THOMSON REUTERS ENDNOTE

[Shanmugapriya* *et al.*, 5.(6): June, 2016] **ISSN: 2277-9655**
IC™ Value: 3.00 **Impact Factor: 4.116**

IJESRT

INTERNATIONAL JOURNAL OF ENGINEERING SCIENCES & RESEARCH TECHNOLOGY

EXPERIMENTAL STUDY ON HIGH STRENGTH SELF COMPACTING CONCRETE INCORPARETED WITH CARBON FIBRE

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DOI: 10.5281/zenodo.54652

ABSTRACT

The Self-Compacting Concrete[1] is a concrete which flows and settles due to its own weight without segregation and bleeding .Self-Compacting Concrete is cast so that no additional inner or outer vibration is necessary for the compaction. It flows like "honey" and has a very smooth surface level[2] after placing with regard to its composition, self-compacting concrete consist of the same components as conventionally vibrated concrete, which are cement, aggregate and water, with the addition of chemical and mineral admixtures in different propositions. . In this study, the trial mix is carried out the cement content is partially replaced with i.e., micro silica that improve the flow ability and strengthening characteristics of the concrete. From these trials, which trial shows the maximum Strength that is adopted as optimum mix based on both workability and strength criteria. That trial is chosen and fibers are added in it. Carbon fiber is added with 0.2% increment into the maximum strength attaining concrete mix i.e 0.2%, 0.4%, 0.6%, 0.8%. The chemical admixtures used are High-Range Water Reducers (super plasticizers) and Viscosity Modifying Agents, which change the rheological properties of concrete. Cubes beam and cylinders is casted for determine the compressive strength, split tensile strength and flexural strength.

KEYWORDS: Self-Compacting Concrete, Carbon fiber, super plasticizers, Viscosity Modifying Agents.

INTRODUCTION

Development of Self-Compacting Concrete (SCC) is a desirable achievement in the construction industry in order to overcome problems associated with cast-in-place concrete. Self-Compacting Concrete is not affected by skills of labors, the shape and amount of reinforcement[1] or the arrangement of a structure and due to its high fluidity and resistance to segregation it can be pumped longer distances. The concept of Self-Compacting Concrete was proposed in 1986 by Professor Hajime Okaruma, but the prototype was first developed in 1988 in Japan, by Professor Ozawa (1989) at the University of Tokyo. Self-Compacting was developed at the time to improve the durability of concrete structures. Since then various investigations have been carried out and SCC has been used in practical structures in Japan, mainly by large construction companies. Investigations for establishing a rational-mix design method and Self-Compacting testing methods have been carried out from the viewpoint of making it a standard concrete.

Self-Compacting Concrete is cast so that no additional inner or outer vibration is necessary for the compaction. It flows like "honey" and has a very smooth surface level after placing with regard to its composition, self-compacting concrete consist of the same components as conventionally vibrated concrete, which are cement, aggregate and water, with the addition of chemical and mineral admixtures in different propositions. Usually, the chemical admixtures used are High-Range Water Reducers (super plasticizers) and Viscosity Modifying Agents, which change the rheological properties of concrete. Mineral admixtures are used as an extra fine material, besides cement, and in some cases, they replace cement. In this study, the cement content was partially replaced with mineral admixture, i.e., micro silica that improves the flow ability and strengthening characteristics of the concrete.

The main reasons for the employment of Self-Compacting Concrete can be summarized as follows:

- To shorten the construction period
- To assure compaction in the structure-especially in confined zones where vibrating compaction is difficult
- To eliminate noise due to vibration-effective especially at concrete products plants.

MATERIALS AND METHODS

- Cement : Ordinary Portland Cement 53 grade (OPC)
- Fine Aggregate : Natural river sand
- Coarse Aggregate : stone size ≤ 12.5 mm are used
- Water : Ordinary Portable Water
- Mineral Admixtures : Micro silica
- Self–Compacting Admixture: Super Plasticizer (SP), Viscosity Modifying Agent (VMA).

Materials Used

cement

Cement is one of the important constituents of mortar. It is the binding material in mortar which is used for all building elements. Ordinary Portland cement 53grade is used for casting the mortar cubes. Various tests are conducted on cement before going to use. Cement properties are evaluated as per the IS methods.

