ISSN 2321-2926

STRENGTH AND DURABILITY INVESTIGATION ON STEEL FIBRE REINFORCED CONCRETE

K.Tarun Kumar[1], P.Sudheer[1], G.Ashok Kumar[1], B.Sai[1], D.Ganesh[1], B. Govindarajulu[2], P. Dinakar[2]

[1]B. Tech Student, Department of Civil Engineering, Aditya Institute of Technology and Management, Tekkali,Andhra Pradesh
[2]Assistant Professor, Department of Civil Engineering, Aditya Institute of Technology and Management, Tekkali,Andhra Pradesh

Abstract: *This research aims to undertake the laboratory investigations to study the effects of varying fibre contents on the mechanical properties such as compressive strength and durability properties by the acid attacks with 1% diluted hydro chloric acid (HCL) and 1% diluted sulphuric acid (H2SO4). The samples are cured for the 7 days and 28 days. The experimental results of SFRC are discussed on M30 grade of concrete with the hooked steel fibres dosage of 0.2%, 0.4%, 0.6%, 0.8%, 1% by the weight of the concrete. The result shows the strength and durability properties of SFRC with varying dosages of steel fibres enhanced in comparison with conventional and chemical immersion.*

Key words: Steel fibre reinforced concrete (SFRC),Strength and Durability

1. BACKGROUND OF THE STUDY

This concept was first introduced by Romualdi and Baston. Concrete is the most widely used structural material in the world with an annual production of over seven billion tons. For a variety of reasons, much of this concrete is cracked.

The reason for concrete to suffer cracking may be attributed to structural, environmental or economic factors, but most of the cracks are formed due to the inherent weakness of the material to resist tensile forces. Again, concrete shrinks and will again crack, when it is restrained.

It is now well established that steel fibre reinforcement offers a solution to the problem of cracking by making concrete tougher and more ductile. It has also been proved by extensive research and field trials carried out over the past three decades, that addition of steel fibres to conventional plain or reinforced and pre-stressed concrete members at the time of mixing/production imparts improvements to several properties of concrete, particularly those related to strength, performance and durability.

The weak matrix in concrete, when reinforced with steel fibres, uniformly distributed across its entire mass, gets strengthened enormously, thereby rendering the matrix to behave as a composite material with properties significantly different from conventional concrete.

Steel Fiber Reinforced Concrete (SFRC) is a revolutionary construction material that combines the durability of concrete with the enhanced mechanical properties provided by steel fibers. In SFRC, small, discontinuous steel fibers are added to the concrete mix to improve its tensile strength, ductility, toughness, and resistance to cracking. This innovative reinforcement technique offers numerous advantages over conventional concrete, making it an increasingly popular choice for a wide range of construction applications.

The introduction to steel fiber reinforced concrete typically highlights its key features and benefits, including:

Increased Strength and Durability: The addition of steel fibers significantly enhances the tensile strength and flexural capacity of concrete, making it better able to withstand heavy loads and external forces. This results in structures that are more durable and resistant to cracking and deformation.

Improved Crack Control: Steel fibers act as micro-reinforcement throughout the concrete matrix, effectively controlling the formation and propagation of cracks. This leads to reduced crack width and improved overall performance under various loading conditions.

Enhanced Toughness and Ductility: SFRC exhibits greater toughness and ductility compared to conventional concrete, allowing it to absorb more energy before failure. This makes it particularly suitable for applications where impact resistance and structural integrity are critical, such as industrial floors, pavements, and tunnel linings.

Design Flexibility: Steel fiber reinforced concrete offers greater design flexibility, allowing for thinner sections, longer spans, and reduced reinforcement requirements compared to traditional concrete structures. This can result in cost savings and more efficient construction processes.

Overall, steel fiber reinforced concrete offers a versatile and cost-effective solution for a wide range of construction projects, providing superior strength, durability, and performance compared to traditional concrete. As the construction industry continues to evolve, SFRC is poised to play an increasingly important role in shaping the future of infrastructure development.

1.1 GENERAL

Concrete is a composite material that is widely used in construction. It is made from a mixture of aggregate (fine, coarse), cement, water and other materials. The cement paste binds the aggregate together and hardens over time. Concrete is strong, durable, and relatively inexpensive, making it a popular choice for a variety of construction projects.

