Mechanical Behaviour of Fibre Reinforced Concrete Under Aggressive Conditions

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***Abstract* - In the present scenario, use of concrete as a structural material is limited to certain extent by deficiencies like brittleness, poor tensile strength, and poor resistance to impact strength, low ductility and low durability. In this study, experimental investigation on the compressive and tensile strengths behavior of P.C.C cubes and cylinders by using Steel fibers in concrete mix and Glass Fiber of thickness 12MM are used. Crimped steel fibers and glass fiber are used and mixed in ratios of 0%, 0.5%, 1.0%, and 1.5% of cement quantity. The grade of cement is 53 and concrete is M40. 2.75mm passed fine aggregate and 20mm size of coarse aggregates is used. Super plasticizer Conplast SP430 is added. Destructive tests are performed to find out the compressive strength and split tensile strength of adopted grade of concrete. These tests are carried out to the specimen's failure in order to understand a specimen's performance or behavior under different loads. The test results show that the strength of the concrete increases with increase in fiber percentage up to certain percentage therefore it is decreasing. Fly ash blended concrete shows considerable resistance to sulphate attack. The strength of the concrete is optimum at 1% of glass fiber and 0.5% of steel fiber. Overall, the glass fiber shows great increment of strength when compared to steel fibers.**

***Index Terms* - Concrete, Fiber reinforced concrete, Glass Fiber, Steel fibers.**

1.INTRODUCTION

1.1 General

Concrete is the most common constructive material in the world used for around centuries due to its very strong and versatile mouldable nature. There are number of reasons why concrete is preferable i.e. due to its ability to withstand deterioration, resistance to high temperature and it is economically cheapest and readily available constructive material with the mixture of cement, fine aggregate, coarse aggregate, water. Concrete being such strongest material, is also being deteriorated due to environmental problems. The effect due to such pollution is questioning the strength properties of concrete which leads to collapse of the structure.

The pollution here, in this research, refers to the different kinds of chemicals that react with the concrete structure such as different industrial wastes that have been dumped into the land, so when construction in such areas takes place then the chemicals that are present reacts with the concrete structure and may damage the integral properties of concrete. Also, when the construction activity takes place offshore then the salts present in the sea water also may cause damage to the concrete structure not directly but by the prolonged chemical reactions that take place.

Hence it seems necessary to improve the ability or to improve the mechanical properties of concrete in different ways possible so that the chemicals or the salts present in the surrounding environment of concrete does not affect the properties of the concrete structure. The properties of concrete can be enhanced by the use of different fibres, mineral and natural admixtures. Many researches have been made and many developments have been done on the durability and strength properties of concrete so that it should sustain for a long period irrespective of any environmental conditions.

1.2 Environmental effect on concrete

The role of concrete and how does it fit in this world of construction industry is simple but wide ranging. There may be limitations but the concrete as a construction material is highly used and identified as a provider of nations infrastructure to economic progress and to quality of life. It is so easily and readily prepared and fabricated into all sorts of conceivable shapes and structural systems in the realms of infrastructure, habitation, transportation, work and play. Its great simplicity lies in that its constituents are most readily available anywhere in the world; the great beauty of concrete, and probably the major cause of its poor performance, on the other hand, is the fact that both the choice of the constituents, and the proportioning of its constituents are entirely in the hands of the engineer and the technologist.

The most important and outstanding quality of the material is inherent alkalinity, providing safe mechanism and non-corroding environment for steel reinforcement embedded in it. Long experience and a good understanding of its material properties have confirmed this view and shown us that concrete can be a reliable and durable construction material when it is built in sheltered conditions, or not exposed to aggressive environments or agents. There is also considerable evidence even when exposed to moderately aggressive environments, concrete can be designed to give long trouble-free service life provided care and control are exercised at every stage of its production and fabrication which is followed by maintenance schemes and well-planned inspection.

1.3 Deterioration and cracking of concrete

It is now well established that the record of concrete as a material of everlasting durability has been greatly impaired, for no fault of its own, by the material and structural degradation that has, nevertheless, become common in many parts of the world .The major reasons for this apparent fall from grace are numerous -partly out of the perceived image of concrete as a material of enduring quality that needs no maintenance, and as a medium that will not deteriorate; and partly by the assumption that somehow the permeability of concrete and protection of the embedded steel against external aggressive agencies will be automatically and adequately provided for by the cover thickness and the presumed quality of concrete. Experience has shown that neither can be assumed as a normal and natural consequence of the process of concrete fabrication. It can be readily seen that there is a fundamental problem in the construction industry - with choice of materials, design, construction, maintenance, repair and rehabilitation.

