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An Experimental Investigation on Effect of Partial Replacement of Cement with Fly Ash and Iron Powder in Self-Compacting Concrete

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ABSTRACT: Self-compacting concrete (SCC) is a modern way of generating concrete which flows and consolidates under its own weight. SCC has many advantages over conventional concrete, it can be used in areas like congested reinforcement, deep concrete placing, availability of less man power and better concrete quality. In SCC, a chemical admixture superplasticizer is used which enhances its properties from conventional concrete. Fly ash is a by-product that is produced at thermal power plants in very large amounts. Only a small amount of this is used in construction materials like bricks, and remaining is left unused. This creates a lot of problem to dispose it in land and is hazardous to environment. Iron powder is one of the by-products from steel industries which has several uses. So, utilization of industrial by-products in concrete reduces its negative impact on environment. The objective of this study is to investigate the properties of SCC which is produced by partially replacing cement with Fly ash and Iron powder with different percentages of weight of cement in concrete. All the flow tests which are mentioned in EFNARC code would be conducted on concrete mixes and also tests like compressive strength, split-tensile strength would be performed. By investigating the results, the behaviour of concrete can be analysed. Finally, the optimum percentage of replacement of fly ash and iron powder would be found out from the results.

KEYWORDS: Self-Compacting concrete (SCC), Superplasticizer, Fly ash, Iron powder, Compressive strength, Split-Tensile strength.

I. INTRODUCTION

Concrete is very commonly used in construction field since many years. The development in concrete technology all over the world is increasing day-to-day. One of the technologies is, "Self-Compacting Concrete". Self-Compacting Concrete (SCC) is a flow-able concrete, which flows under its own self-weight. A conventional concrete requires vibration for compaction of concrete but, SCC does not require any external vibration. The self-compacting concrete is suitable in areas where compaction of concrete is difficult and also in congested reinforcement. The properties of SCC are enhanced by addition of mineral and chemical admixture. An SCC, must possess the following properties:

- (i) Filling ability: the ability of concrete to fill all the corners of the formwork.
- (ii) Passing ability: the ability of concrete to pass the reinforcement.
- (iii) Segregation resistance: the concrete should remain homogeneous before and after placing.

The present scenario in construction shows that there is an increase in construction of large and complex structures, which often results in difficulty of concrete placing. Vibration of concrete in congested reinforcement is difficult, and sometimes also results in segregation. The strength of concrete gets effected due to segregation. So, in order to overcome this problem, the use of SCC is appropriate in such conditions. In countries like Japan, Britain and Sweden the use of SCC is on large scale but in India, the use of SCC is very less. As per the guidelines provided by 'EFNARC' code for SCC mix design, the major difference between the SCC and normal concrete is the use of admixtures. Thus, many studies have been conducted on use of mineral admixtures in SCC and their effects. The studies showed that use of mineral admixtures increased the workability of SCC. Additionally, the mineral admixtures increased fineness of concrete and decreased permeability of concrete. Industrial by-products such as Fly ash, Silica fume, Ground

Granulated Blast-furnace Slag and Copper slag can be used as mineral admixtures in SCC. By use of these industrial by-products concrete cost can be reduced and also environmental pollution can be reduced.

Fly ash is an industrial by-product, produced by the combustion of coal at thermal power plants. The increasing scarcity of raw materials for cement and to decrease environmental pollution by industrial by-products, the use of fly ash in concrete has been significant. Fly ash when used as admixture it improves workability and strength. Fly ash can be either partially replaced with cement or can be added in addition to cement in concrete.

Iron is a natural mineral, which occurs in the earth's crust. Generally, Iron has very high strength properties. In construction of structures like buildings, bridges, dams iron is used as steel reinforcement. Iron powder is produced in iron industries and it as several uses. In the present study the cement is partially replaced with iron powder.

