

An Experimental study on Behaviour of Slurry Infiltrated Fibrous Concrete (SIFCON) Produced by Partial Replacement of Cement with Metakaolin and Fine Aggregate with Robosand

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ABSTRACT: SIFCON is a high-strength, high-performance material containing a relatively high volume percentage of steel fibres. It has high ductility, crack resistance and impact resistance. SIFCON is produced by a process in which fibers are put into an empty mould, after which the fiber mass is infiltrated by a slurry. The mechanical tests like compressive strength, splitting tensile test were done and measured the strength of casted cubes and cylinders. For getting of our aim we have used 15*15*15 cm, D =15cm and L=30 cm moulds for cubes and cylinders respectively. In this paper, cement and fine aggregates are partially replaced by Metakaolin and Robo sand in SIFCON. Metakaolin (MK) is a pozzolanic material, which blends with Portland cement to improve the durability and it, reduces the porosity of concrete as the particle size of Metakaolin is very less. Robosand is one of the most used among such materials to replace river sand, which can be used as an alternative to fine aggregate in concrete. In the present investigation workability and strength was evaluated in three stages. In first stage steel fiber content with various proportions of 2.5%, 5%, and 7.5% from which optimum value is taken. In second stage cement is partially replaced by metakaolin in proportions of 5%, 10%, and 15% and fibers of first stage optimum value. In third stage natural sand is replaced by Robo sand in proportions of 0%, 50%, and 100% to compare strength value with various fibers of (2.5%, 5%, and 7.5%) is studied for cubes and cylinders. The strength characteristics like compressive strength and tensile strength are evaluated. The final results shown that the strength is increasing based on the fiber alignment and fiber content. The inclusion of Metakaolin as a partial replacement of cement provides an excellent improvement in developing the strength compared to conventional. As per the results the compressive and tensile strength of SIFCON for cubes and cylinder which contain a combination of 5% fibers, 10% Metakaolin, 50% Robosand is larger than cubes and cylinder specimen with only 5% fibers. The optimum values are significantly improved results over controlled SIFCON specimen under 56 days curing. From the workability tests it was observed that SIFCON is self-compactable and has better workability.

KEYWORDS: SIFCON, Metakaolin, Robosand, Steel Fibers

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I. INTRODUCTION

SIFCON is unique construction material possessing high strength as well as large ductility and far excellent potential for structural applications when accidental (or) abnormal loads are encountered during services SIFCON also exhibit new behavioural phenomenon, that of "Fiber lock" which believed to be responsible for its outstanding stress-strain properties. The matrix plays the role of transferring the forces between fibers by shear, but also acts as bearing to keep fibers interlock Slurry-infiltrated fibres concrete (SIFCON) can be considered as a special type of fibre concrete with high fibres content.

The matrix usually consists of cement slurry or flowing mortar. SIFCON has excellent potential for application in areas where high ductility and resistance to impact are needed. Only very limited information is available about its behaviour under different types of loading. SIFCON is a type of fibre reinforced concrete (FRC) but it is produced by using a method which is very different from ordinary fibre reinforced concrete. To achieve uniform fiber distribution small length of fibre is used.

These short discrete fibres are placed in the moulds to its full capacity or to the desired volume fraction thus forming a network. Then a fine liquid cement based slurry or mortar is allow to infiltrate over the fibre network. When compared to conventional concrete SIFCON contains relatively high cement and water content. SIFCON has no coarse aggregate but high cementous content. To improve the flow characteristics, controlled quantity of super plasticizer may be used. In SIFCON have no coarse aggregates however it may contain fine (or) coarse sand and additives such as fly ash, Metakaolin and latex emulsions.

All steel fiber types namely straight, hooked and crimped can be used. It possesses excellent mechanical properties coupled with greater energy absorption characteristics and casting process is also different for SIFCON. The fibers content is generally varies from 2% to 20%percent by volume. SIFCON is fabricated by infiltrating a bed of pre-placed fibers with cement slurry. There are four main design factors that should be considered in a SIFCON product these are slurry strength, fiber volume, fiber alignment and type of fiber. The fiber volume depends on the fiber type and the vibration effort needed for proper compaction. Smaller or shorter fibers may pack denser than longer fibers and higher fiber volumes can be achieved with careful and sufficient vibration.