Concrete has been a fundamental material in construction for centuries, offering structural stability and versatility. However, traditional concrete possesses certain limitations, especially in terms of tensile strength, cracking resistance, and durability under harsh environmental conditions. In response to these challenges, various methods of reinforcement have been explored to enhance concrete's mechanical properties and longevity.

One such innovation is Steel Fiber Reinforced Concrete (SFRC), which incorporates steel fibers into the concrete mixture. These fibers act as reinforcement, bridging the micro-cracks that typically form in concrete, thereby improving its tensile strength and resistance to cracking. SFRC has garnered significant attention in recent years due to its potential to overcome the shortcomings of conventional concrete and enhance the performance of structural elements in construction projects.

By exploring the viability of SFRC as a sustainable alternative to conventional concrete, this study aims to promote the adoption of environmentally friendly construction practices. Through systematic experimentation and analysis, this research endeavours to advance the understanding of SFRC and its potential as a high-performance construction material. The findings of this study have the potential to inform engineering practices, facilitate innovation in construction technology, and contribute to the development of more resilient and sustainable infrastructure.

2. OBJECTIVES OF THE STUDY:

The main objective of this study is to provide comprehensive insights into the effectiveness of compressive strength and durability on steel fiber reinforced concrete.

Specific objectives

1. The main objective of this study to provide comprehensive insights into the effectiveness of compressive strength and durability on steel fibre reinforced concrete.
2. To provide insights into how different dosages of hooked steel fibres enhance the strength and durability of SFRC compared to conventional curing and subjected to chemical immersion.
3. To provide an overview of concrete, including its composition, properties, and uses.
4. To explain the process of mixing, placing, and curing concrete.
5. To provide information on the strength, durability of concrete.
6. To discuss the different results of concrete and their applications.
7. To find out the impact of Reverse Logistics process on quality management.

3. METHODOLOGY OF THE STUDY

3.1 INTRODUCTION:

Concrete cubes are commonly used in construction projects for testing the compressive strength of concrete mixes. To create concrete cubes, several key materials are required.

3.2 MATERIALS USED:

- CEMENT
- FINE AGGREGATE
- COARSE AGGREGATE
- WATER
- HOOKED STEEL FIBRE
- DILUTED HYDRO CHLORIC ACID (HCL)
- DILUTED SULPHURIC ACID (H_2SO_4)


Steel fiberCoarse aggregate

CementDiluted acids

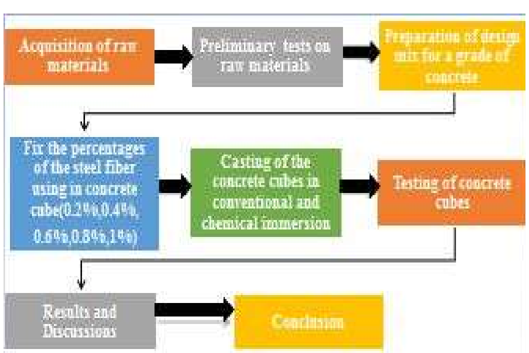


Fig.3.2 Methodology flow chart

- **Acquisition of raw materials:** Procurement process for cement, aggregates, water, and steel fibers.
- **Preliminary tests on raw materials:** Quality checks to ensure materials meet standards.
- **Preparation of design mix:** Determination of concrete mix proportions
- **Fixing steel fiber percentages:** Selection of percentages (0.2%, 0.4%, 0.6%, 0.8%, 1%) for inclusion in concrete mix.
- **Casting of concrete cubes:** Preparation and casting of SFRC cubes.
- **Conventional and chemical immersion:** Treatment of cubes under standard curing conditions and chemical immersion.
- **Testing of concrete cubes:** Conducting compression tests and other relevant tests on cubes.

3.3 TESTS ON MATERIAL:

In summary, testing of materials is essential for ensuring the quality, performance, and durability of concrete structures, while also contributing to cost efficiency, regulatory compliance, and risk management in construction projects.

1.**Quality assurance**: Testing helps ensure that the raw materials used in concrete production meet specific standards and quality requirements. This is essential for the consistency and reliability of the final concrete product.