The three major factors that encourage the transport of aggressive agents into concrete, and influence significantly its service behaviour, design life and safety are cracking, depth and quality of cover to steel, and the overall quality of the structural concrete. These three factors have an interactive and interdependent, almost synergistic, effect in controlling the intrusion into concrete of external aggressive agents such as water, air, chloride and sulphate ions. Chloride and sulphate ions, atmospheric carbonation, and the corrosive effects of the oxides of nitrogen and sulphur, are recognized to be the most potentially destructive agents affecting the performance and durability of concrete structures, whilst the depth of cover, concrete quality, and cracking are the most critical factors in determining the electrochemical stability of steel in concrete.

1.4 Durability and sustainability considerations

It is well-established that the incorporation of industrial by products such as PFA, slag and Rice Husk Ash in concrete can significantly enhance its basic properties in both the fresh and hardened states. Apart from enhancing the properties and controlling bleeding of fresh concrete, these materials greatly improve the durability of concrete through control of high thermal gradients, pore refinement, depletion of cement alkalis, resistance to chloride and sulphate penetration and continued micro-structural development through long term hydration and pozzolanic reactions. Further, concrete can provide, through chemical binding, a safe haven for many of the toxic elements present in industrial wastes; and there are strong indications that these mineral admixtures can also reduce the severity of concrete deterioration problems arising from chemical phenomena such as alkali silica reaction and Thomasite formation.

A critical evaluation of the world scenario described above emphasizes the complex but close interrelationship between three seemingly unrelated but gigantic problems that confront the construction industry, namely The insatiable infrastructure needs of a rapidly growing and urbanizing world coupled with the desire for a better quality of life of nations suffering from a lack of availability and accessibility to world resources, global warming, and the consequent destruction of infrastructure through natural disasters. The need to achieve a balance between economic development and protection of environment the crises in the area of materials and durability. Sustainability implies that the needs of the present generation are met without wasting, polluting or damaging/destroying the environment, and without compromising the ability of future generations to meet their needs. In the construction industry, sustainable development would involve, amongst others, design for durable and functional service life of structures for the duration of their specified design life. Use of waste materials, reduction of waste and recycling of waste. Construction to cause the least harm to our environment.

1.5 Concrete curing in different environmental conditions

The actual important part of any structure or any building would always be its foundation and if the foundation is capable of bearing all the loads that are being transferred to it and most importantly if it can sustain any environmental condition then it would be an ideal one. As we discussed about the environmental pollutions above, the main theme of this study is to develop a concrete mix which would be capable of overcoming different acidic environmental conditions. The acidic environmental conditions lead us to the fact of constructions that are done in aggressive soils and offshore constructions.

Aggressive soils are the one which has traces of acids present in it, which are often caused by industrial wastes being dumped into the ground and an offshore construction is where the foundation is literally present in the sea water. Any concrete that could withstand these environmental conditions gives strength and sustainability to the structures for a long period. We encounter acidic environmental conditions where the soil present beneath has a Ph value of about 6.5 and it is strongly acidic if the Ph value is about 5.5 to 4. Due to the vast amount of pollution caused from industrial wastes, many acids are being dumped into the soil which causes the formation of aggressive soils. The soils that are highly acidic with the presence chemicals such as HCL and H2SO4 and other harmful acids are often termed as aggressive soils.

