pan.
- Later, the SP-430 super plasticizer is proportioned by weight of cement and is added to the water.
- The water with superplasticizer dosage is then added to this mixture and mixed well for about 3-5 minutes.
- The fresh concrete will be usually cohesive and flowable. To know the fresh concrete properties different tests are conducted for each type of mix which are explained later under this chapter.
- This mixed concrete is then poured into the moulds of cube and cylinder.

Curing of the Specimens:

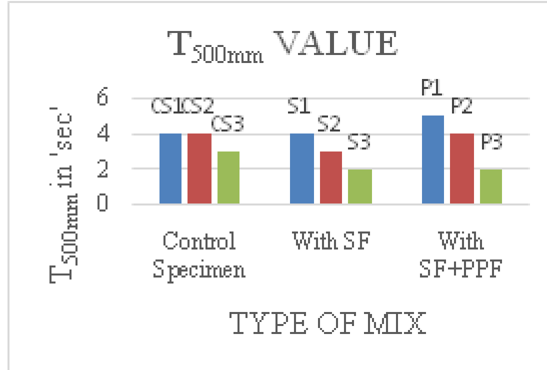
After casting, the specimens are maintained in the mould for minimum hours of 24 and then later they are demoulded and are kept for the curing in the water tank where the potable water is maintained. The specimens are named with designation and casting date and each set of specimens are kept for 3, 7 and 28 days respectively to achieve the required strength.
Testing on the Concrete

III. RESULTS & DISCUSSIONS

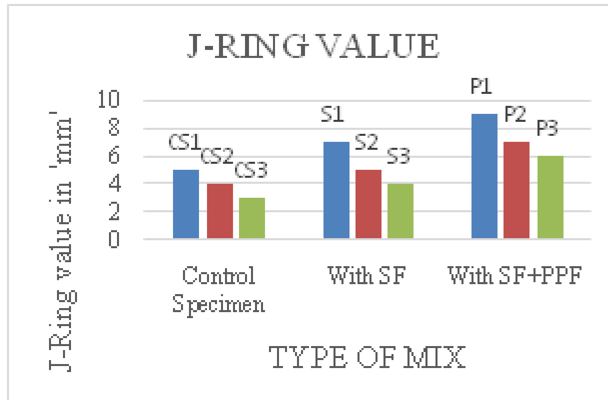
Results of Fresh concrete:



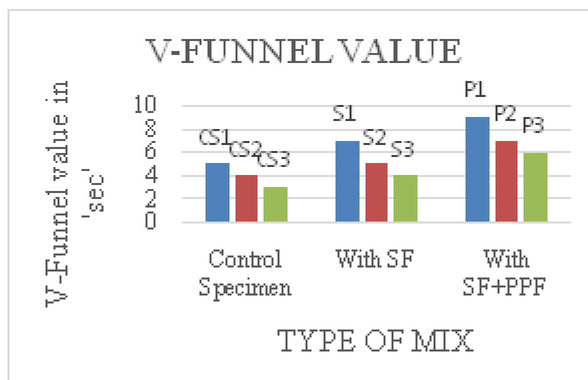
Graph 1 – Slump Flow value of different concrete mix



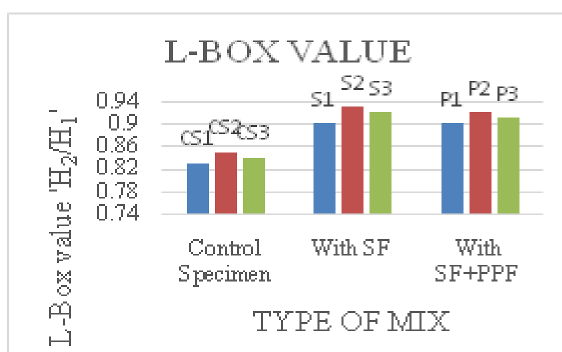
Graph 2 – T_{500mm} value of different concrete mix



