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Regression Analysis for the Axial Strengths of Muti-Blended Steel Fiber Self Compacting Concrete from the Experimentation.

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Abstract*: *The present paper deals with triple blended Self-Compacting Concrete (SCC) where 53 grade of cement is blended with flyash and Condensed Silica Fume (CSF) at different percentages as replacements to the cement. The steel fiber of diameter 1mm; with an aspect ratios varying from 20,30 and 40 were mixed to get the higher mechanical properties such as compressive and tensile strengths at four different percentages. The required number of cube and the cylindrical specimens of triple blended steel fibrous SCC were prepared and evaluated for compressive and the tensile strengths. The magnitude of the test results have indicated that there is enhancement in the axial strength properties of this type of the concrete as the percentage of steel increases up to certain value to fulfil the needs of the SCC as per the America Concrete Institute (ACI) norm. The regression equation is derived for the experimental values for the compressive and the spilt tensile strength of steel fibere self-compacting concrete (SFSCC) and verified acceptance the equation. The results of present investigation would help in the preparation of optimum tri- blended steel fibrous SCC ,which are suitable for practical usages like floor slabs bridge decks, important highways, airport runways and thin shaped concrete structural elements.

Keywords* : *Suppymentary cementatious materials (SCM), Steel fiber, Aspect ratio, robo sand and mechanical strengths, the regression equation.

I. INTRODUCTION

Need for Self Compacting Concrete:

The self-compacting concrete is designed towards better flowability along with concrete stability which was developed in Japan during late 90's, where there is restrained for the compaction of the concrete, especially in the dense reinforcement zones and in the preparation of thin concrete elements.

Advantages of S.C.C.

Advantages like minimization of man power at the site, smooth pouring of the concrete, and better finishing of the concrete with minimum noise level are observed as some of the applications of the SCC compared to the Vibrated cement concrete(VCC).

Details of the study: The study deals with steel fibrous self-compacting concrete which is blended with SCMs such a way that to get M40 grade of the concrete, which is taken as the base mix for this experimentation. The base mix is in accordance with the **IS 10262**[1] specification. For getting SCC the reference mix proportions are rearranged such that Fine aggregate content to total aggregate content in the ratio of 0.58 to 0.64 , fulfil the requirements of the SCC as per the provisions given by **ACI**[2]. The blending includes the replacement of 20% of cement by flyash and also replacement of 10% of cement by silica fume in base mix as the SCMs. The Chemical admixtures like superplasticizer and viscosity modifying agent are also used for better flow ability, workability, and stability of the concrete. The Workability tests likes slump flow, V-funnel and L box tests are conducted as per **EFNARC-2015**[3] standards to get the SCC requirements. The Percentages of fibers are varied from 0.20-0.80 (in four stages) of the volume of the concrete. The aspect ratios of 20, 30 and 40 were used for each percentage. The results axial strengths such as the compressive and tensile strength were examined. The characteristics of different specimens are noted and important conclusions are drawn from the experimentations.

II. LITERATURE REVIEW:

Okamura, [4] proposed mix design method for SCC, the main aim was to carry out the test on cement paste and its mortar in order to examine the properties and requirements of chemical admixtures like superplastizer (SP). **Nan Su et al**, [5] proposed simple mix design procedure for SCC and his focus was to compact voids of loosely filled aggregates with cement binder paste.

Okamura, H, ouchi, M [6] reported the present and future use of the SCC, and developed mix design approach for the rearrangement of FA to total aggregate ratio, until the requirements of the SCC were achieved.

R Petersson O., Billiberg.P., B.K., Y.VAN, (1996) [7] conducted experimental study to develop a Model for SCC, and discussed various Production methods, and Workability of Concrete for the parameters of passing ability, slump flow and segregation resistance.

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M. Pajak, and T. Ponikiewski, (2013)[8] reviewed the flexural behaviour of SCC; reinforced with straight and hooked end steel fibers at different percentages of 0.5 %, 1.0 % and 1.5 %of volume of the concrete. Results were examined and compared with OVC (ordinary vibrated concrete).