Salt in seawater has no significant negative effects on the characteristics of the hardened concrete, and, if durability problems occur, they are mainly related to the corrosion of steel reinforcement rather than the effect on concrete properties. Typically, concrete provides a safe environment for steel, protecting it from corrosion and any other forms of deterioration. However, this protection will dissipate when chlorides are present within the concrete. The critical chloride content also referred to as the chloride threshold limit, is defined as the concentration of chlorides that causes the steel to transform from a passive state where no corrosion is occurring, to an active state, where corrosion may begin to occur. Once chloride threshold is reached, as expected in seawater concrete, a flow of electricity occurs from one area of the steel bar (i.e. anode) to another (i.e. cathode) through the bar's surrounding (i.e. electrolyte). This electrochemical reaction results in forming hydroxide on the cathode's side of the steel bar, which in turn react with iron to form rust (iron oxide), and hence corrosion initiates. Rusting continues to expand causing severe cracks in the concrete substrate and significant deterioration of reinforcement section According to ACI 201.2R-08 Guide for Durable Concrete (2008), a maximum chloride content of 0.20% by cement mass is allowed for reinforced concrete placed in dry or protected environmental conditions. However, for the case of reinforced concrete placed in wet environments, the maximum ratio of the chloride content is 0.1% by cement mass.

Acid attack is the dissolution and leaching acid-susceptible constituents, mainly calcium hydroxide, from the cement paste of hardened concrete. this action results in an increase in capillary porosity, loss of cohesiveness and eventually disintegration, especially when the structure is subjected at one side to water pressure. unlike sulphate attack, the products formed from acid attack are not expansive, and leaching will only occur in structure that are relatively permeable. In high performance concrete system containing cement pastes with a low content of calcium hydroxide, acid attack is relative slow and may involve only the finely divided calcium hydroxide crystals incorporated in the interstices of the calcium silicate hydrates, C-S-H. The micrographs obtained from PFM analysis, supplemented with SEM-EDS studies, reveal that only the top, surface portion of the concrete has been attacked by acidic solution. The rest of the concrete shows no form of deterioration. In the attacked zone ,there is clear evidence of leaching of the cement paste matrix ,leading to increased capillary porosity and loss of cohesion of the matrix. Locally, there is loss of bonding of the cement paste to aggregate, but on the whole, these aspects have not adversely affected the microstructure and the quality of the concrete .in this insistence, long-term durability of the concrete is not likely to be compromised.

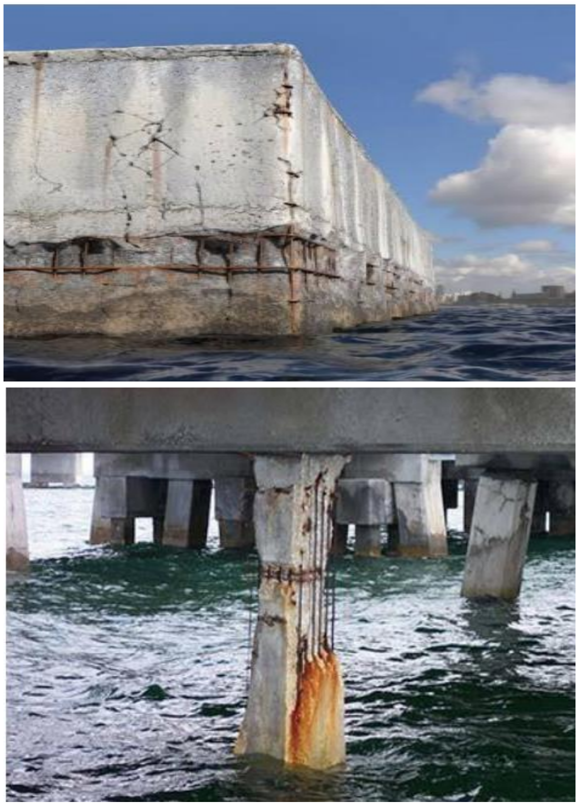


Figure: Deterioration of concrete due to aggressive conditions

2. FIBRE REINFORCED CONCRETE

The usage of fibres in concrete can improve the performance of concrete. Fiber-reinforced concrete (FRC) is concrete which contains fibrous material that increases its structural integrity. When the short discrete fibers are uniformly distributed or randomly oriented in the mix of concrete then it is called fibre reinforced concrete. These fibres form matrix material and provides strength. There are different types of fibres available based on material like steel fibres, glass fibres, polypropylene fibres, asbestos fibres, carbon fibres, organic fibres. The main usage of fibres in concrete is to increase durability and tensile strength properties. The properties that are enhanced by the use of fibres are compressive strength, flexure, toughness, split tensile strength, fatigue strength, impact resistance and overall structural behaviour.