Fineaggregate

Sand is either round or angular grain and is often found mixed in various grading of fineness sat different zones. IS383-1970 will specify about the four zones and its fineness modulus. The four zones of river sand are used for the preparation of mortar cubes. Though it contains impurities itha strobe cleaned and well sieved so that the mortar will not affect the structure. Fine aggregate properties are evaluated as per the IS methods.

Coarse Aggregate

Coarse aggregate is chemically stable material in concrete. It contributes to the heterogeneity of the cement concrete and there is weak interface between cement mix and aggregate surface in conventional concrete. The properties such as moisture content, water absorption would help in adjusting the quality of mixing water. The strength properties of coarse aggregate such as aggregate abrasion value, aggregate abrasion value, modulus of elasticity, compressive strength, and aggregate crushing value would 17 determine the limits of strength of concrete which could be achieved with a given aggregate. Coarse aggregate is used natural crushed aggregate. To suit the needs of scale of the test specimen, coarse aggregates is passed through IS 20 mm sieve and retained on IS 12.5 mm sieve.

Water

Potable water shall be used for the production of SCC. In case of conventional concretes, the water is proportionate only with the cement content. It is called as the water- cement ratio. This influences the mix and thereby workability. But, in the case of SCC, instead of water-cement ratio the term water binder-ratio will be used. This means the content of water mixed in the SCC is proportionate to the total binders such as cement, fly ash etc. The pH value of water lies between 6 and 8 indicates the water is free from organic matters.

Mineral Admixtures

Mineral admixtures and chemical admixtures are the extra ingredients other than water, cement, aggregates and fibers. These are added to the concrete batch plant during batch mixing or at the start when other quantities are added. Admixtures offer very favorable effects to the properties of fresh or hardened concrete only if proper use of admixtures is made possible.

Admixtures improve the quality of concrete, accelerate setting time, or decelerate setting time in case of any misshaping. Now there is a wide range of admixtures available in the market that enhances resistance against freeze and thaw effect. It made possible of earlier attainment of strength. Admixture enhances the workability of fresh concrete with lesser amount of water than the required one. In this case concrete will have more strength, because water aids in workability but in the same manner it has a negative effect on the strength of concrete. Therefore, finish-ability of concrete also becomes noticeable.

Mineral admixtures are the fine ground solid materials I.e. Fly ash, slag and micro silica. It is added to the concrete generally in larger amount than any other type. Because mineral admixtures have an ability to enhance workability as well as finish-ability of freshly laid concrete.

Mineral admixtures are also utilized as a partial replacement of cement, a cement is the most expensive material in concrete. Hence, with the use of mineral admixtures reducing concrete cost is very likely possible.

Mineral admixtures are the waste products of industries. Hence by using in concrete, maximum sustainability can be achieved. It also supports in reducing thermal cracking in concrete by reducing heat of hydration. At the end we can say that this type of admixtures enhances the durability and serviceability of concrete.

In this study micro silica is used as mineral admixtures.

Micro Silica

Micro Silica, also referred to as micro silica or condensed micro silica, is a byproduct material that is used as a pozzolan. This by-product is a result of the reduction of high-purity quartz with coal in an electric arc furnace in the manufacture of silicon or ferrosilicon alloy. Micro silica rises as an oxidized vapour from the 2000°C (3630°F) furnaces. When it cools it condenses and is collected in huge cloth bags. The condensed micro silica is then processed to remove impurities and to control particle size. Micro silica is used in amounts between 5% and 10% by mass of the total cementitious material. It is used in applications where a high degree of impermeability is needed and in high strength concrete.

Chemical Admixtures

Chemical Admixtures represents those ingredients which can be added to the concrete mixture immediately before or during mixing. The use of chemical admixtures such as water reducers or plasticizers, retarders, high-range water reducers or Super Plasticizers (SP) and viscosity modifying agents (VMA) are necessary to improve some fundamental characteristics of fresh and hardened concrete. They make more efficient use of the large amount of cementitious material in high strength and self – compacting concretes and help to obtain the lowest practical water to cementing materials ratio.

Chemical Admixtures efficiency must be evaluated by comparing strengths of trial batches. Also, compatibility between cement and supplementary cementing materials, as well as water reducers, must be investigated by trial batches.