Valeria Corinaldesi et al. (2011)[9] examined self-compacting concretes mixes using three different types of fibers made of steel, poly-vinyl-alcohol (PVA) and high toughness polypropylene (PPHT) and two different types of SCMs addition (limestone powder and powder from recycled concrete). The result showed that the use of recycled-concrete powder instead of limestone powder for preparing SCC observed to be good, particularly for fresh concrete flow ability.

Padmanabhan Iyer, **Sara Y. Kenno**, **Sreekanta Das 2015**,[10] Fiber-reinforced concrete (FRC) has become a new material used in various civil constructions such as building pavements, industrial floors, and airport runways. In this work, basalt chopped fibers in filament form was used to develop an FRC material is known as basalt fiber-reinforced concrete (BFRC) to evaluate the probable improvement in the 28-day compressive strength and modulus of rupture.

Sahmaran.M, Yutseven.A,and Yaman (2005)[11] used the fibers in the form of straight and hooked-end steel fibres and exucted tests in fresh and hardened state of the concrete. It was found that it is possible to attain self-compaction with 60 kg/m3 of fibre content.

Vítor M.C.F. Cunha, Joaquim A.O. Barros, Jose M. Sena-Cruz (2006)[12] examined the effect of steel fiber content and concrete age on compressive strength behaviour of SCC. Compressive strength and modulus of elasticity increased with age but was observed that there was a decresasing these values when the quantity of steel fibers was increased from 30 kg/m^3 to 45 kg/m^3.

Deepak Kumar,Arvinder Singh (2015)[13] Over the last few decades, the astonishing developments of superplasticizers techniques allowed enhancement achievements on the conception of concrete mixes showing self-compacting property.

According to **Kosmatka,S.H., and Wilson, M.L (2011)**[14], SCMs (supplementary cementatious materials) improved the workability of concrete grades. Flyash and slag cement have generally has been valuated to improve concrete workability.

Vijaya G. Dr. V aishali, G. Ghorpade (2011)[15] Self compacting concrete (SCC) has been developed in order to get long term durable concrete structures. The strength of the based mix proportion of SCC was arrived based on NANSU approach of mix design for M40 grade. This was developed by varying percentages of fiberss from 0.0%, 0.25%, 0.5%, 0.75%, 1.00%, 1.1%, 1.2%, 1.3% and 1.4%of volume of the concrete.The EFNARC[1] gave guidelines for mix design for S.C.C, and specifications about the initial mix compositions, volume of paste, volume of fine particles, and dosage of superplasticizers, viscosity agents are reported. Various workability tests along with the limiting values are also examined.

Ganeshan, N et al [16] reported the affect of steel fiber on the strength behaviour of FRSCC subjected to flexure, in this experimentation used ideal volume content of fibers was observed to be 0.5 percent, different aspect ratios of 15,25 and 35 were tried.

III. EXPERIMENTAL INVESTIGATION:

Materials:

Cement 53 Grade:

Cement of 53 grade from the locally available is used and examined the physical ,chemical properties. Reported these are in accordance to specifications of per **IS: 10269**[14]-1987.

Fine Aggregate:

In this experimentation, fine aggregate (natural river sand) was obtained from local market, 30 percentage of this sand is replaced by manufacture sand (robo sand). The physical properties of combined fine aggregate like specific gravity, bulk density, gradation and fineness modulus are tested in accordance with **IS-2386** [15]. Specific gravity is 2.64 and the fineness modulus is 2.82.

Coarse Aggregate:

The crushed granite aggregate of maximum 12 mm is used. The physical properties of coarse aggregate like specific gravity, bulk density, gradation and fineness modulus are tested in accordance with **IS-2386** [15]. The specific gravity is 2.6 and the fineness modulus is 5.48.

FlyAsh:

In the current investigation, the F-type fly ash was used as one of the cement replacement material. It is obtained from Vijayawada thermal power station in Andhra Pradesh. The specific surface of fly ash is found to be 4750 cm^2/gm by Blaine's permeability apparatus, and observed this value is very nearer to the fineness of 53 grade of the cement.

Condensed Silica Fume:

Condensed Silica Fume was obtained from M/s V.B.C Ferro Alloys Ltd., Rudraram Near Hyderabad. Its fineness was found to be more than 10,000cm^2/gm;it is almost twice that of the flyash or 53 grade of cement particle.