Concrete is an equivalent mixture of cement, fine aggregate, coarse aggregate water and admixtures in a proportioned quantity. Where as in SIFCON, coarse aggregate is absent. In this present project work cement is partially replaced with Metakaolin, and fine aggregate is replaced with Robosand.

II. MATERIAL USED

i. Cement

OPC 53 grade cement conforming to IS: 12269-1987 is used as a binding material.

Table No. 1: properties of cement

Properties of cement	Results
Specific gravity	3.13
Fineness	5%
Initial setting time	32 min
Final setting time	580 min
Normal consistency	32%

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Vol. 7, Issue 4, April 2018

ii. **Metakaolin**

It is one of the recently developed supplementary cementous materials that conforms ASTM C 680 CLASS-N pozzolanic specification Metakaolin is differ from other supplementary cementous material.

Table No. 2: properties of Metakaolin

Physical properties	Results
Appearance	white
ph(10% solids)	4.5-5.5
bulk density	0.4-0.5
Specific gravity	2.6

iii. **Fine Aggregate**

In the present investigation locally available river sand clean and dry Robo sand conforming to IS: 383-1970 was used .The river sand is tested according to IS 2886(part-1V)-1963 properties given in below table.

Table No. 3: properties of fine aggregate

Properties of fine aggregate	Results
Specific gravity	2.66
Fineness modulus	3.3
Water absorption	1.8%
grading zone	Zone II

iv. **Water and Super plasticizer**

Ordinary water fit for human utilization is used for preparing SIFCON specimen. The super plasticizer CONPLAST-430 is used to increase the workability.

Table No. 4: Specifications of CONPLAST SP-430

Parameter	Results
Specific gravity	1.20to 1.21 at 30 ⁰
Chloride content	NIL IS9103-1999 and BS:5075
Air Entrainment	Additional 1%air is entrained

v. **Steel fibers**

For the present work we have used crimped steel fibers confirms to ASTM A820 Type I cold drawn wire. Testing confirms with ASTM A820

Table No. 5: Properties of steel fiber

Diameter	0.6mm
Length	30mm
Aspect ratio	50
Tensile strength of the wire	>1450Mpa

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Vol. 7, Issue 4, April 2018

III. PROPOSED METHODOLOGY AND DISCUSSION

METHODOLOGY

SIFCON is best suited in few areas.

- Precast concrete member products, bridge decks, overlays and pavement rehabilitation.
- It can also used in long span structures
- It resists the sudden impact.
- It can also used at refractory application such as furnace lintel and saddle piers.
- In security application such as security vault and secret rooms.

IV. MIX PROPORTION AND SPECIMEN CASTING

Generally SIFCON the percentage of fibers can be from 2 to 20 percent. Normally for making SIFCON mix ratio of cement and sand can be 1:1, 1:1.5 or 1:2 and water cement ratio is varies from 0.3 to 0.45. Different specimens are taken with variation of steel fiber content. The strength characteristics like compressive strength and tensile strength are evaluated. Specimens are casted and tests are carried out after curing periods of 7, 28 and 56 days.

- Cement and fine aggregate = 1:1.5
- Metakaolin = 5%, 10% & 15%
- Robo sand = 0%, 50% & 100%
- Water/cement = 0.45
- Steel fibers = 2.5%, 5% & 7.5%

V. CASTING AND CURING SPECIMEN

In this present work different specimen such as cubes & cylinders were casted. Prepared slurry is poured after applying lubricant to the moulds without any compaction. A number of tests were carried out to determine the design mix proportion of concrete in the laboratory. In the present work the strength of hardened concrete is determined. All the specimens were prepared with IS recommendation. Moulds are allowed to dried for 24 hours and then hardened specimens are remoulded and kept in water for 7, 28 and 56 days.