Graph 3 – J-Ring value of different concrete mix



Graph 4 – V-Funnel value of different concrete mix

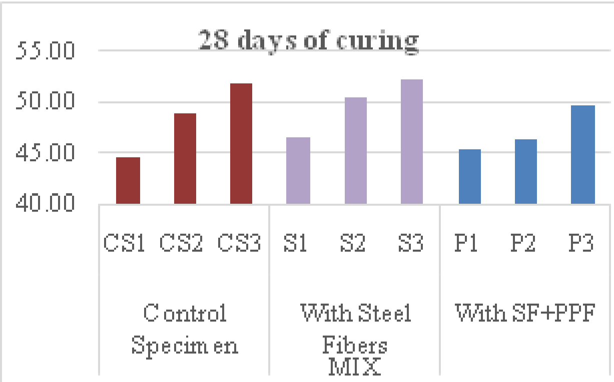


Graph 5 – L-Box value of different concrete mix

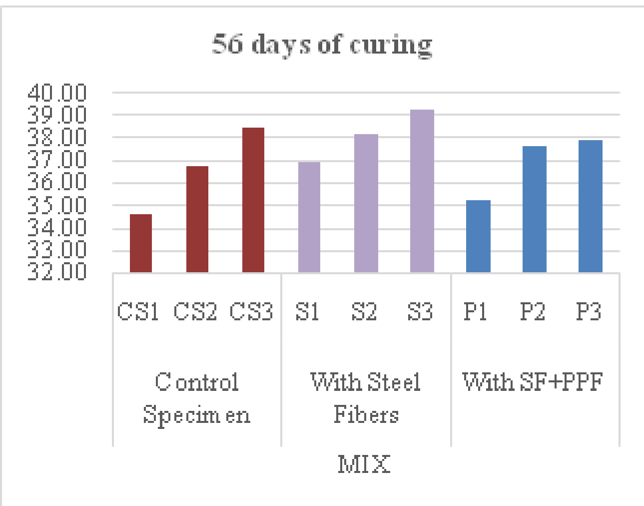
Results of Hardened concrete:

Cube Compressive Strength:

Compressive strength at Normal Room Temperature:

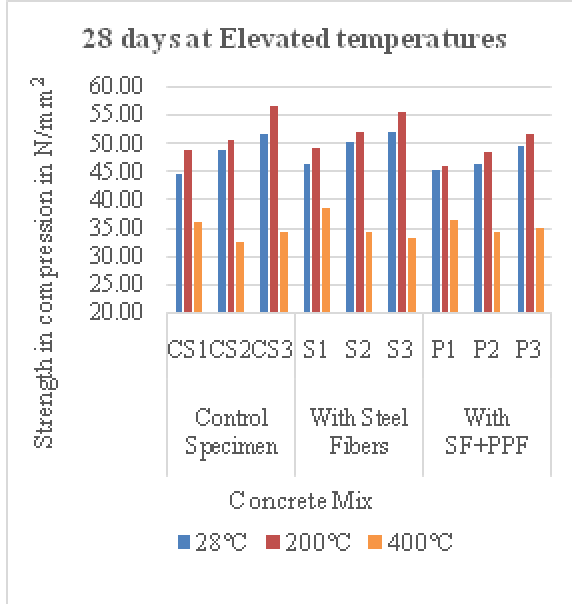


Graph 6 – Strength in compressionof different mix for curing period of 28 days

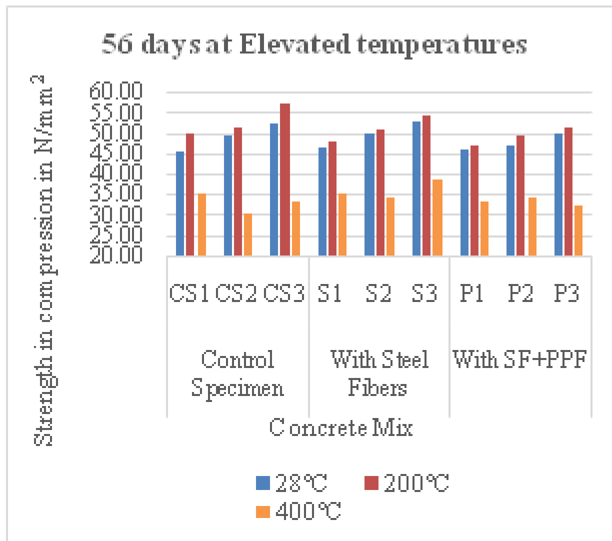


Graph 7 – Strength in compressionof different mix for curing period of 56 days

Compressive strength at Elevated Temperature:



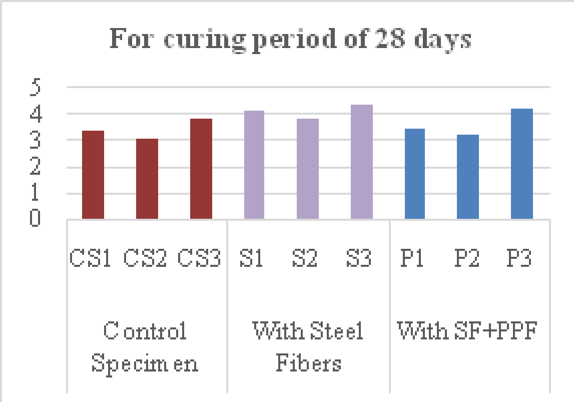
Graph 8 – Variation of strength in compression at elevated temperatures for 28 days of curing



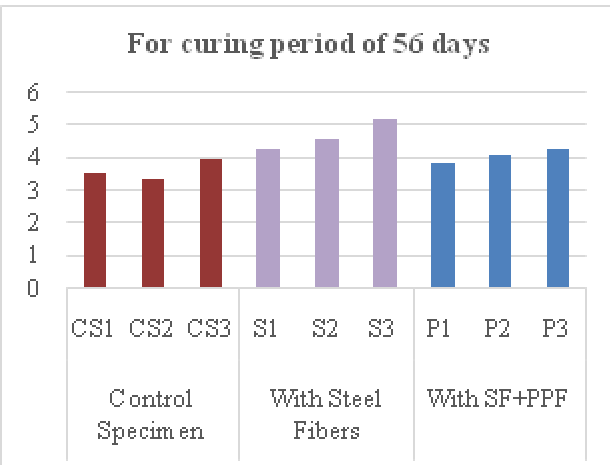
Graph 9 – Variation of Compressive Strength at elevated temperatures for 56 days of curing