Viscosity Modifying Agent (VMA):

The addition of VMA: ensured the homogeneity and the reduction of the tendency of the highly fluid mix to seperate, the Glenium-stream (Master Matrix) VMA of M/s. BASF INDIA LTD., is adopted in this entire work.

Superplasticizer:

Superplasticizer used in this investigation is Glenium B233 of M/s. BASF India Ltd. was employed for the preparation of SCC.

Steel Fibres:

Mild steel fibres of 1mm diameter were used at various aspect ratios of 20, 30 and 40. The percentage of fiber is tried from 0.20 to 0.80 in four stages.

Water:
Potable water is used for concrete making in this experimentation.

Concrete Mix Design:
The concrete mix of M40 grade was designed as per IS 10262-2009[16] using the materials selected above. The details of the basic mix are shown in tables 1, and the design mix for SCC employed in this work is mentioned in table 2. The SCMs such as flyash and CSF are used as replacement to OPC at optimum percentages of 20 and 10 to achieve triple blending. The water to binder ratio is maintained at 0.45.

Table.1 Concrete Mix Proportions for M40 (VCC)*

Sl. No.	Concrete Grade	Cement	Fine Aggregate	Coarse Aggregate	Water/Cement
1	M_{40}	1	1.38	2.4	0.45

Table.2 Concrete Mix Proportions for M40 (SCC)**

Sl. No.	Concrete Grade	Cement	Fine Aggregate	Coarse Aggregate	Water/ Cement
1	M_{40}	1	2.22	1.3	0.45

***VCC- vibrated cement concrete**
****SCC-self compacting concrete**

Optimum Dosages of Chemical Admixtures used:
By gradually enhancing the dosages of superplasticizer and VMA by trials, the final dosages of 1.0 and 0.15 were arrived to achieve the final triple blended fibrous self compacting concrete mix to satisfy the workability requirements for the percentage of steel fibers up to 0.4, later for percentage of steel fibers 0.6 and 0.8 the super plasticizer is 1.2 and VMA is 0.2 of the weight of cement is employed, to fulfil the need of SCC in accordance to ACI or EFNARC.

Workability Tests:
Workability tests as per EFNARC-2015[1] specifications like slump flow, V-Funnel, L-Box, were conducted and the results of various trials are represented in table.3. At the third trial the results satisfied the specifications in accordance to code.

Table.3 Quantities of Materials required with Mineral Admixtures (20% Fly Ash and 10% CSF)

Sl. No.	Materials required	Quantities in Kg. per m^2 for M_{40}
1	Cement	344
2	Fly Ash	90
3	CSF	45
4	Fine Aggregate	1064
5	Coarse Aggregate	624
6	Water	215

Tests on Hardened Concrete (Fibrous Triple Blended SCC):
Number of Mixes:
Total of 13 mixes are tried in the present experimental investigation, in addition to the reference mix. The percentages of fly ash and CSF were kept constant at 20% and 10% replacements of cement in the multi- blended concrete mixes the steel fiber percentages of 0.2, 0.4, 0.6 and 0.8 by volume and three aspect ratios of 20, 30 and 40 were examined.

Mixing, Casting, Curing and Testing:
The mixes of SCC as stated above were prepared as per standard specifications. The trials of the mixes are shown in table 4. All the ingredients, mineral admixtures and chemical admixtures were added while preparing the fresh concretes. Number of specimens were cast for conducting the tests for compression, tension and flexural properties. After air drying, the specimens were subjected to water curing. Testing was carried out at the age of 28 days. Standard procedures were followed for curing and testing. Tests were conducted on the cube specimens for compression and on the cylinder. Specimens for tensile strength and beam specimens for flexural strength.

Table.4 Trial Tests for Workability

Sl. No.	Method	Trial mix1	Trial mix2	Trial mix3	Acceptance criteria
1	Slump flow	460	550	680	650-800mm
2	T_{50}cm slump	-	7	4	2-5 seconds
3	V-funnel test	52	22	8	6-12
4	V-funnel at T_5	63	26	10	6-15
5	L-Box test	2.2	0.8	0.95	0.8-1

IV. RESULTS AND DISCUSSION:

Workability Results:
In the experimental investigation, M40 concrete is designed and performed, it can be seen that superplasticizer (Glenium B223) was used in it is 1.0 to 1.2% percentages. The Viscosity Modifying Agent (Glenium Stream 2) used in this experimentation was maintained at 0.15 to 0.2% of weight of cement; with these percentages, steel fibre self-compacting concrete satisfying the requirements.