II. LITERATURE REVIEW

Arulsivanantham [1] et al. (2017), has done a review paper on self-compacting concrete which is made using various admixtures and fibres. This paper discusses about the mix design of SCC and the tests to be conducted on fresh concrete, and their acceptance values. In this paper, the need for SCC and its importance is clearly explained. The properties of SCC are also discussed.

S. Mahesh [2] (2014), has conducted a study by replacing cement with fly ash in SCC. In this it has been found that workability of concrete increased with increase of superplasticizer. For 30% replacement of fly ash the properties of fresh concrete were good when compared to other percentages. Viscosity modifying agent (VMA) also plays a significant role in order to reduce segregation. The mechanical properties showed an increase in strength with fly ash in SCC. The concrete was tested for durability and it was very high.

H. Shankar Sanni [3] et al. (2015), conducted a study on self-compacting concrete incorporating fly ash. In the study it was found the use of fly ash increased the workability of concrete and also strength. The optimum percentage of fly ash was found to be 30% of cement content. The flow characteristics have increased with fly ash. Mechanical properties of concrete were found out and find to be increase with fly ash.

Purumani Supriya [4] (2016), has done a study on self-compacting concrete by using different mineral admixtures. The mineral admixtures were Metakaolin, fly ash, Ground granulated blast furnace slag (GGBS) with different percentages. From the study it was found that all the three can be used as admixture in SCC. It was found that 10-15% of metakaolin, 20-25% of fly ash and 30-35% of GGBS are optimum for replacement of cement. Finally, in the study it was found that GGBS is better replacement than metakaolin and fly ash. The split tensile strength and flexural strength have also increased. The powder content was chosen as per the guidelines provided in EFNARC code.

G. Sakthi Ganesh [5] (2017), have investigated the mechanical and durability properties of self-compacting concrete. In his study he replaced cement with fly ash with different percentages. For 15% replacement the mechanical test results obtained were satisfactory. Rapid chloride penetration test (RCPT) was carried out to determine workability of SCC. For 15% replacement more chloride penetration was observed.

Satish Kumar [6] et al. (2017), carried out a study in order to study the effect of partial replacement of cement with pozzolanic materials like silica fume and fly ash. The adopted water cement ratio is 0.36. Tests were conducted on fresh concrete it was observed that addition of fly ash improved the workability whereas silica fume decreased workability. The strength of concrete increased with increase in silica fume than fly ash. Finally, from the results it was observed that 30% of fly ash along with 2% of silica fume produced high workability and strength.

P. Sachin Prabhu [7] et al. (2018), has a done a study on behaviour of Self-Compacting Concrete with Cement replacement materials. In this study the cement was replaced with fly ash and wood ash with different percentages, it was observed the workability increased gradually and then decreased. The optimum percentage was 10% for both fly ash and wood ash in combination. The strength was increased by 10%.

S. Arun Chaitanya [8] et al. (2019), has done a review paper on self-compacting concrete using mineral admixtures. The mineral admixtures used in the study were fly ash, and copper slag. In this paper tests on fresh concrete and



mechanical properties were considered. From the results, it was observed that for 20-30% of fly ash replacement workability of concrete increased and also strength of concrete. A maximum of 30% increase in strength of concrete was observed. The copper slag was replaced with fine aggregate and the optimum percentage was observed at 40%.

III. MATERIALS AND THEIR PROPERTIES

3.1 Properties of Cement: A cement is a binder material, which is used in construction. Cement when mixed with water gets hardened and bind the materials together. The major raw materials used for cement are lime (CaO), silica (SiO₂), alumina (Al₂O₃) and gypsum. Various tests are performed on cement to determine its quality and strength. The tests on cement are performed as per the guidelines provided in IS: 4031-1988.