Properties of CONPLAST SP – 337

Super plasticizers, also known as plasticizers, include water-reducing admixtures. Compared to what is commonly referred to as a "water reducer" or "mid-range water reducer", super plasticizers are "high-range water reducers". High range water reducers are admixtures that allow large water reduction or greater flow ability without substantially slowing set time or increasing air entrainment. Conplast-SP337 disperses the cement particles effectively in the concrete mix and hence exposes a larger surface area to the hydration process

Properties of Conplast SP – 337

PROPERTIES OF CONPLAST SP – 337	
Appearance	Brown liquid
Specific gravity	1.18 to 1.20 at 270C

ISSN: 2277-9655
Impact Factor: 4.116

Properties of GLENIUM B233

The use of Viscosity Modifying Agent (VMA) gives higher possibilities of controlling segregation in SCC when the amount of powder is limited. This admixture helps to maintain very good homogeneity and also reduces the tendency to segregate. GLENIUM is a premier ready-to-use, liquid, organic, viscosity-modifying admixture (VMA) specially developed for producing concrete with enhanced viscosity and controlled rheological properties.

Properties of Glenium B233

PROPERTIES OF GLENIUM B233	
Appearance	Light Brown liquid
Relative Density	1.09 at 25^0 c
pH	>6
Chloride ion content	< 0.2 %

Fibres

Concrete made with Portland cement has certain characteristics: it is relatively strong in compression but weak in tension and tends to be brittle[3]. The weakness in tension can be overcome by the use of conventional rod reinforcement and to some extent by the inclusion of a sufficient volume of certain fibres. The use of fibres also alters the behavior of the fibre-matrix composite after it has cracked, thereby improving its toughness. In this study, carbon and glass fibres are used.

Carbon Fibre

Carbon fibres [4]are manufactured by carbonizing suitable organic materials in fibrous forms at high temperatures and then aligning the resultant graphite crystallites by hot-stretching. The fibres are manufactured as either Type I (high modulus) or Type II (high strength) and are dependent upon material source and extent of hot stretching for their physical properties. Carbon fibres are available in a variety of forms and have a fibrillar structure similar to that of asbestos. Carbon fibre is available as continuous strands or as individual chopped fibres.

Continuous strands are normally pre-placed and aligned to provide the optimum fibre orientation during fabrication. Chopped fibres[4] are generally incorporated during the mixing process and are therefore orientated randomly throughout the mix. A satisfactory mix of chopped carbon fibre[9], cement and water is difficult to achieve because of the large surface area of the fibre.

EXPERIMENTAL RESULT

Trail mixes and Workability for SCC (without fibre)

The trial mixes taken for development of Self-compacting concrete with various percentages of micro silica are summarized in the table .

Mix Design for SCC (without fibre)

Trials	Cement	Micro Silica kg/m^3	Fine aggregate kg/m^3	Coarse Aggregate kg/m^3	Water kg/m^3	Super Plasticizer (%)	Viscosity Modifying (%)
S_1	503.50	26.50	890	740	195	2	1
S_2	477	53	890	740	195	2	1
S_3	570	30	890	740	195	2	1
S_4	540	60	890	740	195	2	1
S_5	522.50	27.50	890	740	195	2	1
S_6	495	55	890	740	200	2	1

Workability Test

Tests on fresh concrete were performed to study the workability of SCC. The tests conducted are listed below:

1. Slump flow test
2. V- funnel flow test
3. L-box test

The acceptance criteria for the fresh properties of SCC are listed in Table .

Acceptance criteria for SCC as per EFNARC

S. No.	Method	Unit	Typical range of values	
			Minimum	Maximum
1	Slump-flow	Mm	650	800
2	V-funnel	Sec	8	12
3	L-Box	h_2/h_1	0.8	1.0

For the formulation of Self-Compacting Concrete trail mixes was worked out as per ERNARC Specifications above table .