3. OBJECTIVES OF RESEARCH

1. To compare the mechanical properties like compressive strength and tensile strength of steel and glass fibre reinforced concrete.
2. To study the behaviour of steel and glass fibre reinforced concrete under saline water and aggressive soil condition which means soil treated with hydrochloric acid (HCL) and sulphuric acid (h2so4).
3. To assess the depth of penetration of harmful elements and identify the traces of acids.
4. To study the microstructure of concrete in saline water and in aggressive soils.

5. SCOPE OF RESEARCH

1. To obtain proper mix proportions according to the IS.
2. For the future building codes and the IS to permit sea water for the curing of concrete thus we could save the critical resources especially in coastal areas where there is rapid infrastructural growth and the climatic or the environmental aggressiveness increasing.
3. Constantly improving the sustainability of concrete that leads to significant environmental and technological advances resulting in the cost saving and preserving the precious resources like fresh water.
4. To conduct compressive strength test and split tensile strength test on cubes and cylinders by adding steel and glass fibres in various percentages to the conventional concrete by IS methods.

Literature Review

Teja R. Patil and Ajay N. Burile concluded that the addition of steel fibers at 0.5 % by volume of concrete reduces the cracks under different loading conditions. The brittleness of concrete can also be improved by addition steel fibers than glass fibers. Since concrete is very weak in tension, the steel fibers are beneficial in axial-tension to increase tensile strength.

A.P.Modak and G.P.Deshmukh concluded maximum compressive strength for M20 Grades of concrete was obtained by addition of 1.5%. It is observed that compressive strength increases from 8 to 21% for 7 days ,6 to 12% for 28 days. Workability of concrete increases by the use of steel fibre reinforced concrete.

Qingfu Li and Qiuyu Zhang (2019), the experimental results for concrete specimens with FA and GGBS indicated that the compressive strength at early curing stage, such as 1 and 3 days, decreases with an increasing of content FA, and initially increases with an increasing of content of GGBS and then decreases beyond the critical content. At the later stage, the compressive strength of concrete specimens with FA and GGBS has a similar regulation that the test value increases firstly and then decreases with the content of admixtures increasing. The importance of w/c in compressive strength and shrinkage of concrete is obvious. With the increasing of w/c, the compressive strength and shrinkage of concrete decreases by degrees.

Akinsola Olufemi Emmanuel, Fatokun Ajibola Oladipo and Ogunsanmi Olabode E. (2012) The findings revealed that concrete sample cast and cured with fresh water gained appreciable compressive strength over 150 days period while sample cast and cured with ocean and lagoon water slowly increase in strength but lower when compared with fresh water reinforced concrete element. Therefore, the study recommended that a rich mix other than 1:3:6 and 1:3:5 i.e. after trials 1:2:4 be strictly enforced on construction sites for concrete under saline attack, increase concrete cover be used for protection against corrosion, and that non-destructive test be carried out on all formworks under vertical loads like slabs and beams before they are stripped.

Jose B. Aguiar, Aires Camoes and Pedro M. Moreira (2008) The obtained results indicate that the overall performance of epoxy resin was better than the other selected types of protections.

The performance of the used protected concretes against chemically aggressive environments was generally better than the performance of the unprotected concretes. The used epoxy coated concrete achieved the best results in all the chemical environments that include

chlorides, sulphates, one acid and one base. The composition of the concretes is an important factor talking about performance against chemically aggressive environments. The unprotected and the protected concrete with higher cement content and lower water-cement ratio performed better than the others concretes, against penetration of chlorides, due to the less porosity. Related to sulphates and sulphuric acid attacks, unprotected and protected concretes that performed best, were made with the lower cement content and the higher water-cement ratio. The high porosity is good to accommodate expansions caused by reactions that occur during these attacks.

Venkata Rambabu V and Amit B Mahindrakar **(2017)** concluded weathering agents will influence the fresh and hardened properties of concrete and an essential research has to be done to enable concrete to fill its role. Water cement ratio is one of factor dominating the performance of concrete. Ordinary Portland can be replaced by Portland pozzolana cements, but it needs study. Epoxy resins may be used to come over the problems of corrosion, but it needs study. Addition of admixtures is needed to meet the demands. Reduction pores in concrete will serve better in environment. Type of curing adopted in m arine regions will play a lead role for sustainability of concrete.