- Compressive strength
- Split tensile strength

VI. TEST AND RESULTS

Workability:

a) L BOX TEST

Blocking ration $H_2/H_1 = 0.85$

Where

H_1 = height of concrete at horizontal portion

H_2 = height of concrete in vertical portion

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Vol. 7, Issue 4, April 2018

b) V-funnel test

Time of flow $T_f = 0.85$ SEC

RESULTS ON TEST CONDUCTED ON HARDENED SIFCON SPECIMEN

A. SET -1

Cubes Compression test result

Used cement and sand as constant .There is three mixes in variation of steel fibers content

MIX-1	2.5 % fibers
MIX-2	5 % fibers
MIX-3	7.5 % fibers

With absence of admixture. The strength increased at 2.5% & 5% fibers whereas in 7.5% fibers there is decrease in compressive strength. Due to high amount of steel fibers .Strength is highly influenced on alignment of steel fibers. As per results we got optimum value at steel fibers 5% and this optimum value is taken for partially replacement of cement in metakaolin.

Cylinder split tensile strength result

We have used cement and sand constant with various steel fibers content as mentioned below . the strength criteria is mainly based on the alignment as per the result we obtained the highest strength value at 5% fibers .There is strength decreased at 7.5% fibers . As per results the optimum value is taken at steel fibers of 5% for next set.

MIX-1	2.5 % fibers
MIX-2	5 % fibers
MIX-3	7.5 % fibers

Table No. 6: (set-1) various percentages of steel fibers

SPECIMEN DESIGNATION	STEEL FIBERS CONTENT	COMPRESSION STRENGTH(N/mm ²)		
		7days	28days	56days
MIX-1	2.5%	26.2	35.9	37.7
MIX-2	5%	29.7	39	41.1
MIX-3	7.5%	26.7	37.8	38.8

In the below fig-1 it explains about the strength variation of various percentages for 5% fibers there is increase in strength. Whereas this curing period is done for 7,28&56days .where as there is decrease in strength at 7.5% fibers.

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Vol. 7, Issue 4, April 2018

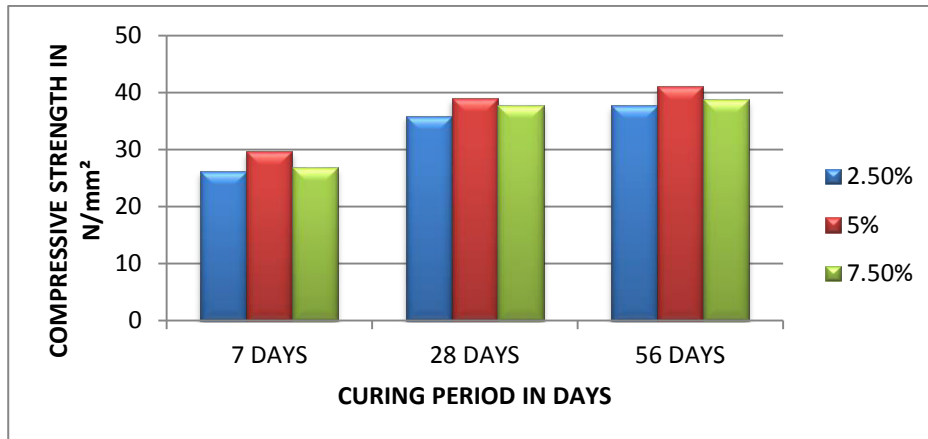


Fig-1 (set: 1) Compressive strength versus curing period Various for percentage of steel fibers

In tableno.7 the tensile strength variation was taken for cylinder specimen .They are tested for 7,28&56 days .There are less cracks observeded .

Table No. 7: (set-1) various percentages of steel fiber

SPECIMEN DESIGNATION	STEEL FIBERS CONTENT	TENSILE STRENGTH(N/mm ²)		
		7days	28days	56days
MIX-1	2.5%	5.09	8.5	8.56
MIX-2	5%	9.06	9.86	9.91
MIX-3	7.5%	6.7	9.13	9.1

In the below fig-2 there is increases of strength when compared to 2.5%.we observed that there is decrease in strength at 7.5%fibers.