Slump flow test

V-Funnel test

L-Box test

Workability Results

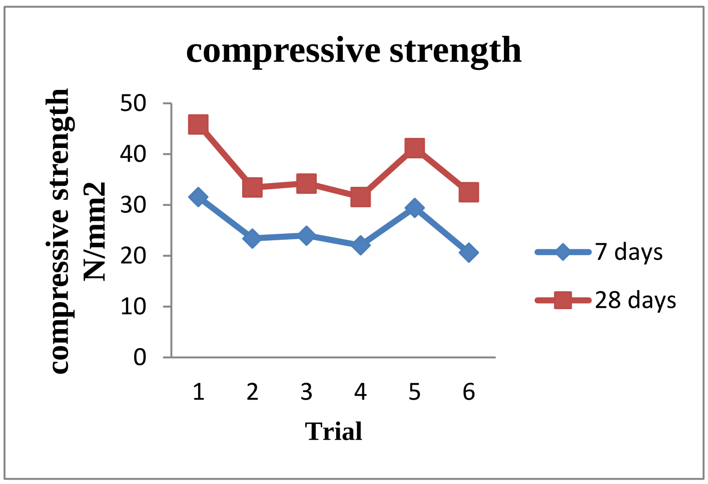
Trails	**Slump flow**	**V-Funnel**	**L-Box**
	Mm	**sec**	**h_2/h_1**
S1	790	8	1
S2	750	10	0.9
S3	760	11	1
S4	650	10	0.9
S5	590	12	0.7
S6	750	9	0.8

The workability property of the mix was evaluated by Slump flow test, V-funnel test
And L-box test. Test result value was compared with acceptance criteria. From the comparison the test result of all the mix has satisfied with acceptance criteria except trial mix 5.

ISSN: 2277-9655
Impact Factor: 4.116

Compressive Strength (N/mm^2)

Trials	Compressive strength(N/mm^2) 7 days	28 days
S1	31.56	45.87
S2	23.42	33.45
S3	23.96	34.23
S4	22.04	31.57
S5	29.45	41.21
S6	20.6	32.54

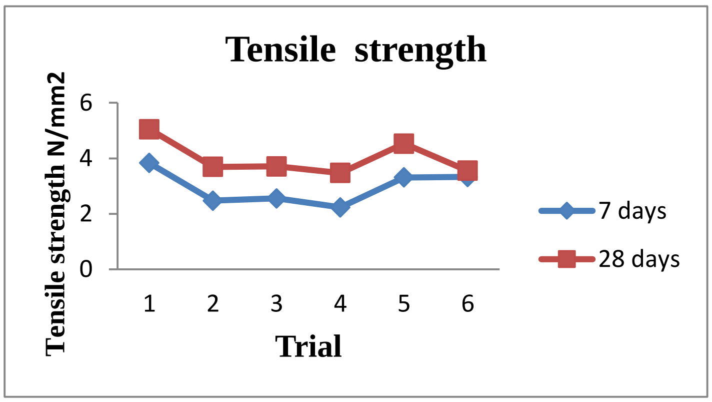


Compressive strength of Trails

The cement content in first trial mix is taken as 530kg/m^3, the compressive strength at 5% replacement of micro silica is 45.87 N/mm^2. The compressive strength at 10% replacement of micro silica is 33.45 N/mm^2, which is lower than the 5% replacement for the same mix proportion. In third and fourth trials, total cement content is taken as 600 kg/m^3 which show the compressive strength of 34.23 N/mm^{2}at 5% replacements and 31.57 N/mm^2 at 10% replacement of micro silica respectively. In fifth trial total cement content is 500 Kg/m^3 and cement is replaced by 50% of micro silica which shows a very low compressive strength of 30N/mm^2.In sixth and seventh trials the total cement content is taken as 550kg/m^3 which gives the compressive strength of 41.21 N/mm^{2}at 5% replacement and 32.54 N/mm^2 at 10% replacement of micro silica respectively.

Tensile Strength (N/mm²)

Trials	Tensile strength(N/mm²)	
	7 days	**28 days**
S1	3.83	5.05
S2	2.47	3.69
S3	2.55	3.71
S4	2.23	3.47
S5	3.31	4.53
S6	3.33	3.55



Tensile strength of Trails

Split tensile strength result of concrete are listed in table 5.10.Based on the result, the highest split tensile strength value is 5.05Mpa which is obtained at 28 days by replacement of 5 % micro silica in concrete . Fig 5.5 shows that the split tensile strength of concrete for various mixes.