2.**Performance prediction**: By conducting tests on raw materials, engineers and construction professionals can predict the performance of concrete in terms of strength, durability, workability, and other important properties. This information is vital for designing concrete mixes that meet project requirements.

3.**Optimization of mix proportions**: Testing allows for the optimization of mix proportions to achieve desired properties in concrete. Through trial and error, adjustments can be made to the mix design based on material test results to enhance performance and efficiency.

4.**Compliance with standards and regulations**: Many construction projects are subject to regulatory requirements and standards governing the quality of materials used in concrete production. Testing ensures compliance with these standards, thereby mitigating legal risks and ensuring the safety and longevity of structures.

5.**Quality control during production**: Regular testing during concrete production serves as a quality control measure to detect any deviations or inconsistencies in material properties. This allows for timely adjustments to be made to maintain the desired quality of the final product.

6.**Risk mitigation**: Testing helps identify potential weaknesses or deficiencies in raw materials that could compromise the integrity or performance of concrete structures. By addressing these issues early on, the risk of structural failures or premature deterioration can be minimized.

4. LITERATURE REVIEW

In this chapter, a brief description of steel fiber reinforced concrete and its strength and durability and overview on the historical development and applications of SFRC and review of studies investigating the relationship between steel fiber parameters and concrete properties.

- **Marcos-Meson &V. Fischer (2019)** Durability of Steel Fibre Reinforced Concrete (SFRC) exposed to acid attack.It has been observed that severe exposure of SFRC to acids leads to loss of binder and strength in concrete and eventually loss of section.It has been found that steel fibre high strength concrete (SFHSC) is not suitable for hygrothermal curing compared to normal strength concrete.
- **N. Dsouza et.al (2018)**Strength and durability aspects of steel fibre reinforced concrete.It has been observed that by adding steel fibres there was increase in the compressive strength in SFRC more than that of conventional concrete. The maximum percentage increase in compressive strength was achieved at 1.5% of fibre dosage. The main purpose of the present study is to examine the influence of metal fibers on the leaching of concretes in aggressive media. To do this, it was deemed necessary to follow the evolution of the mechanical characteristics and certain durability indicators of fiber-reinforced concretes and others without fibers that were immersed in several acidic solutions, namely HCl, H_2SO_4 and CH_3COOH, over a period of 135 days. The same operation was repeated with the NH_4NO_3 solution.
- **Job Thomas& Ananth Ramaswamy (2017)** Mechanical Properties of Steel Fibre-Reinforced Concrete.The maximum increase in the compressive strength due to the addition of steel fibres was found to be quite small less than 10% in various grades of concrete. The maximum increase in the tensile strength, namely split tensile strength due to the addition of steel fibres, was found to be about 40% in various grades of concrete. The study indicates that the fiber matrix interaction contributes significantly to enhancement of mechanical properties caused by the introduction of fibers, which is at variance with both existing models and formulations based on the law of mixtures.
- **P. Vamsi et.al (2016)** Durability Studies on Steel Fibre Reinforced Concrete.Steel fibres were found to be effective to acid resistance and Compressive strength decreased with increase in fibre dosage when subjected to acid curing compare to normal curing. The experimental investigation was focused on the effect of various fiber dosages to resist the chemical attack. Mix proportion was designed using IS 10262-2009 [5] and IS 456-2000 [6] with mean target strength of 38.25 MPa (M30) for control mix. Ordinary Portland cement.
- **G. Velayutham&Cheah (2014)** The Effects of Steel Fibre on the Mechanical Strength and Durability of Steel Fibre Reinforced high strength Concrete (SFRHSC) Subjected to Normal and Hygrothermal Curing.It has been found that steel fibre high strength concrete (SFHSC) is not suitable for hygrothermal curing compared to normal strength

5.RESULTS AND DISCUSSIONS

5.1 General:

ISSN 2321-2926

Details of laboratory experiments carried out with strength and durability on steel fiber reinforced concrete have been discussed in the previous chapter. In this Chapter a detailed discussion on the results obtained from various laboratory tests are presented. Further, the results of the track constructed on the SFRC (Steel fiber reinforced concrete) also discussed.

5.2 Preliminary laboratory test results:

In the laboratory, we conducted many tests to estimate the index properties of concrete materials like fineness, specific gravity, bulking of sand etc.. and also, we calculate the compressive test and durability test results .