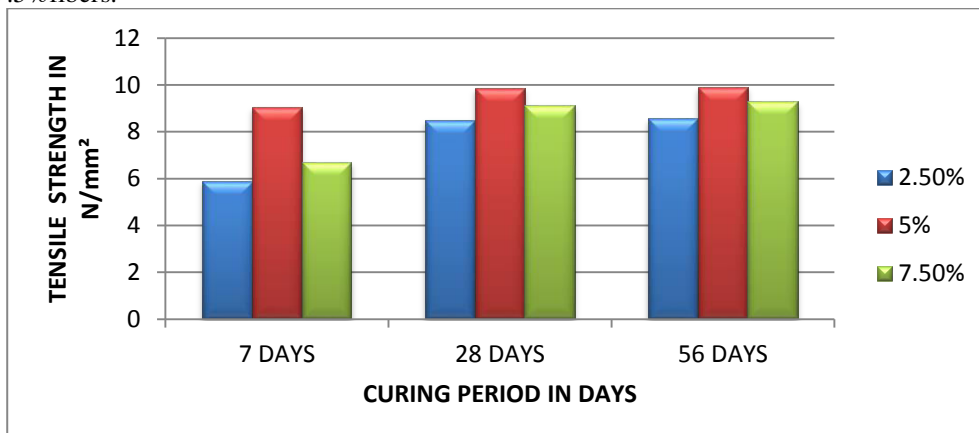


Fig-2: (set-1) Tensile strength versus curing period various for percentage of steel fibers

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Vol. 7, Issue 4, April 2018

A. SET-2

Cubes Compression test result

Cement is replaced with metakaolin (5%,10%15%) & sp 4% In this set we have taken the partially replacement of cement with metakaolin, sand remains constant , steel fibers 5% from (TABLE NO: 6)and CONPLAST SP 430 super plasticizer (4%) is taken to avoid the voids. As per TABLE NO: 8 there are three mixes with the variation of metakaolin percentage.

MIX-4	5% METAKOALIN
MIX-5	10%METAKOALIN
MIX-6	15%METAKOALIN

There is decrease in strength at 15% metakaolin. As per results we got optimum at 10% metakaolin it is considered in further sets.

Cylinder split tensile strength results:

In this set we have taken the various percentage of metakaolin in the cement as partially replacement and sp4% .In this tensile strength result we got optimum of 10% metakaolin is taken for further test. Here the metakaolin is used to improve strength .we also observed that there is a strength decrease at 15% metakaolin.

MIX-4	5% METAKOALIN
MIX-5	10%METAKOALIN
MIX-6	15%METAKOALIN

Table No. 8: (set-2) percentage of metakaolin in cement. Partial replacement of cement with metakaolin

SPECIMEN DESIGNATION	METAKAOLIN %	COMPRESSION STRENGTH (N/mm ²)		
		7days	28days	56days
MIX-4	5%	27.96	37.65	39.04
MIX-5	10%	30.06	41.45	41.2
MIX-6	15%	29.33	40	41.2

In fig -3 this tests are conducted for cubes specimen .various percentage of metakoaling helps to reduces the pores in Slurry. As per the results there is decrease of strength at 15% metakoalin and we get optimum value of 10%metakoalin.

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Vol. 7, Issue 4, April 2018

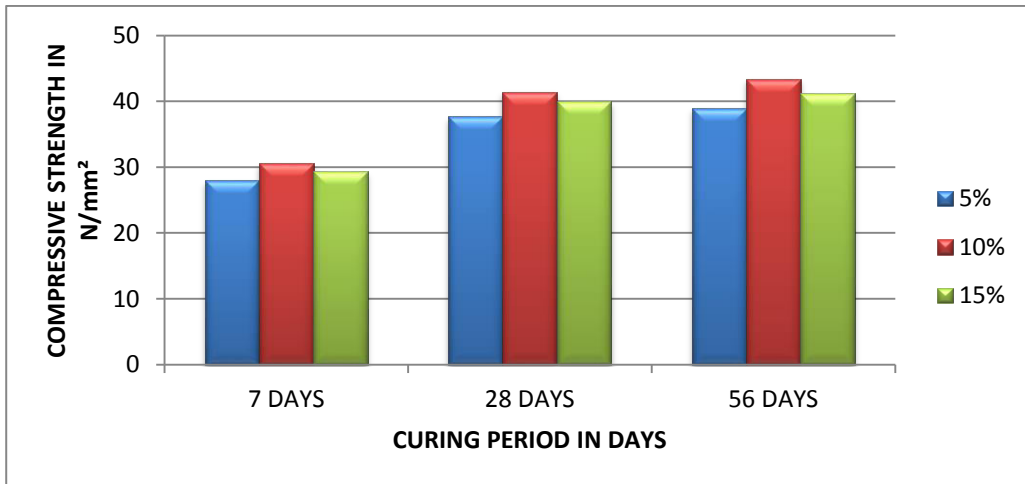


Fig-3: (set-2) Compressive strength versus curing period for partially replacement of cement with metakaolin