Compressive Strength:
The concrete mix with triple blending (Fly ash 20% & CSF 10%) and 0.8 percentage of steel fiber is showing higher compressive strength than the reference mix (Table 5). The SCMs like flyash, and CSF contribute towards marginal enhancement in the strength in addition to beneficial flow properties. It can be noted from table-4, that the compressive strength of SCC of M40 grades is increasing with increase in fiber percentage. The size of the cube in this test is used 150mm side. There is increase in the compressive strength with aspect ratio also. In this investigation the maximum percentage of fiber is kept at 0.8 and the maximum aspect ratio was 40. Hence, it is clear that up to certain optimum percentage and optimum aspect ratio, steel fibres contribute towards strength and fulfilling the rheological needs as per the standards. At 0.2,0.4,0.6 and 0.8percentages of steel fiber with the aspect ratio 40 ,the percentage of increase in the compressive strength is 12%, 22%, 28%,and 54% respectively with reference to the base mix. The variation of compressive strength of the triple blended steel fiber self compacting concrete is shown in fig 1.

Table.5 Compressive Strength of different batches of Self Compacting Concrete

Sl. No.	CODE No.	Fibre Percentage	Aspect Ratio	Fly Ash Percentage	Condensed Silica Fume Percentage	Average Cube Compressive Strength at 28 days N/mm^2
1	M0	0	-	20	10	44.50
2	M1	0.20	20	20	10	47.25
3	M2	0.20	30	20	10	48.15
4	M3	0.20	40	20	10	49.82
5	M4	0.40	20	20	10	48.25
6	M5	0.40	30	20	10	51.25
7	M6	0.40	40	20	10	54.15
8	M7	0.60	20	20	10	53.25
9	M8	0.60	30	20	10	58.30
10	M9	0.60	40	20	10	60.74
11	M10	0.80	20	20	10	59.90
12	M11	0.80	30	20	10	63.72
13	M12	0.80	40	20	10	68.50

Regression equation for the Compressive strength results:

In the above results of the compressive strength of the FSCC, regression equations are found from the data, and best fit the second degree polynomial equation for the various percentage of steel fiber for different aspect ratio. Comparison and validity of the results are shown in table 6, 7 and 8.

For **0.2** percentages of steel fiber, Regression equation is

$Y=-K_1 X^2 + K_2 X + 44.50$---------------------- (|1)

K_1=0.0001,

K_2=0.1263, Limits are $20 \leq X \leq 40$

Where Y is compressive strength in MPa,and X-indicate the aspect ratio.

Table 6 .validity of the regression equation for 0.2 percentage of steel fiber

Aspect ratio X	Compressive strength from the experimental data	From the Regression equation Y	Percentage error
20	47.25	47.06	0.38
30	48.15	48.38	0.47
40	49.82	49.71	0.21

For 0.6 percentages of steel fiber, the Regression equation equation is

$Y = K_1 X^2 + K_2 X + 44.5$-------------------------------------(2)

K_1= -0.0025,

K_2= 0.5132, $20 \leq X \leq 40$

Table 7 .validity of the regression equation for 0.6 percentage of steel fiber.

Aspect ratio X	Compressive strength from the experimental data	From the Regression equation - Y	Percentage error
20	53.25	53.76	0.96
30	58.30	57.64	1.12
40	60.74	61.02	0.47

For **0.8** percentages of steel fiber, the Regression equation is

$Y = K_1 X^2 + K_2 X + 44.5$----------------------------------(3)

K_1= -0.0074,

K_2= 0.8888, $20 \leq X \leq 40$

Table 8 .validity of the regression equation for 0.8 percentage of steel fiber.

Aspect ratio X	Compressive strength from the experimental data	From the Regression equation Y	Percentage error
20	59.90	59.32	0.97
30	63.72	64.50	1.23
40	68.50	68.18	0.46

By observing the experimental data and theoretical data the percentage of maximum error is less than 1.3% from the equations 1,2 and 3, hence above second degree polynomial equations is valid form the aspect ratios 20 ,30 and 40.