Table:5.1

Tests on cement:

S.No.	Description	Test result	Range	Code book
1	Fineness	2.5%	<10%	IS:4031(P-1)-1988(1)
2	Normal consistency	32%	26 to 34%	IS:4031(P-4)-1988(2)
3	Initial setting time	38mins	min.30 minutes	IS:4031(P-5)-1988(3)
4	Final setting time	420mins	max.600minutes	IS:4031(P-5)-1988(4)
5	Specific gravity	3.12	Around 3.15	IS:4031(5)
6	soundness	1.3mm	<10 mm	IS:4031(P-3)-1988(6)

Table: 5.2

Tests on fine aggregate:

S.No.	Description	Test result	Range	Code book
1	Specific gravity	2.66	2.6-2.9	IS:2386(P-3)-1963(1)
2	Fineness modulus	2.65	2-4	IS:2386(P-4)-1963(2)
3	Bulking of sand	28%	20 to 40%	IS:2386(P-3)-1963(3)

Table: 5.3

Tests on coarse aggregate:

S.No.	Description	Test result	Range	Code book
1	Specific gravity	2.74	2.6 to 2.9	IS:2386(P-3)-1963(1)
2	Fineness modulus	8.71	6.5 to 9	IS:2386(P-1)-1963(2)

Table: 5.4

Workability tests:

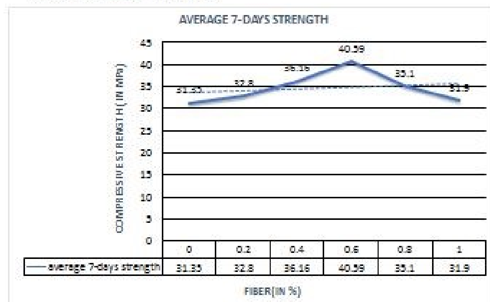
S.No.	Description	Test result	Range	Code book
1	Slump cone	29mm	25 - 50mm	SP:23-1982(1)
2	Compaction factor	0.8	0.80 - 0.85	SP:23-1982(2)
3	Vee – bee consistometer	8 sec	5 - 10 sec	SP:23-1982(3)

3.3 Strength and durability test results:

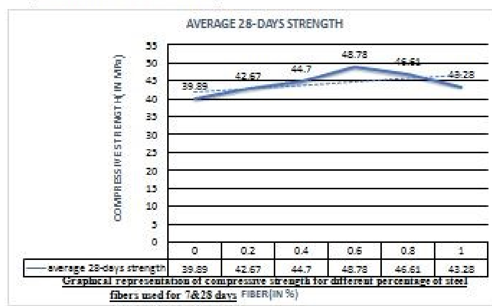
Table: 5.5

S.No.	FIBER PERCENTAGE	No.of days	Sample-1 in MPa	Sample-2 in MPa	Sample-3 in MPa	Average in MPa
1.	0%	7 days	31.36	31.32	31.39	31.35
		28 days	39.72	40.19	39.76	39.89
2.	0.2%	7 days	32.74	33.01	32.66	32.8
		28 days	42.60	42.56	42.87	42.67
3.	0.4%	7days	36.83	35.29	36.36	36.16
		28 days	44.85	44.57	44.69	44.7
4.	0.6%	7days	39.76	42.5	39.52	40.59
		28 days	48.46	49.23	48.65	48.78
5.	0.8%	7days	35.29	35.17	35.01	35.1
		28 days	46.43	46.9	46.52	46.61
6.	1.0%	7days	31.38	32	32.36	31.9
		28 days	43.04	43.08	43.72	43.28

concrete cubes under 7- days curing

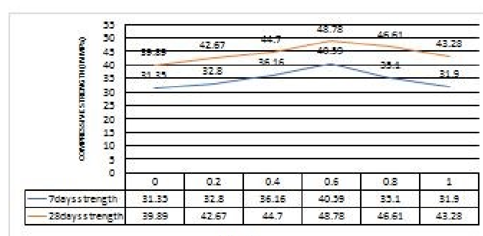


Graphical representation of compressive strength for different percentage of steel fibred concrete cubes under 28-days curing



Graphical representation of compressive strength for different percentage of steel fibers used for 7&28 days

12



Variation of compressive strength of M30 grade concrete mixes at 7&28 days curing

The compressive strength of cubes after 7 & 28 days of curing for all the concrete mixes of M30 grade concrete are shown in below table. The variation of compressive strength with 7 &28 days of curing for all the concrete mixes. It is observed that the compressive strength of concrete mix 0.6% fiber cubes has shown maximum value when compared to all the other mixes at 7&28 days curing period.