SCC trial mixes with Carbon fibres

Trails	Carbon Fibre %	Cement kg/m³	Micro Silica kg/m³	C.A kg/m³	F.A kg/m³	Water	SP (%)	VMA (%)
1	0.2	503.50	26.50	890	740	195	2	1
2	0.4	503.50	26.50	890	740	195	2	1
3	0.6	503.50	26.50	890	740	195	2	1
4	0.8	503.50	26.50	890	740	195	2	1

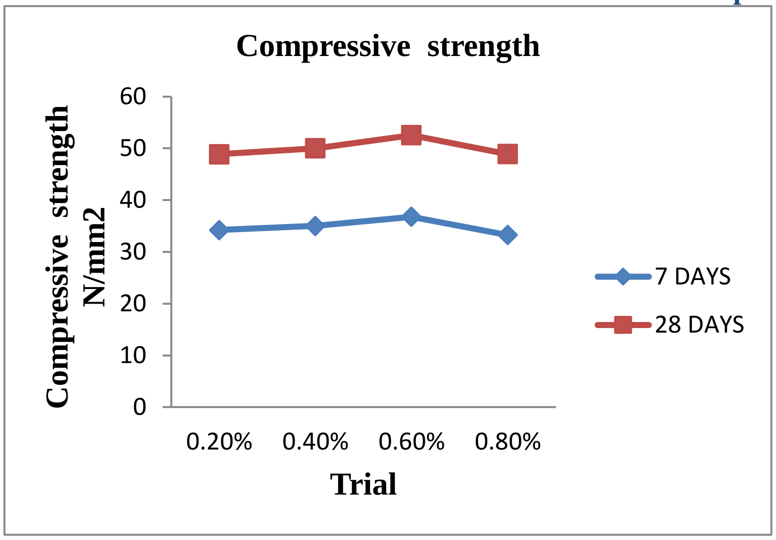
Workability values of trials

Trials	Slump Flow (mm)	V- Funnel (sec)	L-Box (h_2/h_1)
0.2%	710	9.9	0.96
0.4%	680	10.9	0.96
0.6%	643	11.5	0.86
0.8%	635	14.3	0.75

Compressive strength results

Trials		Compressive strength(N/mm²)	
		7 days	**28 days**
0.2%	C	34.21	48.87
0.4%	C	35.01	50.02
0.6%	C	36.78	52.54
0.8%	C	33.25	48.90

ISSN: 2277-9655
Impact Factor: 4.116

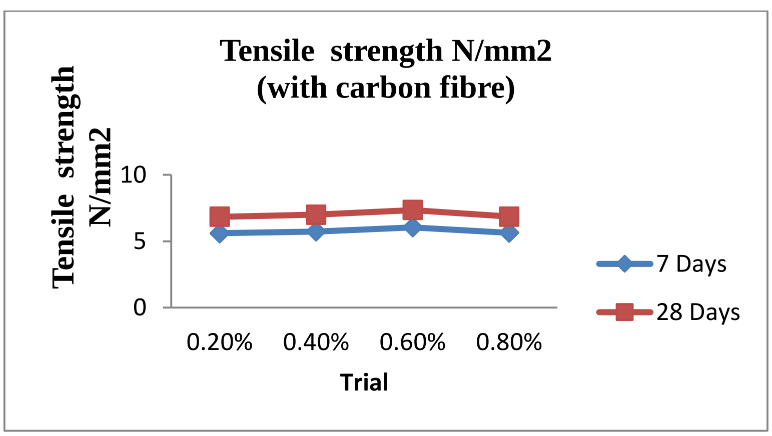


Compressive Strength of trials (with fibres)

The compressive strength of the trials at 0.2%, 0.4%, 0.6% and 0.8% of carbon fibre was find out. It was found that the addition of fibres increase the strength of the mix gradually .The compressive strength of the mix increase till 0.6% of fibres and decreases with further increase in fibre percentage. The compressive strength of the mix at 0.6% addition of fibres is 52.54N/mm^2.