Mix proportions for trail:
Cement = 390 kg/ m³
Water =152 litre
Fine aggregate = 678 kg
Coarse aggregate = 1220 kg
Super plasticizer = 2.81 kg
Water Cement ratio = 0.43

Therefore, mix proportion for M40 grade is;
Cement: fine aggregate: coarse aggregate: water:
1 : 1.73: 3.13 : 0.43

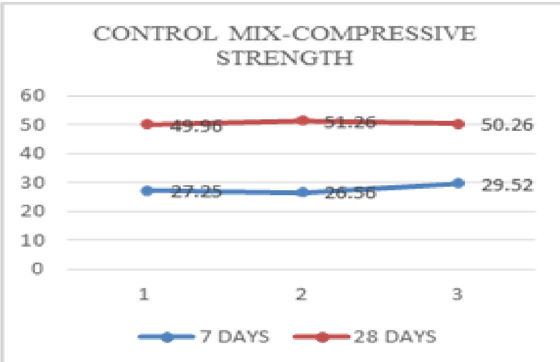
5. EXPERIMENTAL STUDY

The materials were collected, and the required tests were conducted as per the Indian standards. Based on the trail mixes and the observation the materials were mixed at specified proportions and the specimens were prepared at the standard conditions and are tested in the laboratory.

6. RESULTS AND DISCUSSIONS

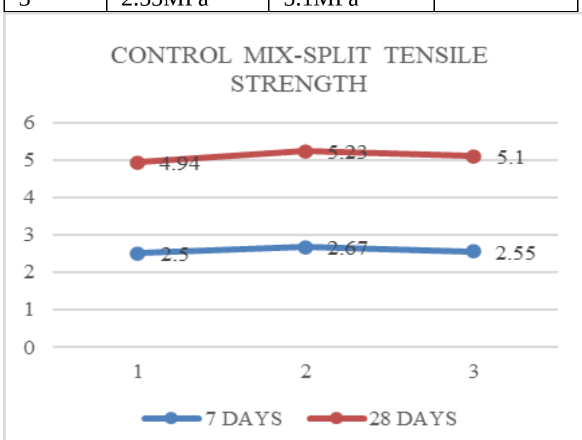
The test results such as compressive strength, split tensile strength of hardened concrete cubes of grade M40 of steel fibres and glass fibres which are mixed in the percentages of 0%, 0.5%, 1%, 1.5% along with the addition of 25% of fly ash. The tests are conducted at the ages of 7 days, 28 days and after curing in the different chemical solutions.

S.NO	COMPRESSIVE STRENGTH		
	7 DAYS	28 DAYS	AVERAGE
1	27.25MPa	49.96MPa	50.49MPa
2	26.56MPa	51.26MPa	
3	29.52MPa	50.26MPa	



Graph: Graph of control mix compressive Strength

S.NO	COMPRESSIVE STRENGTH		
	7 DAYS	28 DAYS	AVERAGE
1	2.5MPa	4.94MPa	5.09MPa
2	2.67MPa	5.23MPa	
3	2.55MPa	5.1MPa	



Graph: Graph of control mix split tensile Strength

Table: Glass Fibre and Constant Flyash Under Normal Curing

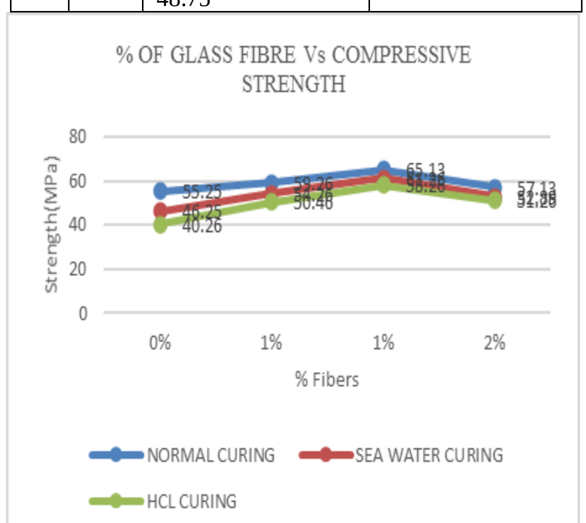
S. No	Mix %	Compressive Strength After 56 Days(Mpa)	Average Compressive Strength(Mpa)
1	0	56.26	55.25
		55.25	
		54.26	
2	0.5	59.26	59.26
		60.27	
		58.26	
3	1	63.26	65.13
		65.46	
		66.67	
4	1.5	58.26	57.13
		57.59	
		55.56	