Tensile Strength:

The concrete mix with triple blending (Fly ash 20% & CSF 10%) and 0.8 percentage of steel fiber is showing higher split tensile strength than the reference mix (Table 9). The mineral admixtures like flyash and CSF contribute towards increase in the split tensile strength in addition to additional beneficial properties. It can be noted from table-6 that the split tensile strength of SCC of M40 grades is increasing with increase in fibre percentage. The size of the cylinder used in this test is 100mm diameter and 300mm height. There is increase in the split tensile strength with aspect ratio also. In the present investigation the maximum percentage of fibre and aspect ratio is maintained same as mentioned above. For the maximum aspect ratio (40) ,At 0.2 0.4 0.6 0.8 percentage of steel fiber,the percentage of increase in the tensile strength is around 16%,23%,38% and 62% respectively. The variation of tensile strength of the triple blended fiber reinforced self compacting concrete is shown in fig 2.

Table.9 Split Tensile Strength of different batches of Self-Compacting Concrete

Sl. No.	CODE No.	Fibre Percentage	Aspect Ratio	Fly Ash Percentage	Condensed Silica Fume	Average split tensile Strength at 28 days N/mm^2
1	M0	0	-	20	10	4.25
2	M1	0.20	20	20	10	4.55
3	M2	0.20	30	20	10	4.80
4	M3	0.20	40	20	10	4.90
5	M4	0.40	20	20	10	4.85
6	M5	0.40	30	20	10	6.45
7	M6	0.40	40	20	10	6.80
8	M7	0.60	20	20	10	5.65
9	M8	0.60	30	20	10	5.80
10	M9	0.60	40	20	10	6.25
11	M10	0.80	20	20	10	6.40
12	M11	0.80	30	20	10	6.65
13	M12	0.80	40	20	10	6.85

Regression equation for the split tensile strength results:
In the above results of the spilt tensile strength of the FRSCC, regration equations are found from the data, and fit the appropriate polynomial equation for the various percentage of steel fiber for different aspect ratio. Comparison and validity of the results are shown in table 10 ,11 and 12.
For **0.2** percentages of steel fiber, Regression equation is

$Y=- K_1X^2 + K_2X + 4.25$----------------------------(4)

$K_{1=} 5 E^{-6}$,
$K_2 = 0.0169$,
$20 \le X \le 40$
Where Y is split tensile strength in MPa and X-indicate the aspect ratio.

Table 10 .validity of the regression equation for 0.2 percentage of steel fiber

Aspect ratio X	Split tensile strength from the experimental data	From the Regression equation Y	Percentage error
20	4.55	4.58	0.65
30	4.80	4.75	1.04
40	4.90	4.91	0.20

It indicates above polynomial equation is best fit for the above split tensile strength.
For 0.6 percentages of steel fiber, the Regression equation is

$Y= K_1X^2 + K_2X + 4.25$-------------------------------- (5)

$K_{1=} -0.0008$,
$K_2 = 0.0804$,

$20 \le X \le 40$

Table 11 .validity of the regression equation for 0.6 percentage of steel fiber.

Aspect ratio X	Split tensile strength from the experimental data	From the Regression equation - Y	Percentage error
20	5.65	5.54	1.94
30	5.80	5.94	2.41
40	6.25	6.18	1.12

For **0.8** percentages of steel fiber, the Regression equation is

$Y= K_1X^2 + K_2X + 4.25$------------------------------------ (6)
$K_{1=} -0.002$,
$K_2 = 0.1428$, $20 \le X \le 40$

Table 12.Validity of the regression equation for 0.8 percentage of steel fiber.

Aspect ratio X	Split tensile strength from the experimental data	Regression equation - Y	Percentage error
20	6.40	6.31	1.41
30	6.65	6.73	1.20
40	6.85	6.76	1.31

By observing the experimental data and theoretical data the percentage of maximum error is less than 1.5%, from the equations 4,5 and 6,hence above second degree polynomial equation is valid form the aspect ratios varying in between 20 to 40.
It indicates above polynomial equation is best fit for the above split tensile strength of the FRSCC having percentage of steel is **0.8**.