Tensile strength results

Trials	**Tensile strength(N/mm^2)**	
	7 days	28 days
0.2%	5.60	6.84
0.4%	5.73	7.00
0.6%	6.04	7.35
0.8%	5.63	6.85

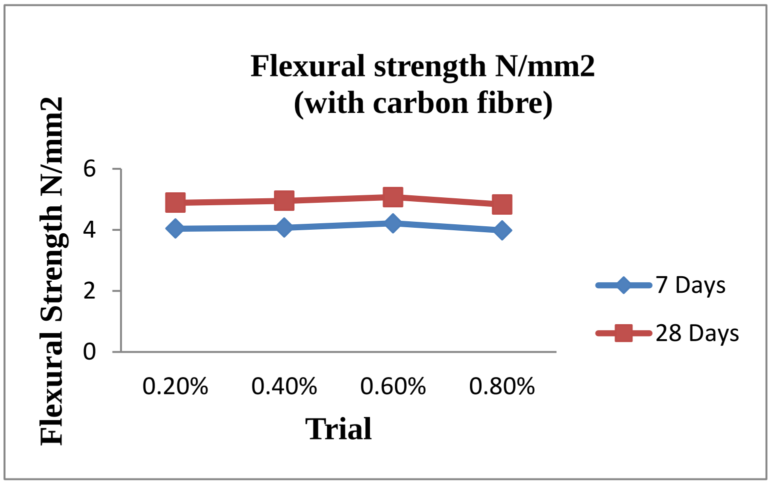


Tensile Strength of trials (with fibres)

The tensile strength of the trials at 0.2%, 0.4%, 0.6% and 0.8% of carbon fibre was find out. It was found that the addition of fibres increase the strength of the mix gradually .The tensile strength of the mix increase till 0.6% of fibres and decreases with further increase in fibre percentage. The compressive strength of the mix at 0.6% addition of fibres is 7.35N/mm^2 .The tensile strength of the trials at various percentage of addition of fibres was found out. The tensile strength of the mix at 0.6% of fibres shows good results

Flexural strength results

Trials	**Flexural strength(N/mm^2)**	
	7 days	28 days
0.2%	4.04	4.89
0.4%	4.07	4.95
0.6%	4.21	5.07
0.8%	3.98	4.83



Flexural Strength of trials (with fibers)

The flexural strength of the trials at 0.2%, 0.4%, 0.6% and 0.8% of carbon fibre was find out. It was found that the addition of fibres increase the strength of the mix gradually .The tensile strength of the mix increase till 0.6% of fibres and decreases with further increase in fibre percentage. The flexural strength of the mix at 0.6% addition of fibres is 5.07 N/mm^2 .The above figure shows the flexural strength of the mix with fibers. The flexural strength of the mix at 0.6% of fibers shows good results.

RESULTS AND DISCUSSION

For the formulation of Self-Compacting Concrete 6 trail mixes was worked out as per ERNARC Specifications.

The workability property of the mix was evaluated by Slump flow test, V-funnel test and L-box test. Trial 1, in which 5% of cement was replaced with micro silica the slump flow value was 790mm, V-funnel values was 8 seconds and L-box result was 1.0 which satisfies the EFNARC Specification for SCC.

In trial 2 at 10% replacement of cement with micro silica, the slump flow value was 750 mm which is lower than 5% replacement. Similarly V-funnel value was10 seconds which shows that the mix has low passing ability compared to 5% replacement.

In trial 3, the cement content was changed to 600 kg/m^3. At 5% replacement of cement with micro silica the slump flow value was 760mm, V-funnel value was 11 seconds and L-box result was 1.0. For the same cement content at 10% replacement of cement with micro silica slump flow value was 650mm, V-funnel values was 10 seconds and L-box result was 0.9, which shows that the workability get decreased with increase in micro silica content

In trial 4, the cement was equally replaced with micro silica (50% replacement). It shows the slump flow value of 590 mm, a V-funnel value was 13 seconds and does not satisfies the L-box test. This trial does not satisfy any one of the workability test, which shows that equal replacement of micro silica greatly affects the workability.

In trial 5, the cement content was varied to 500 kg/m^3. At 5% replacement of cement with micro silica the slump flow value was 590mm, a V-funnel value was 13 seconds and L-box result was 0.7. For the same cement content at 10% replacement of cement with micro silica slump flow value was 750mm, V-funnel values was 9 seconds and L-box result was 1.0, which shows that the workability get decreased with increase in micro silica content.