Mix	Fiber percentage	Compressive strength (Mpa) at 7 days curing	Compressive strength (Mpa) at 28 days curing
1	0%	31.35	39.89
2	0.2%	32.80	42.67
3	0.4%	36.16	44.7
4	0.6%	40.59	48.78
5	0.8%	35.10	46.61
6	1%	31.90	43.28

Values of compressive strength of M30 grade concrete mixes at 7&28 days curing

Mix	Fiber percentage	Original compressive strength (Mpa) at 7 days curing	Changed compressive strength (Mpa) at 7 days curing
1	0%	39.89	32.13
2	0.2%	42.67	39.74
3	0.4%	44.70	41.37
4	0.6%	48.78	42.33
5	0.8%	46.61	42.13
6	1%	43.28	41.62

RESULTS OF ACID CURING CUBES

Variation of weights of M30 grade concrete mixes at days of HCL curing

The weights of cubes after 14 days of acid curing for all the concrete mixes of M30 grade concrete are shown in below table. The variation of weights with 14 days of curing for all the concrete mixes. It is observed that the compressive strength of concrete mix 0.6% fiber cubes has shown maximum value when compared to all the other mixes at 14 days curing period.

Weights of M30 grade concrete mixes at 14 days HCL curing

Table 5.8:

Mix	Fiber percentage	Original Weights of samples in H_2SO_4 curing (In Kg)	Changed Weights of samples in H_2SO_4 curing (In Kg)
1	0%	8.07	8.05
2	0.2%	8.11	8.09
3	0.4%	8.27	8.19
4	0.6%	8.22	8.17
5	0.8%	8.17	8.16
6	1%	8.29	8.22

7-DAYS COMPRESSIVE TEST RESULTS OF ACID CURING CUBES

Variation of compressive strength of M30 grade concrete mixes at 7 days of HCL curing

The compressive strength of cubes after 7 days of curing for all the concrete mixes of M30 grade concrete are shown in below table. The variation of compressive strength with 7 days of HCL curing for all the concrete mixes. It is observed that the compressive strength of concrete mix 0.6% fiber cubes has shown maximum value when compared to all the other mixes at 7 days HCL curing period.

Values of compressive strength of M30 grade concrete mixes at 7 days HCL curing

Table 5.9:

Table 5.9:

Mix	Fiber percentage	Original compressive strength (Mpa) at 7 days curing	Changed compressive strength (Mpa) at 7 days curing
1	0%	39.89	32.13
2	0.2%	42.67	39.74
3	0.4%	44.70	41.37
4	0.6%	48.78	42.33
5	0.8%	46.61	42.13
6	1%	43.28	41.62

Variation of compressive strength of M30 grade concrete mixes at 7 daysH_2SO_4 curing

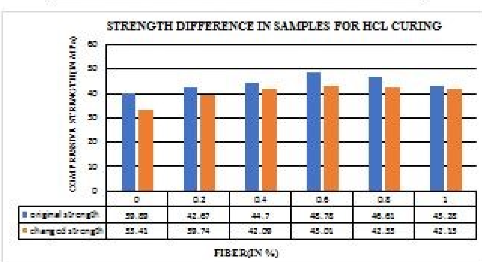
The compressive strength of cubes after 7 days of curing for all the concrete mixes of M30 grade concrete are shown in below table. The variation of compressive strength with 7 days of H_2SO_4 curing for all the concrete mixes. It is observed that the compressive strength of concrete mix 0.6% fiber cubes has shown maximum value when compared to all the other mixes at 7 days H_2SO_4 curing period.