Table: Glass Fibre and constant Fly ash Under Sea Water Curing

S. No	Mix %	Compressive Strength After 56 Days(Mpa)	Average Compressive Strength(Mpa)
1	0	45.12	46.25
		46.36	
		47.27	
2	0.5	56.01	54.26
		55.53	
		51.24	
3	1	60.31	61.26
		61.45	
		62.02	
4	1.5	53.81	52.89
		51.69	
		53.17	

Table: Glass Fibre and Constant Flyash Under Hcl Curing

S. No	Mix %	Compressive Strength After 56 Days(Mpa)	Average Compressive Strength(Mpa)
1	0	38.36	40.26
		40.12	
		42.3	
2	0.5	49.88	50.46
		52.16	
		49.34	
3	1	59.63	58.26
		57.20	
		57.95	
4	1.5	51.21	51.26
		53.82	
		48.75	



Graph: Graph of glass fiber V/s compressive strength

Table: Steel Fibre And Constant Flyash Under Normal Curing

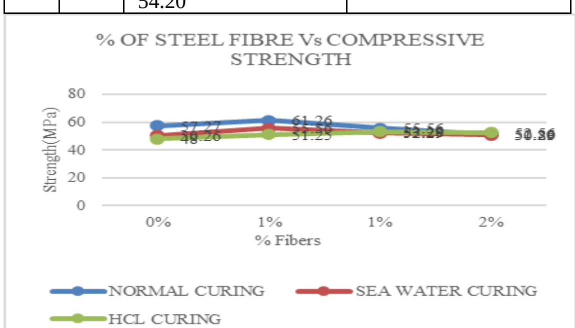
S. No	Mix %	Compressive Strength After 56 Days(Mpa)	Average Compressive Strength(Mpa)
1	0	56.66	57.27
		55.12	
		60.03	
2	0.5	60.80	61.26
		62.11	
		60.87	
3	1	53.89	55.56
		56.31	
		56.48	
4	1.5	50.28	51.26
		51.66	
		51.84	

Table: Steel Fibre and Constant Flyash Under Sea Water Curing

S. No	Mix %	Compressive Strength After 56 Days (Mpa)	Average Compressive Strength(Mpa)
1	0	49.08	50.26
		50.22	
		51.48	
2	0.5	53.98	55.56
		54.11	
		58.59	
3	1	50.98	52.29
		52.75	
		53.14	
4	1.5	48.78	50.89
		51.22	
		52.67	

Table: Steel Fibre And Constant Flyash Under Hcl Curing

S. No	Mix %	Compressive Strength After 56 Days(Mpa)	Average Compressive Strength(Mpa)
1	0	46.66	48
		48.54	
		48.80	
2	0.5	53.12	51.25
		52.11	
		48.52	
3	1	52.65	53.28
		54.12	
		53.07	
4	1.5	51.32	52.56
		52.16	
		54.20	



Graph: Graph of Steel Fiber Vs compressive strength

SPLIT TENSILE STRENGTH TEST:

Table: Glass Fibre and Constant Flyash Under Normal Curing

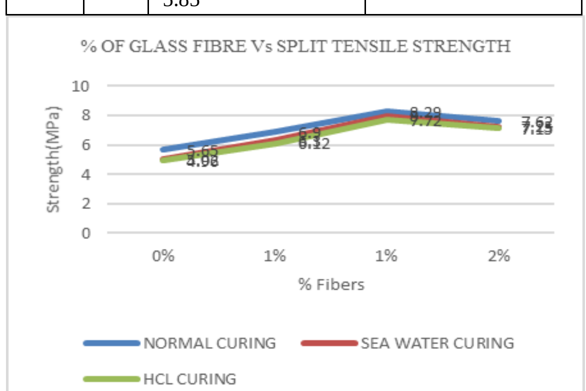
S.No	Mix %	Split Tensile Strength After 56 Days(Mpa)	Average Split Tensile Strength(Mpa)
1	0	5.02	5.65
		6.78	
		5.15	
2	0.5	6.74	6.90
		5.82	
		8.14	
3	1	8.01	8.29
		6.89	
		9.97	
4	1.5	5.97	7.62
		8.78	
		8.11	