The cement content in first trial mix is taken as 530kg/m^3, the compressive strength at 5% replacement of micro silica is 45.87 N/mm^2. The compressive strength at 10% replacement of micro silica is 33.45 N/mm^2, which is lower than the 5% replacement for the same mix proportion. In third and fourth trials, total cement content is taken as 600 kg/m^3 which show the compressive strength of 34.23 N/mm^{2}at 5% replacements and 31.57 N/mm^2 at 10% replacement of micro silica respectively..In sixth and seventh trials the total cement content is taken as 550kg/m^3 which gives the compressive strength of 41.21 N/mm^{2}at 5% replacement and 32.54 N/mm^2 at 10% replacement of micro silica respectively.

Considering the tensile strength results, trial 1 shows the strength of 5.05 N/mm^2. Similarly for flexural strength also trial 1 shows the maximum results of 4.74 N/mm^2.

From these trials, Trial 1 which shows the compressive strength of at 7 days was 31.56 N/mm^2 and at 28 days was 45.87 N/mm^2 was adopted as optimum mix based on both workability and strength criteria. This trial is chosen and fibres are added in it.

Carbon Fibres are added in the range of 0.2%, 0.4%, 0.6%, and 0.8% of total volume of concrete.

At 0.2% addition of fibre, the slump flow value was 710 mm for carbon fibre respectively. Considering the V-funnel and L-box test also the glass fibre shows low workability compared to carbon fibres.

At 0.4% addition of fibres, the slump flow value was 680 mm for carbon fibre, which shows that with increase in fibre content the carbon fibre shows low workability compared to glass fibres. In V-funnel test, carbon fibres show 10.9 seconds. In L-Box test, the carbon and fibre shows the value of 0.94.

At 0.8% addition of fibres, the workability is greatly affected and does not satisfy the workability test.

The compressive strength of the mix at 0.2 % addition of fibres, the compressive strength was 48.87 N/mm^2 for carbon fibre. The compressive strength of the mix at 0.4 % addition of fibres, the compressive strength was 50.02 N/mm^2 for carbon fibre. At 0.4% addition of fibres compressive strength increases by 7.5 % for carbon fibre.

The compressive strength of the mix at 0.6 % addition of fibers, the compressive strength was 52.54 N/mm^2 for carbon fiber. The compressive strength of the mix at 0.8 % addition of fibers, the compressive strength was 48.90 N/mm^2 for carbon fibre. The compressive strength increases till 0.6% addition of fibers and decreases at 0.8% addition of fibres. At 0.6% addition of fibres compressive strength increases by 12 % for carbon fibre.

At 0.6% addition of fibres, the flexural strength was of 5.07 N/mm^2 for carbon fibres respectively. Similarly considering tensile strength, 0.6% addition of fibres gives good strength of 7.35 N/mm^2 and 7 N/mm^2 for carbon fibres.

CONCLUSION

- Based on the experimental investigations, the following conclusions are drawn.
- From the formulated six trials, 6 trials satisfy the workability property as per EFNARC Specification for SCC.
- From these trials, Trial 1 which shows the compressive strength of at 7 days was 31.56 N/mm2 and at 28 days was 45.87 N/mm2 was adopted as optimum mix based on both workability and strength criteria. This trial is chosen and fibres are added in it.
- In that optimum trial mix, Carbon Fibres added in the range of 0.2%, 0.4%, 0.6%, and 0.8% of total volume of concrete.
- Up to 0.6% addition of fibres the workability property are satisfied as per EFNARC Specifications.
- At 0.8% addition of fibres, the workability is greatly affected and does not satisfy the workability test.
- The compressive strength increases till 0.6% addition of fibres and decreases at 0.8% addition of fibres.
- The compressive strength of the mix at 0.6 % addition of fibres, the compressive strength was 52.54 N/mm2 and 50.05 N/mm2 for carbon fibre.
- At 0.6% addition of fibres compressive strength increases by 12 % for carbon fibre.
- Considering tensile strength, at 0.6% addition of fibres gives good strength of 7.35N/mm2 respectively.
- Similarly considering the flexural strength, at 0.6% addition of fibres gives good strength of 5.07 N/mm2 respectively.

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