Split Tensile Strength:

Split Tensile Strength at Normal Room Temperature:

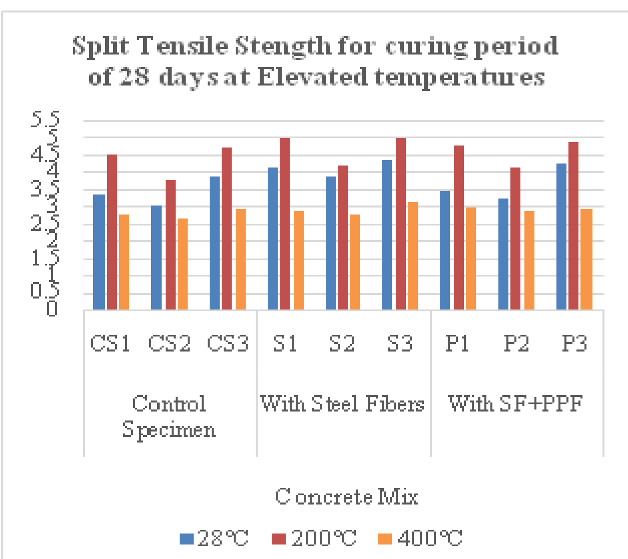


Graph 10 –Splitting Tensile Strength of different mix for 28 days of curing

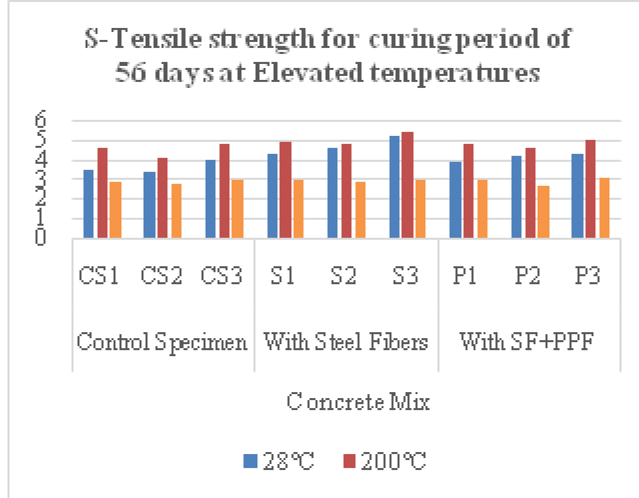


Graph 11 –S-T Strength of different mix for 56 days of curing

S-Tensile strength at Elevated Temperature:



Graph 12 –S-Tensile Strength at elevated temperatures for 28 days



Graph 13 –S-Tensile Strength at elevated temperatures for 56 days

IV. CONCLUSIONS

As per the result obtained, graphs plotted and considerations were made as following important conclusions may be drawn based on the above observations:

- The fresh concrete properties prepared with Steel fibers and Hybrid fibers got decreased while compared with control specimen. Hence, the addition of fibers to SCC has a negative effect for concrete workability.
- The concrete mix method i.eNan su method was successfully adopted for preparing SCC and all the mix proportions were satisfactory and met the guidelines and requirements of EFNARC.
- The strength in compression of the specimens prepared with steel fibers (S1, S2, S3) increased by 10% thereby proving that the FRC has positive effect on the strength of the concrete in compression.
- The strength in compression of all specimens kept under temperature of 200ºC after curing period of 28 days showed improved results by 4% from normal room temperature curing while the concrete lost its strength considerably for 400ºC temperature by average of 30%, making concrete weaker at higher temperature.
- The addition of Poly Propylene fibers along with steel fiber reduced the strength in compression when compared with control specimens. Hence, the addition of PPF with SF has negative effect.
- The Splitting tensile strength of the cylinder specimens prepared with steel fibers (S1, S2, S3) increased by 12% thereby proving that the FRC has

positive effect on the split tensile strength of the concrete.

- The splitting tensile strength of all cylinder specimens kept under temperature of 200ºC after 28 days of curing showed improved results by 6% from normal room temperature curing while the concrete lost its strength considerably for 400ºC temperature by average of 28%, making concrete weaker at higher temperature.
- The addition of Poly Propylene fibers along with steel fiber reduced the Splitting Tensile strength of the concrete when compared with control specimens. Hence, the addition of PPF with SF has negative effect.
- The mix prepared with 30% of GGBS (CS3, S3, P3) showed greater results for strength in compression and tensile compared to 30% of fly ash and 100% cement. Hence, GGBS acts as good puzzolanic material and replacement for cement.

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