In table no.9 there we had conducted test for cylinder specimen for 7,28&56days as per the results there is increase of strength at 10% metakaolin. decrease of strength of strength at 15% metakaolin.

Table No. 9: (set-2) percentage of metakaolin in cement. Partially replacement of cement with metakaolin

SPECIMEN DESIGNATION	METAKAOLIN %	Tensile STRENGTH (N/mm ²)		
		7days	28days	56days
MIX-4	5%	7.31	9.31	9.52
MIX-5	10%	8.4	10.4	10.83
MIX-6	15%	7.72	8.1	8.58

In the fig -4 there is increases of strength metakaolin10%. Metakaolin reduces thepores on the slurry it helped to workability of slurry

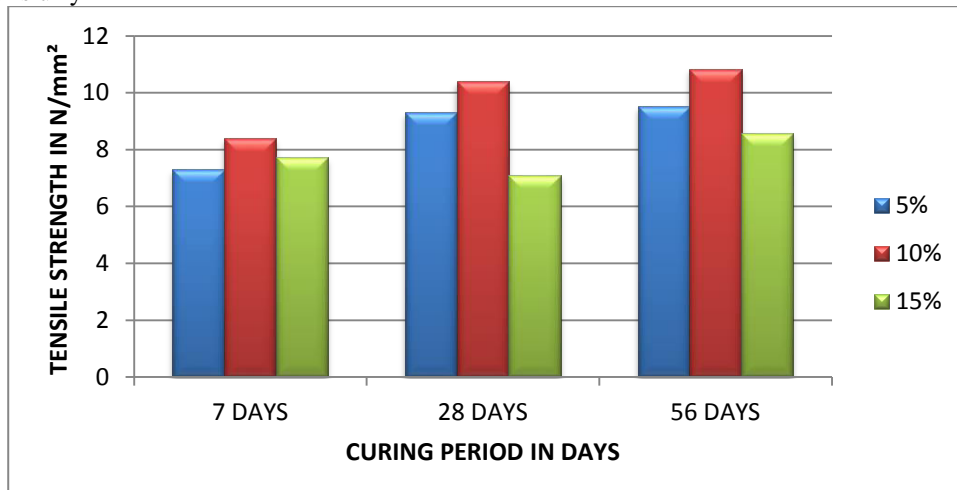


Fig-4: (set-2) Split tensile strength versus curing period for partially replacement of cement with metakaolin

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Vol. 7, Issue 4, April 2018

B. SET -3

Cubes Compression test result:

Various percentage of steel fibers, replacement of cement with metakaolin (10%), fine aggregate with Robo sand (50%) & sp 4%. In this set consists of three mixes where three mixes are taken.

MIX-7	2.5 % fibers
MIX-8	5 % fibers
MIX-9	7.5 % fibers

With cement is partially replaced with metakaolin (10%) and fine aggregate is replaced with replaced by Robo sand (50%) and CONPLAST SP -430 super plasticizer (4%) is used as per IS recommendation. As per the result in the below TABLE NO.9 we have observed that strength is increasing at fibers of (2.5%&5%) with Robo sand 50% .there is a decrease of strength in 7.5% fibers . There is decrease in strength because of improper bonding between the slurry.

Cylinder split tensile strength results:

Various percentage of steel fibers, replacement of cement with metakaolin (10%), fine aggregate with Robosand and sp4%. Where sp4% reduces the pores in the slurry gives more workability .as per results the strength got decreased at steel fibers 7.5%.

Table No. 10: (set-3) various percentages of steel fibers along with partially replacement of cement with metakaolin (10%) replacement fine aggregate with Robosand (50%) & sp 4%.