Influence of Fibre Percentage on Strength:
In SCC higher percentages of steel fibers interfere with the flow ability of SCC. Up to the optimum percentage, the strengths increase. The optimum percentage of steel is found to be 0.80%. The highest values were recorded with combination of flyash 20 % and condensed silica fume 10% . The variation is shown in figs 1 and 2.

Influence of Aspect Ratio of Steel Fibre on SCC:
As the aspect ratio of the fiber increases: it can be observed that there is marginal enhancement in the strengths. Increase in the aspect ratio particularly contributes towards more in split tensile strength but there is limit for higher aspect ratios particularly in the case of SCC.

As the aspect ratio is high: it will effect the flow of concrete because its weight is more. With the higher aspect ratios there may be balling effect also. Hence ,In the present investigation the optimum aspect ratio is found to be 40.

Use of Triple Blending:

In this work, M40 concrete mix was adopted as the reference mix and triple blending was carried out with 20% fly ash and 10% silica fume. The main benefit received in strength out of triple blending may be marginal but it has helped in workability. In the case of high strength concrete mixes and high performance concrete, triple blending really helps in strength gaining and long term durability. Hence, for practical modern concrete industry where SCC is employed, triple blending of cement using mineral admixtures is desirable.

Mineral Admixtures:

Out of the two mineral admixtures considered in the preset investigation, flyash and condensed silica fume effectively contribute towards the strength as well as flow property of the concrete. Based on their fineness values it is noted that for flyash is 20% ,where as CSF is 10% as partial replacement for the cement.