Table: Glass Fibre and Constant Flyash Under Sea Water Curing

S. No	Mix %	Split Tensile Strength After 56 Days(Mpa)	Average Split Tensile Strength(Mpa)
1	0	5.43	5.02
		4.99	
		4.64	
2	0.5	7.34	6.3
		6.11	
		5.45	
3	1	7.34	8.0
		8.52	
		8.14	
4	1.5	6.64	7.25
		8.96	
		6.15	

Table: Glass Fibre and Constant Flyash Under Hcl Curing

S.No	Mix %	Split Tensile Strength After 56 Days(Mpa)	Average Split Tensile Strength(Mpa)
1	0	3.67	4.96
		5.31	
		5.90	
2	0.5	5.66	6.12
		8.02	
		4.68	
3	1	6.87	7.72
		8.87	
		7.42	
4	1.5	7.06	7.15
		8.54	
		5.85	



Graph: Graph of glass fiber Vs split tensile strength

Table: Steel Fibre And Constant Flyash Under Normal Curing

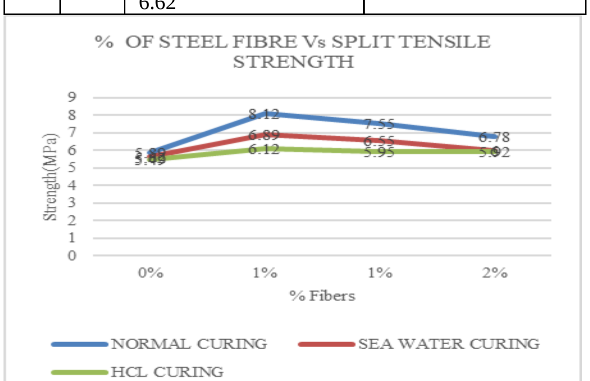
S. No	Mix %	Split Tensile Strength After 56 Days(Mpa)	Average Split Tensile Strength(Mpa)
		5.06	
1	0	4.92	5.89
		7.69	
		7.12	
2	0.5	8.76	8.12
		8.48	
		8.92	
3	1	7.21	7.55
		6.52	
		7.82	
4	1.5	6.55	6.78
		5.97	

Table: Steel Fibre and Constant Flyash Under Sea Water Curing

S. No	Mix %	Split Tensile Strength After 56 Days(Mpa)	Average Split Tensile Strength(Mpa)
		5.11	
1	0	6.72	5.62
		5.03	
		6.66	
2	0.5	7.23	6.89
		6.78	
		5.98	
3	1	7.65	6.55
		6.02	
		5.95	
4	1.5	6.00	6.00
		6.05	

Table: Steel Fibre and Constant Flyash Under Hcl Curing

S. No	Mix %	Split Tensile Strength After 56 Days(Mpa)	Average Split Tensile Strength(Mpa)
		5.32	
1	0	5.61	5.49
		5.54	
		6.02	
2	0.5	5.89	6.12
		6.45	
		6.45	
3	1	5.98	5.95
		5.42	
		6.02	
4	1.5	5.12	5.92
		6.62	



Graph: Graph of steel fiber Vs split tensile strength

7.CONCLUSIONS

Based on the study, following conclusions may be drawn.

- Strength of the concrete increases with increase in fiber percentage up to certain percentage therefore it is decreasing.
- Fly ash blended concrete shows considerable resistance to sulphate attack.
- The strength of concrete is optimum at 1% of glass fiber and 0.5% of steel fiber.
- There is an increment of 29.04% of compressive strength at 1% glass fiber under normal curing is observed.
- There is an increment of 21.37% of compressive strength at 0.5% steel fiber under normal curing is observed.
- There is an increment of 62.86% of split tensile strength at 1% glass fiber under normal curing is observed.
- There is an increment of 59.52 % of split tensile strength at 0.5% steel fiber under normal curing is observed.
- There is a decrement of strength in case of seawater curing and HCL curing in both cases.
- Overall, the conclusion is that glass fibers shows great increment of strength when compared to steel fibers.

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