SPECIMEN DESIGNATION	STEEL FIBERS CONTENT	COMPRESSION STRENGTH (N/mm ²)		
		7days	28days	56days
MIX-7	2.5%	30.8	42.36	43.3
MIX-8	5%	35.5	47.1	47.89
MIX-9	7.5%	32.06	43.32	44.31

In fig-5 various percentage of steel fibers along with partially replacement of cement with metakaolin (10%)and replacement of Robosand (50%) there is increase of strength at 5% fibers .

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(A High Impact Factor, Monthly, Peer Reviewed Journal)

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Vol. 7, Issue 4, April 2018

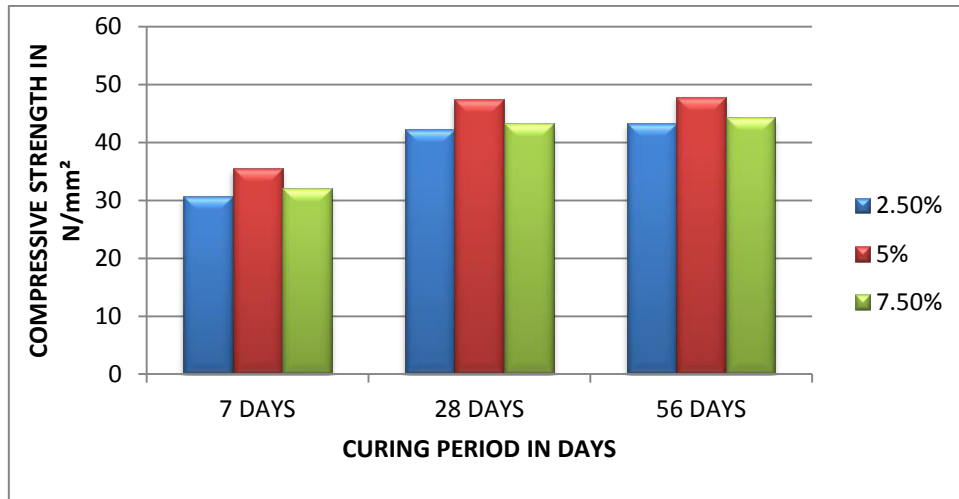


Fig-5: (set-3) compression strength versus curing period for various percentages of steel fibers along with replacement of cement with metakaolin (10%) and fine aggregate with Robosand (50%)

For table no: 11 as per the results there is increase of strength at 2.5% 5% .where as we observed that there decrease of strength at 7.5% fibers.

Table No. 11: (set-3) various percentages of steel fibers along with partially replacement of cement with metakaolin (10%) replacement fine aggregate with Robo sand (50%) & sp 4%

SPECIMEN DESIGNATION	STEEL FIBERS CONTENT	TENSILE STRENGTH (N/mm ²)		
		7days	28days	56days
MIX-7	2.5%	7.8	9.7	9.73
MIX-8	5%	8.47	10.47	10.5
MIX-9	7.5%	7.75	9.8	9.84

For fig-6 shows the result variation for fibers percentage. Fibers helps to get interlock of slurry and help to increase the strength .as per the results we got optimum value of 5% fibers.