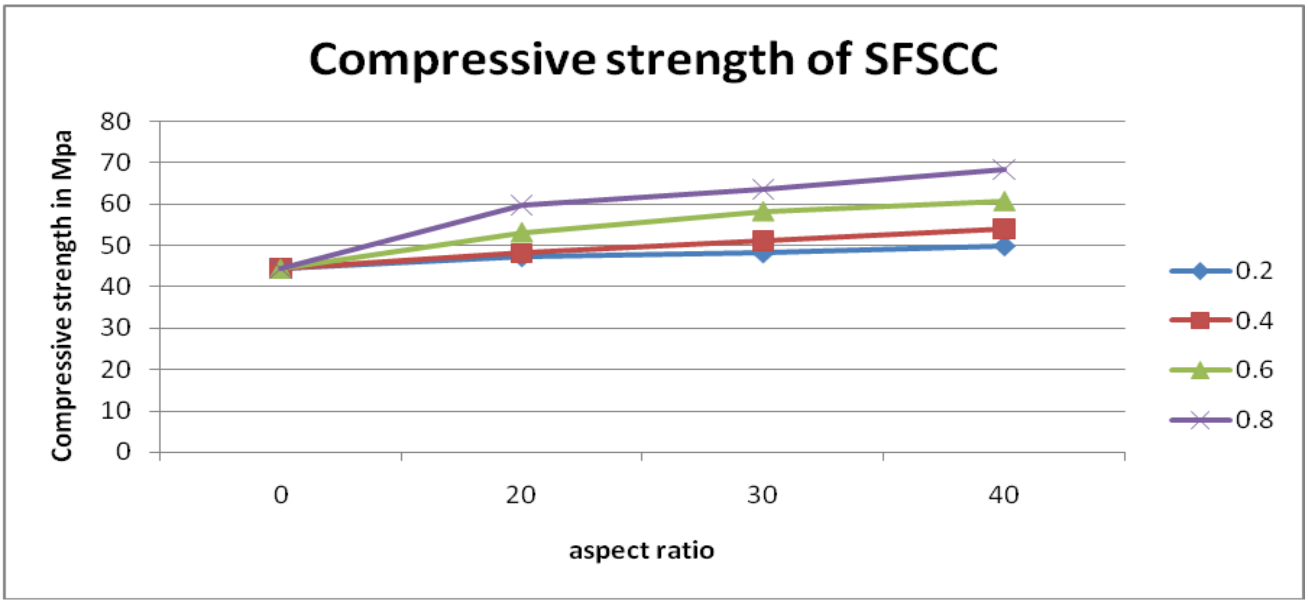

Fig 1. Variation of compressive strength of the SFSCC

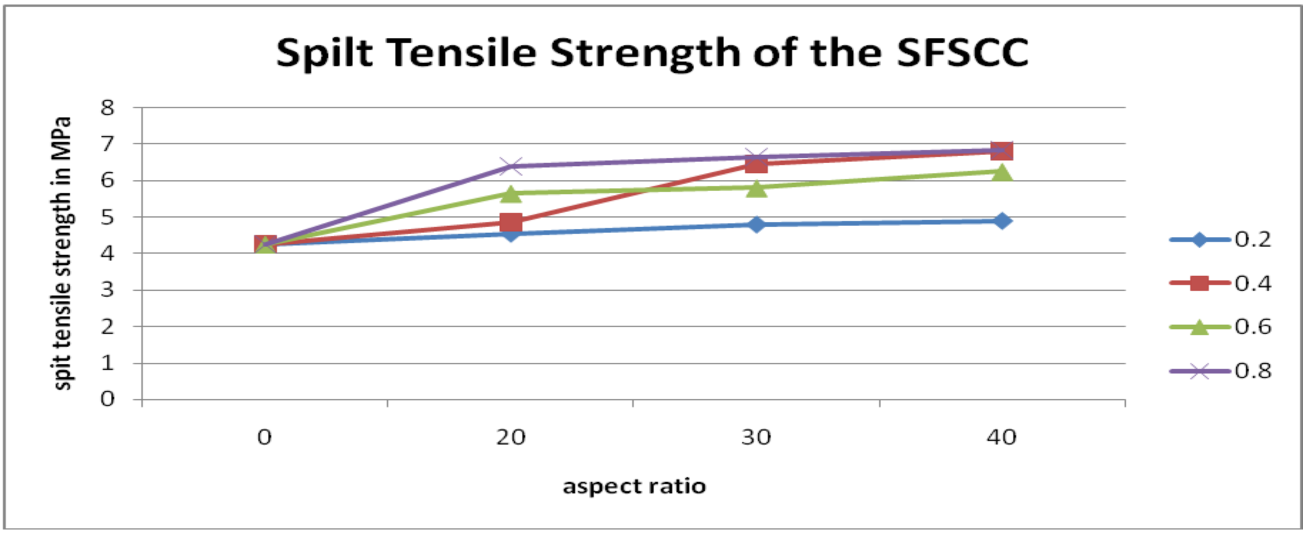

Fig 2. Variation of the spit tensile strength of the SFSCC

V. CONCLUSIONS:

Based on the investigations results, the following conclusions are noted.

1. The maximum percentage of superplasticizer is 1.0 and the VMA is 0.15, for the percentage of steel fiber up to 0.4; later for 0.6 and 0.8 the limiting dosage of SP and VMA are 1.2 and 0.2 % respectively
2. The concrete mix with multi blending (fly ash 20% and silica fume 10%) shows higher strength than the reference mix in addition to the rheological parameters.
3. The highest compressive strength was obtained with 0.80%of steel fiber, and an aspect ratio of 40 with triple blending.

The compressive strength has increased by 54% compared to the reference mix.

4. The values of split tensile strength are noted that there is increasing with the addition of steel fibers. The highest values are recorded at 0.80% of steel fibers with an aspect ratio of 40. The percentage of increase is 62 % compared to the reference mix.
5. In this experimentation, artificial sand used as replacement to fine aggregate up to 30%, which contains no organic and harmful impurities, hence there is a significant development in strength of concrete.
6. Equations developed from the experimentation either for compressive strength and split tensile strength is valid for a specified percentage of steel fiber and aspect ratio varies from 20 to 40.
7. In practical SCC constructions, use of fibers in concrete matrix helps in increasing the mechanical properties.