Table 1 Physical properties of Cement

Physical Property	Value
Fineness of cement	8%
Normal consistency of cement	30%
Initial setting time of cement	55 min
Final setting time of cement	320 min
Specific gravity of cement	3.04

3.2 Properties of Aggregate: The aggregate passing through 4.75 mm and retained on 0.075 mm sieve are known as fine aggregate. Generally, river sand is used as fine aggregate in concrete. It helps in filling of voids in concrete. Sand mainly constitutes silica and argillaceous or siliceous or calcareous materials. Natural sand is formed due to weathering of rocks. The aggregate size which are above 4.75 mm are generally called as coarse aggregate. Generally crushed stones are used as coarse aggregate in concrete. The size of aggregate varies depending on concrete grade and purpose. Coarse aggregate have different shapes such as angular, rounded, flaky and elongated, of these angular shape have great interlocking property. The coarse aggregate provides maximum strength to the concrete.

Table 2 Physical properties of Aggregate

Physical property	Fine aggregate	Coarse aggregate
Specific gravity	2.66	2.72
Water absorption	1%	0.81%

3.3 Properties of Fly ash & Iron powder:

Table 3 Physical properties of Fly ash & Iron powder

Physical property	Fly ash	Iron powder
Specific gravity	2.29	5.08



Fig: 1 Fly ash



Fig: 2 Iron powder

IV. EXPERIMENTAL METHODOLOGY

The present study has done in three stages. In stage-1 the mix design of M30 grade SCC is done based on trial-and-error method. In stage-2 the cement is then replaced with fly ash to increase the workability of SCC and the optimum percentage of replacement is found out. The replacement is done with 10%,20%,30% of cement content. Then in stage-3 with optimum percentage of fly ash the cement is then partially replaced with iron powder and the effect is observed. The replacement is done with 5%,10%,15% of cement content. For mix design of SCC there is no specific design procedure, but some guidelines are provided in IS 10262 (2019) and also in EFNARC code. So, based on the guidelines the mix design has been done.

Table 4 Quantity of Materials for 1m³

Mix	Cement kg/m ³	Fine Agg. kg/m ³	Coarse Agg. kg/m ³	Water lit/m ³	% of fly ash	Fly ash kg/m ³	% of Iron Powder	IP kg/m ³	SP lit/m ³	VMA lit/m ³
1.	440	987.4	731	211.2	0	0	0	0	5.28	1.76
2.	396	987.4	731	211.2	10	44	0	0	5.28	1.76
3.	352	987.4	731	211.2	20	88	0	0	5.28	1.76
4.	308	987.4	731	211.2	30	132	0	0	5.28	1.76
5.	330	987.4	731	211.2	20	88	5	22	5.28	1.76
6.	308	987.4	731	211.2	20	88	10	44	5.28	1.76
7.	286	987.4	731	211.2	20	88	15	66	5.28	1.76

Many different test methods have been developed in order to determine the workability properties of SCC. As of now no single method have universal approval and all of them have their limitations. Similarly, no single method determines all the properties of workability. So, to determine the workability of SCC different tests need to be performed on fresh concrete. The tests procedures which are mentioned in EFNARC code for SCC are considered to determine workability. When considering these tests, one should remember it must satisfy three different properties namely filling ability, passing ability and segregation resistance. The different tests performed need to satisfy the acceptance value to in order to produce high workable SCC. The tests performed on hardened concrete are compressive strength test and split tensile strength.



Fig: 3 J-Ring



Fig: 4 Slump Flow



Fig: 5 V-Funnel



Fig: 6 L-Box

V. TEST RESULTS

The tests were performed on fresh concrete and hardened concrete and it is important to analysis the results. The analysis of results provides a clear information about the behaviour of concrete under different condition. In the analysis of results the results obtained are compared with one other to determine its behaviour. The results can be easily analysed with the help of graphs.