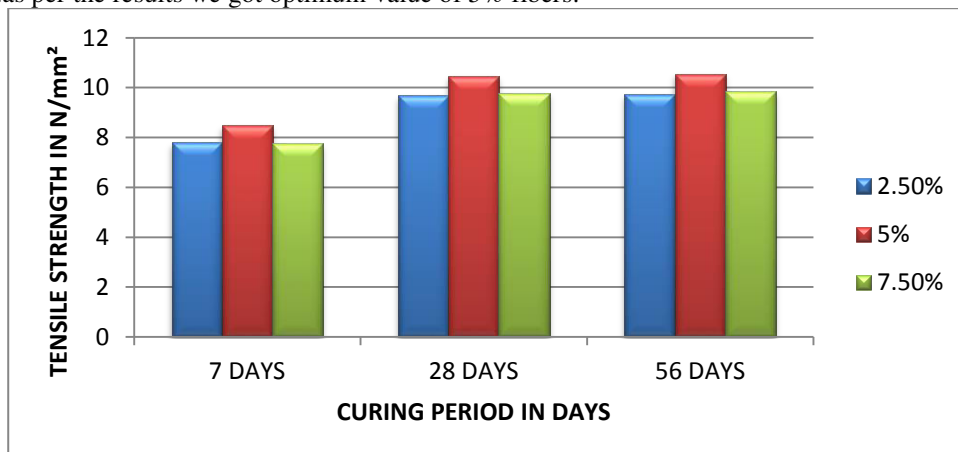


fig-6 :(set-3) Tensile strength versus curing period for various percentages of steel fibers along with replacement of cement with metakaolin (10%) and fine aggregate with Robo sand (50%)

International Journal of Innovative Research in Science, Engineering and Technology

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Vol. 7, Issue 4, April 2018

C. SET -4:

Cubes Compression test result

Partially replacement of cement with metakaolin (10%) and replacement fine aggregate with Robo sand (100%) & sp 4%. In this set it also consists of three mixes

MIX-10	2.5 % fibers
MIX-11	5 % fibers
MIX-12	7.5 % fibers

In variation of steel fibers along with partially replacement of cement with metakaolin (10%) and fine aggregate with Robo sand (100%) and SP4% is added to avoid the voids to increase the durability .As per result in TABLE NO: 11 there is decrease in strength at fibers of 7.5%.

Cylinder split tensile strength result

Partially replacement of cement with metakaolin (10%) and replacement fine aggregate with Robosand (100%) & SP 4%. Here the strength is decreased at 7.5% fibers. Where Robosand helps to give more strength as per the results we got the optimum value is 5%.

Table No. 12: (set-4) various percentage of steel fibers along with partially replacement of cement with metakaolin (10%) replacement fine aggregate with Robo sand (100%) & sp 4%

SPECIMEN DESIGNATION	STEEL FIBERS CONTENT	COMPRESSION STRENGTH (N/mm ²)		
		7days	28days	56days
MIX-10	2.5%	27	37.9	38.9
MIX-11	5%	33.03	43.64	44.82
MIX-12	7.5%	29.64	39.01	40.01

In fig-7 the results gives the optimum value at 5% fibers with replacement of cement with metakaolin 10%and And fine aggregate with Robo sand 100%

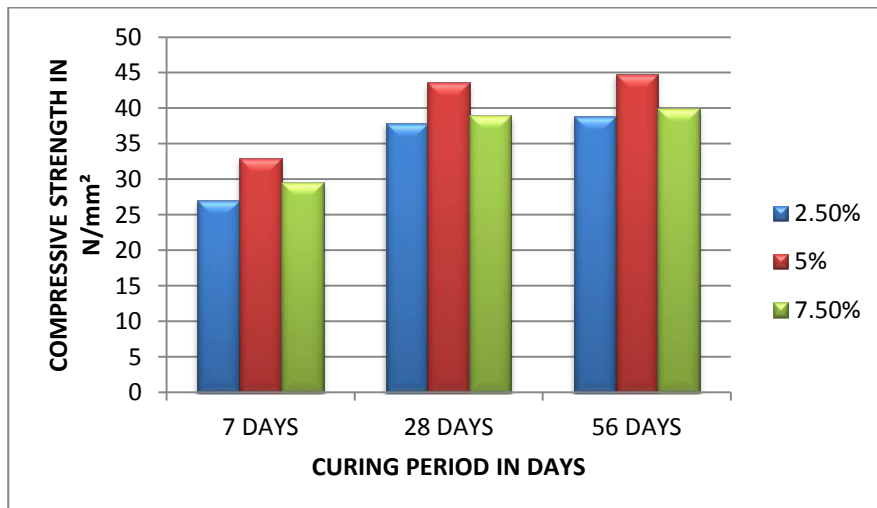


Fig-7 : (set-4) Compression Strength verses curing period for various percentages of steel fibers along with replacement of cement with metakaolin (10%) and fine aggregate with Robo sand (100%)

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(A High Impact Factor, Monthly, Peer Reviewed Journal)