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REFERENCES

1. IS 10262-2009 – GUIDE LINES FOR DESIGN MIX FOR THE CONCRETE, BUREAU OF INDIAN STANDARDS,NEW DELHI 110002.
2. ACI 237R-07-Self-consolidating Concrete, reported by ACI committee 237, American Concrete Institute.
3. EFNARC, -"Specifications and Guidelines for Self-Consolidating Concrete", 2005.
4. H.Okamura, K.Ozawa 1997- "Self Compacting High Performance Concrete", Journal structural engineering international,Volume 6-Issue-4-PP-269-270
5. Nan Su,M Buquan 2003,- 'A new method for the mix design of medium strength flowing concrete with low cement content', Cement & Concrete Composites, vol. 25,Issue 2,PP. 215–222.
6. H.Okamura, M, Ouchi, "Self Compacting Concrete Development, Present use and Future", 1st International RILEM Symposia on Self Compacting Concrete, PP-3-14
7. PETERSSON,O.,BILLIBERG,P,Y VAN, AND B.K.,(1996)- "A MODEL FOR SELF-COMPACTING CONCRETE, PRODUCTION METHODS AND WORKABILITY OF CONCRETE", EDITED BY P.J.M. BARTOS, D.L. MARRSY, D.J. CLEAND, EDITORIAL: E&FN SPON, LONDRES, 1996.
8. M.Pajak and T.Ponikiewski.2013-"Flexural behavior of self-compacting concrete reinforced with different types of steel fibers", Construction and Building Materials Vol. 47 pp 397-408, 2013.
9. Valeria Corinaldesi and Giacomo Moriconi,2011-"Characterisation of self compacting concrete prepared with different fibers and mineral additions", Cement & Concrete Composites, Vol. 33 pp 596-601
10. PADMANABHAN IYER, SARA Y. KENNO, SREEKANTA DAS,(2015)-MECHANICAL PROPERTIES OF FIBER-REINFORCED CONCRETE MADE WITH BASALT FILAMENT FIBERS, JOURNAL OF CIVIL ENGINEERING –JOURNAL OF MATERIALS IN CIVIL ENGINEERING,VOLUME-27,ISSUE11,DOI:10.1061/(ASCE)MT.1943-5533.0001272
11. Sahmaran M, Yutseven A, Yaman (2005)- Workability of hybrid fiber reinforced self-compacting concrete. Building and Environment. 2005 Dec 31; Volume-40(12)PP:1672-7.
12. Vítor M.C.F. Cunha, Joaquim A.O. Barros, José M. Sena-Cruz.(2006)- "Compression behaviour of steel fibre reinforced self-compacting concrete: age influence and modeling." Material science published in 2006. DOI: 10.1617/s11527-007-9259-4
13. Kosmatka, S. H., and Wilson, M.L.(2011),- Design and Control of Concrete Mixtures, Engineering Bulletin 001, 15th Edition, Skokie, IL: Portland Cement Association, 2011. **:** Journal of Materials Sciences and Applications**,** Vol.6 No.1,
14. Vijaya G. Dr. V aishali, G. Ghorpade.(2011)-The behaviour of self compacting concrete with waste plastic fibers when subjected to acid attack. 2011. ISSN : 0975-4024.International journal of engineering and technology,Volume 8,issue 3,PP-1521-1527
15. Ganeshan. N et al. (2005),- "Strength and behaviour of Steel fibre reinforced self-compacting concrete in Flexure", International Conference of Advances in Concrete composites and Structures , 2005, pp. 2691-2698
16. IS -10269- Specification of Ordinary Portland cement Properties, BUREAU OF INDIAN STANDARDS,NEW DELHI 110002
17. IS-383-2016 Coarse and Fine aggregate for concrete specifications (third revision) BUREAU OF INDIAN STANDARDS, NEW DELHI 110002.
18. Ouchi M and M hibino(200)-"development ,applications and investigation of self compacting concrete", International workshop,Japan,PP-05-15
19. Sathish Kumar K, Karthik,P Vijayan,V santhanantham,Jansi,V(2016)-"Comparative study on self compacting concrete using steel fiber and basablt fiber",International journal of current Innovations Research,Volume 2,issue 5,may 2016.
20. Yousuf frith, Thierry Vidal, Bracelet Turnasinze, and Gerard Pons," Flexural and shear behavior of steel fiber reinforced SCC beams," KSCE Journal of Civil Engineering-2013,pp-1383-1393
21. Athiyamaan, V and G Mohan Ganesh, " Statistical and detailed analysis on fiber-reinforced self-compacting concrete containing admixtures-A state of the art of Review" IOP Conference Series, Material Science and Engineering, 2017, (DOI.org/10.1016/J.conbuild mat.2020.118450)
22. IS-516-1959 code of practice for testing hardend concrete.BIS Publications new delhi (INDIA)

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