5.1 Slump Flow Test:

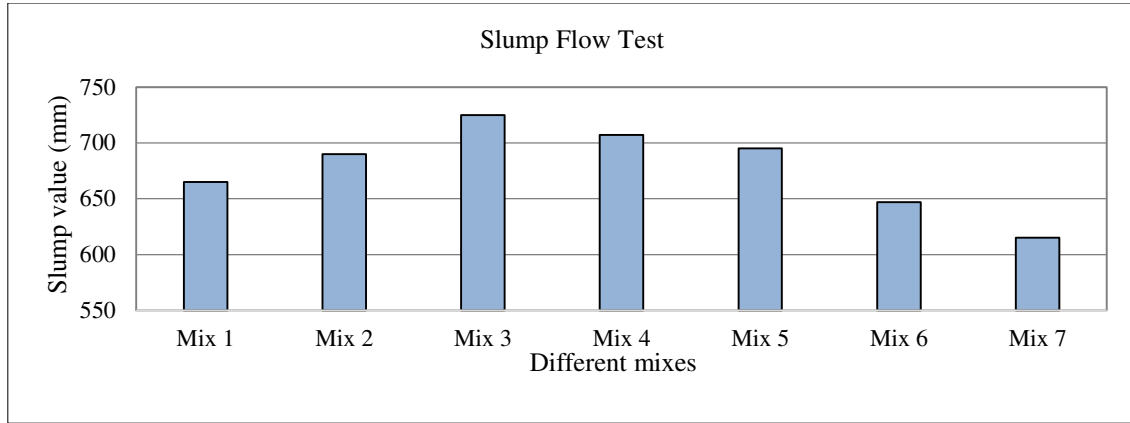


Chart 1: Variation of Slump Flow Test

5.2 J-Ring Test:

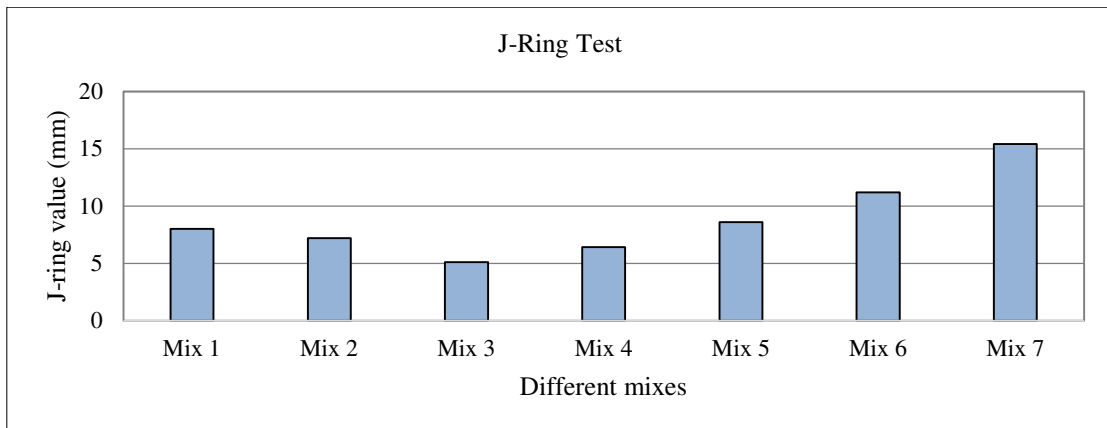


Chart 2: Variation of J-Ring Test

5.3 V-Funnel Test:

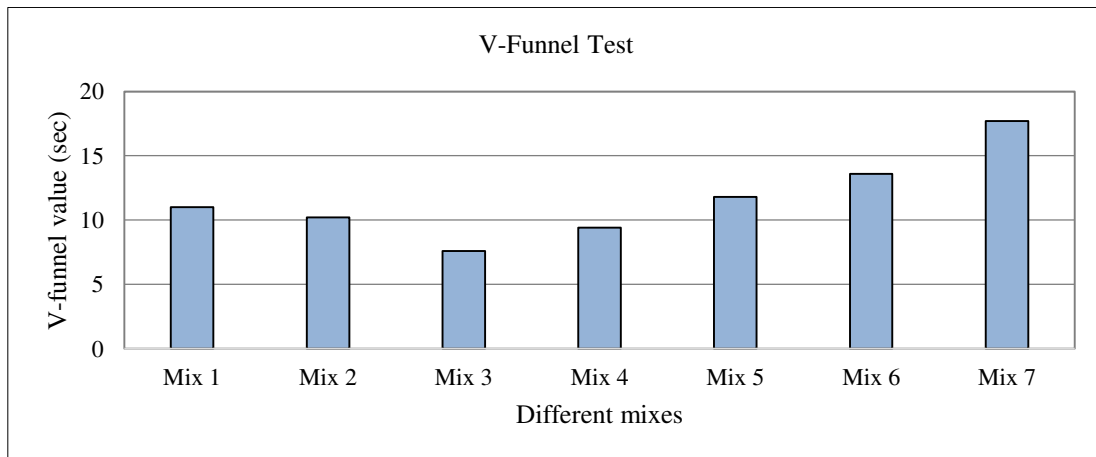


Chart 3: Variation of V-Funnel Test



5.4 V-Funnel at T_{5min} :

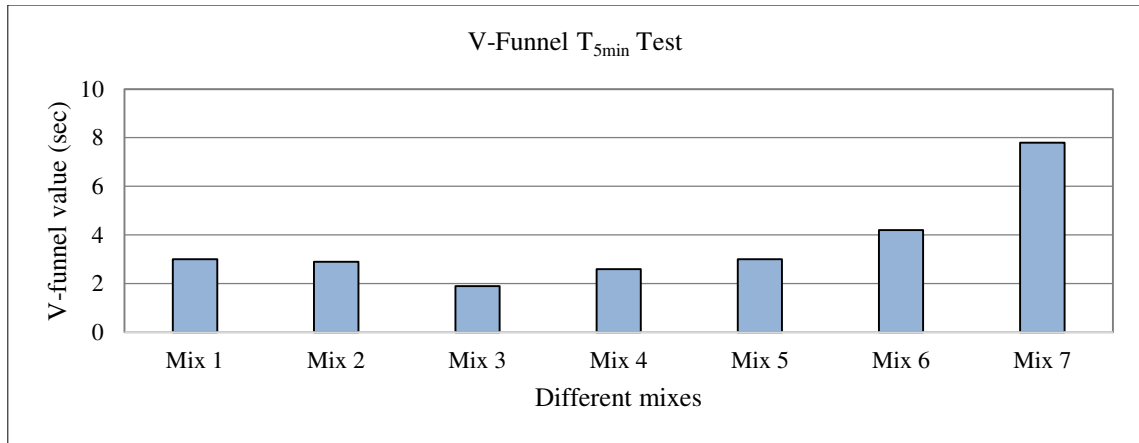


Chart 4: Variation of V-Funnel at T_{5min} Test

5.5 L-Box Test:

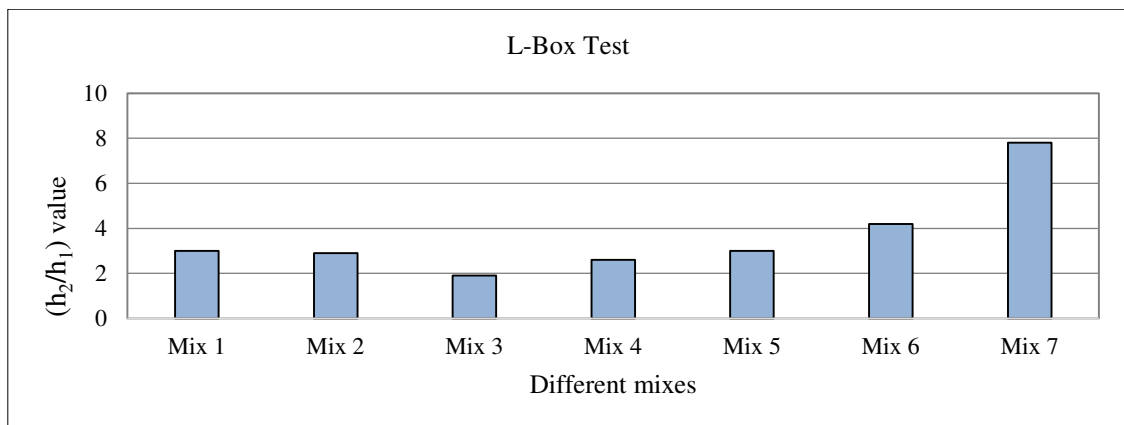


Chart 5: Variation of L-Box Test

5.6 Weight of Concrete Cubes:

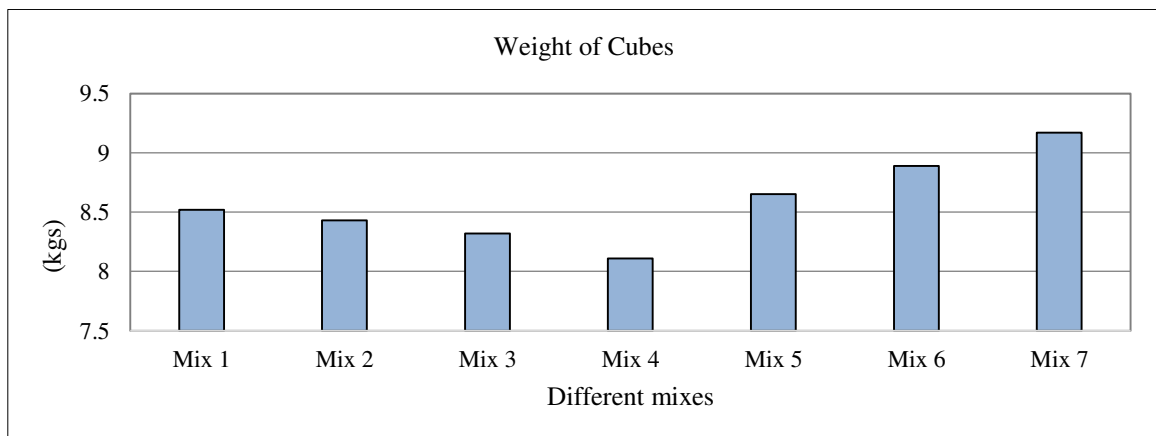


Chart 6: Variation of Weight of Concrete Cubes

5.7 Compression Test:

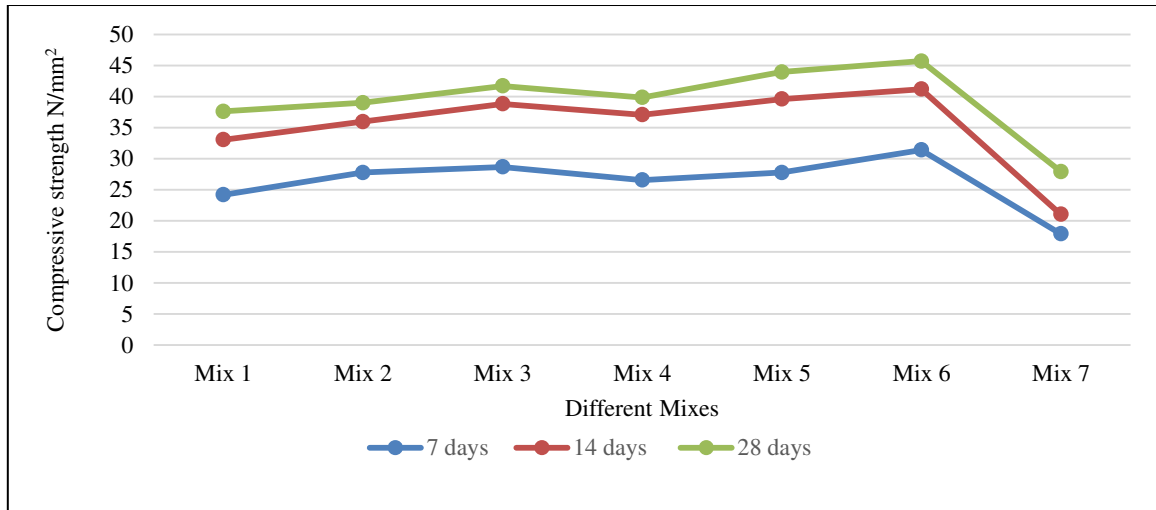


Chart 7: Variation of Compressive strength of Concrete

5.8 Split-Tensile Test:

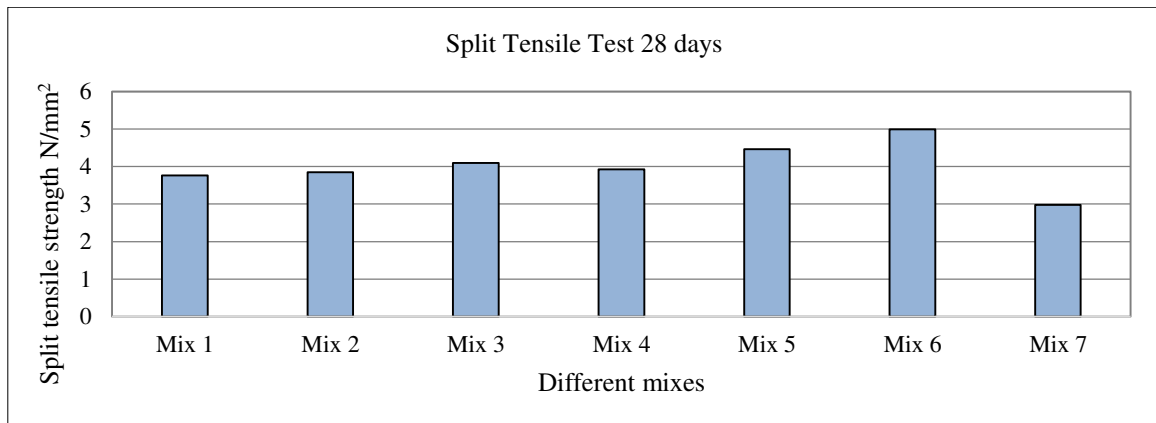


Chart 7: Variation of Split-Tensile strength of Concrete

VI. CONCLUSION

By the investigation on SCC with partial replacements of fly ash and iron powder, the following conclusion has been made

- (i) The normal mix concrete satisfies all the requirements of an SCC. But to improve workability of SCC more cement was replaced with fly ash.
- (ii) When filling ability of SCC is considered the mix with 20% replacement of fly ash obtained high flow and 9% increase in flow was observed. It shows that finer the particle size in concrete more the flow value.
- (iii) The passing ability of SCC through reinforcement was high for 20% fly ash replacement and also low segregation.
- (iv) An increase of 63% in passing ability and 56% of reduction in segregation was observed.
- (v) By considering the tests on fresh concrete it was observed that 20% fly ash replacement was optimum.
- (vi) For the concrete mix with 5% iron powder and 20% fly ash replacement, the flow, segregation of SCC was within the acceptance value. But for 10%, 15% iron powder the flow of SCC decreased and failed the acceptance criteria. The failure of mix may be due to high density of iron powder.

- (vii) By measuring the weight of concrete cubes, it was observed that self-weight of concrete slightly decreased with fly ash replacement, and the weight increased when iron powder is replaced.
- (viii) When compressive strength and split tensile strength of different mixes were compared it was observed that by iron powder replacement the strength increased gradually and decreased. As iron has high strength properties the strength of concrete increased. A maximum of 21% and 30% increase in compressive strength and split tensile strength was observed.
- (ix) Thus, fly ash can be used as a mineral admixture in SCC to improve its work ability. It was also observed that fly ash not only increases workability of SCC but also increases its strength.
- (x) Iron powder can be used as partial replacement of cement to increase its strength, but only in less amount as it decreases the flow of SCC. The optimum percentage is 5%.
- (xi) By cost analysis of concrete, it was found that with utilization of fly ash and iron powder decreased the rate of concrete. So, an economical SCC mix can be produced.

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