Values of compressive strength of M30 grade concrete mixes at 7 days H_2SO_4 curing

Table 5.12:

Mix	Fiber percentage	Original compressive strength (Mpa) at 7 days curing	Changed compressive strength (Mpa) at 7 days curing
1	0%	39.89	33.72
2	0.2%	42.67	38.93
3	0.4%	44.70	41.26
4	0.6%	48.78	43.72
5	0.8%	46.61	42.22
6	1%	43.28	39.16

14-DAYS COMPRESSIVE TEST RESULTS OF ACID CURING CUBES



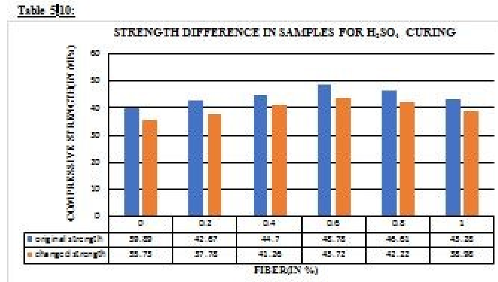
Variation of compressive strength of M30 grade concrete mixes at 14 days HCL curing

Mix	Fiber percentage	Original compressive strength (Mpa) at 14 days curing	Changed compressive strength (Mpa) at 14 days curing
1	0%	39.89	33.41
2	0.2%	42.67	39.74
3	0.4%	44.70	42.09
4	0.6%	48.78	43.01
5	0.8%	46.61	42.33
6	1%	43.28	42.13

The compressive strength of cubes after 14 days of curing for all the concrete mixes of M30 grade concrete are shown in below table. The variation of compressive strength with 14 days of HCL curing for all the concrete mixes. It is observed that the compressive strength of concrete mix 0.6% fiber cubes has shown maximum value when compared to all the other mixes at 14 days HCL curing period.

Values of compressive strength of M30 grade concrete mixes at 14 days HCL curing

Table 5.10:



Variation of compressive strength of M30 grade concrete mixes at 14 days H_2SO_4 curing

The compressive strength of cubes after 14 days of curing for all the concrete mixes of M30 grade concrete are shown in below table. The variation of compressive strength with 14 days of H2SO4 curing for all the concrete mixes. It is observed that the compressive strength of concrete mix 0.6% fiber cubes has shown maximum value when compared to all the other mixes at 14 days H2SO4 curing period.

Values of compressive strength of M30 grade concrete mixes at 14 days H_2SO_4 curing

6.CONCLUSION

Based on the analysis of experimental results and discussions there upon the following

Mix	Fiber percentage	Original compressive strength (Mpa) at 14 days curing	Changed compressive strength (Mpa) at 14 days curing
1	0%	39.89	35.73
2	0.2%	42.67	37.78
3	0.4%	44.70	41.26
4	0.6%	48.78	43.72
5	0.8%	46.61	42.22
6	1%	43.28	38.98

1.The compressive strength of normal concrete and concrete with steel fibres are compared and observed that the strength of normal concrete is lesser than the steel fibre reinforced concrete.

2.The compressive strength increases with increase in percentage of steel fibres up to 1 % by weight of coarse aggregate.

3.From the results of compressive strength of 7 and 28 days curing, 0.6% of steel fibres by weight of coarse aggregate having the highest strength for M30 grade concrete.

4.From the durability tests the maximum strength value obtained at 0.6% of steel fibres and 0.4% sample are come closer to it.

REFERENCES

1.Marcos-Meson, V.Fischer, G.Edvardsen, C.Skovhus, T.L. and Michel, A., 2019. Durability of Steel Fibre Reinforced Concrete (SFRC) exposed to acid attack–A literature review. Construction and Building Materials, 200, pp.490-501.

2.N.Dsouza, N.N.Patil, and Rajashekhar Swamy, 2018. Strength and durability aspects of steel fibre reinforced concrete. Int J CivEngTechnol, 9(7), pp.948-957

3.J.Thomas, A.Ramaswamy, 2017. Mechanical properties of steel fibre-reinforced concrete. Journal of materials in civil engineering, 19(5), pp.385-392.

4.P.V. Krishna, and N.S.Rao , 2016. Durability studies on steel fibre reinforced concrete. Proc. International journals of engineering and technology, 3(08).

5.G. Velayutham, and C.B.Cheah, 2014. The effects of steel fibre on the mechanical strength and durability of steel fibre reinforced high strength concrete (SFRHSC) subjected to normal and hygrothermal curing. In MATEC Web of Conferences (Vol. 10, p. 02004). EDP Sciences.