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Vol. 7, Issue 4, April 2018

In table no.12 there is increase of strength at 2.5% fibers, 5% fibers. There is decrease of strength at 7.5% fibers. As per results when compared to conventional there is a good strength criterion but as per when compared to steel fibers content there is decrease of strength

Table No. 12: (set-4) various percentage of steel fibers along with partially replacement of cement with metakaolin (10%) replacement fine aggregate with Robo sand (100%) & sp 4%

SPECIMEN DESIGNATION	STEEL FIBERS CONTENT	Split Tensile STRENGTH (N/mm ²)		
		7days	28days	56days
MIX-10	2.5%	7.03	9.01	9.03
MIX-11	5%	8.7	10.8	10.9
MIX-12	7.5%	7.17	8.65	8.1

In fig-8 the tensile strength variation got optimum value of 5% fibers .when compared to remaining 2.5% & 7.5% fibers .where superplasticizer help to improve the workability and reduces the pores on the casting specimen

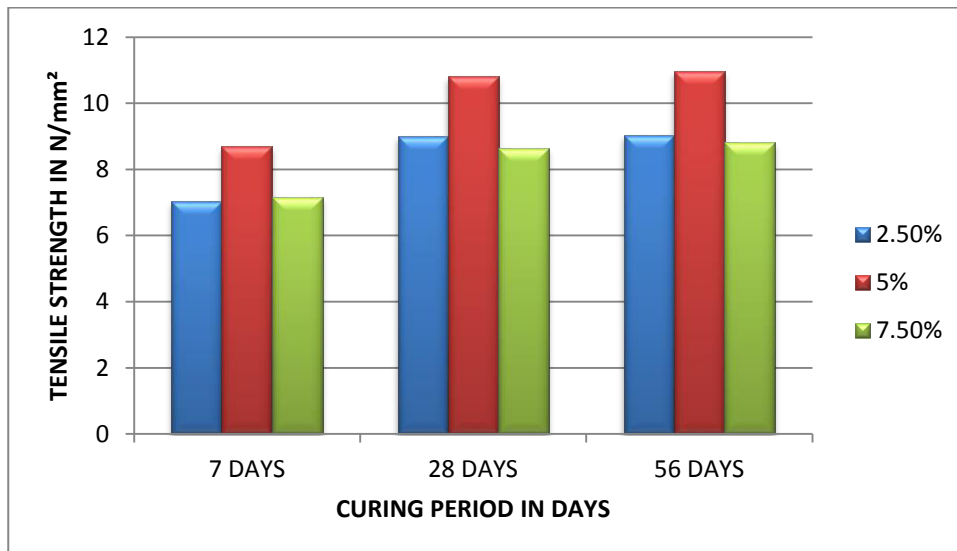


FIG-8: (set-4) Tensile strength versus curing period for various percentages of steel fibers along with replacement of cement with metakaolin (10%) and fine aggregate with Robo sand (100%)

VII. RESULTS DISCUSSION

Based on the compressive and tensile strength tests the optimum values from set 1 & set 2 are taken to get the ultimate strength. Based on the steel fibers alignment and the fibers content the ultimate strength values are obtained. For my aim of this paper is to study the partially replacement of cement with metakaolin and fine aggregate with Robo sand we got the target strength at set-3 i.e., partially replacement of cement with metakaolin at 10% and fine aggregate with Robo sand 50%. Steel fibers help to interlock the slurry and gives high strength. It should be noted that 5% of steel fibers, 10% of metakaolin and Robo sand 50% got target strength. As the amount of increase of steel fibers there is occurrence of cracks will be more and bonding will not be proper.

International Journal of Innovative Research in Science, Engineering and Technology

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Vol. 7, Issue 4, April 2018

VIII. CONCLUSION

- It is observed that strength is increasing base on the fiber alignment and fiber content.
- The inclusion of metakaolin as a partial replacement of cement provides an excellent improvement in developing the strength compared to conventional.
- As per the results the compressive and tensile strength of SIFCON for cubes and cylinder which contain a combination of 5% fibers, 10%metakoalin, 50% Robo sand is larger than cubes and cylinder specimen with only 5% fibers.
- The optimum values are significantly improved results over controlled SIFCON specimen under 56 days curing.
- From the workability tests it was observed that SIFCON is self-compactable and has better workability.

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