

Comparative Study On The Structural Performance Of M25 And M30 Grade Concrete With Industrial Slag And Sisal Fiber Integration

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Abstract- The rapid growth of the construction sector has intensified the demand for sustainable alternatives to natural aggregates and traditional concrete additives. This experimental study evaluates the structural feasibility of incorporating iron ore slag waste as partial replacements for natural coarse aggregates in M25 and M40 grade concrete. Furthermore, the study explores the synergistic effect of natural sisal fiber integration on the mechanical performance of the optimized mix. Coarse aggregates were replaced with iron ore slag at substitution levels of 20%, 40%, and 60% by weight. Mix proportions were designed following the IS 10262:2019 standard. The fresh and hardened properties of the concrete, including workability, compressive strength, and split tensile strength, were rigorously tested at 7 and 28-day curing intervals. The investigation identified the optimum replacement ratio that balances structural integrity with workability. To address the inherent brittleness of the concrete mixes, sisal fibers were subsequently integrated into the identified optimum mix at 0.5% increments (up to 2% by volume). The results demonstrate the comparative performance of the slag-replaced concrete against the control mix, highlighting the influence of fiber reinforcement on tensile strength and crack resistance. This research provides a critical framework for the utilization of industrial by-products in civil engineering, demonstrating that while aggregate replacement affects workability, strategic fiber integration can effectively mitigate strength degradation, leading to more sustainable and cost-effective construction materials.

Keywords- Industrial Slag, Sisal Fiber, Sustainable Concrete, Compressive Strength, Aggregate Substitution, Construction Waste, workability, compressive strength, split tensile strength test, water absorption test.

I. INTRODUCTION

Concrete is composite material which consists of cement, coarse aggregate, fine aggregate and water in required proportions. Concrete is a material which used for the purpose of construction in now a days. Due to its composite nature concrete is weak in tension but strong in compression. Basic Principle involved in the increase in strength of concrete is heat of Hydration. Generally in design of concrete mix, cement, fine aggregates and coarse aggregates are using from a long years back. These three materials only play a crucial

role in designing of a particular grade of concrete. But now a days there is a scarcity in aggregates. So, some new materials which are very near to our surroundings and some type of materials have to be introduce for replacing the fine aggregates, coarse aggregates and as well as cement to get the same strength as that these basic materials can give.

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So, we have to search for different materials to reduce the quantity of basic natural materials in the concrete mix without changing any mix design procedure and considerations. We cannot replace the whole basic material in the concrete, but some extent we can replace with other materials. There are some research were done on waste materials which are very near to our surroundings like crushed plastic, Stone dust, over burnt bricks, M – sand , glass powder, coconut shells, waste tires, slag, fly ash produced from industries, broken glass pieces, rich husk ash, coconut shell ash, etc. to use them in concrete mix along with basic natural aggregates. In their methodologies, some of the above materials were used to replace the cement and some of the materials used to replace the aggregate. In those researches observed that these materials can be used in some extent percentages.

The increase in demand for the ingredients of concrete is met by partial replacement of materials by the waste materials which is obtained by means of various industries. Iron ore Slag is a byproduct of metal smelting and hundreds of tons of it are produced every year all over the world in the process of refining metals and making alloys. Iron ore slag can be use in the construction industry as aggregate in concrete by replacing natural aggregates.

This experimental study is based on the performance of concrete by replacement of aggregate with waste iron ore slag with different percentages 0, 10%, 20%, 30%, and 40%. This project describes the feasibility of using the waste iron ore slag in concrete production as replacement of coarse aggregate and effective percentage of Iron ore slag would be determined for obtaining maximum strength by conducting workability compressive strength and tensile strength tests.

The objective of the present study was to investigate

experimentally the properties of Concrete with the following test results

- Workability
- Compressive strength
- Flexure strength
- Tensile strength

II. REVIEW OF LITERATURE

The usage of industrial by-products especially industrial wastes in making of concrete is an important study of worldwide interest. Many researchers have investigated the possible use of Iron ore slag as a concrete aggregate. For this investigation, some of the important literatures were reviewed and presented briefly. This research is supported with the related reading material previous research about the Iron ore slag which had been done as the references to describe more and explain the characteristic and application of Iron ore slag as partial replacement in the concrete production. So far the reutilization Iron ore slag and has been practiced, but the amount of wastes reused in that way is still negligible. Hence, the need for its application in other industries is becoming absolutely very useful for getting benefit. Construction industry can be the end user of all tile wastes and in the same way can contribute Green building practices.

Albano et al. (2009) in this study include concrete with 10% of reused plastic waste show a compressive force that happen the average strength ideals for concrete with medium strength in the middle of 21 & 30 MPa aimed at curing time of 28 days. They testified that the compressive force at the stage of 28 days is close the standards for 60 days. Each issues were occupied in attention such by way of the kind of disappointment and the creation of honeycombs, small workability, element size which are answerable for minor compressive force of concrete covering plastic collection than concrete covering ordinary collection. The decrease in compressive force was additionally in concrete covering greater crumbling plastic collection than minor one.

Quasrawi et al. (2009) conducted a research on the utilization of steel slag as fine aggregate. Compressive strength and 28-day tensile strength tests were performed based on different slag ratios. The results indicated the improvement of compressive strength for replacement slag ratios of 15-30% and tensile strength for replacement slag ratios of 30-50%. The total substitution of natural fine aggregate with crystallized slag affects positively the tensile, flexural and compressive strength. The partial substitution of natural aggregate with slag aggregates permits a gain of strength at long term. The entire substitution of fine aggregates with slag aggregates should be avoided, it affects negatively the strength.

Frigione (2010) establishes minor values of splitting tensile strength in material covering plastic collection ready consuming great water/cement value than in parallel mix ready at little w/c value. Through exchanging 5% by weight of fine collection (natural sand) per an equal mass of plastic collection man-made from the unwanted plastic bottles. Example with dissimilar cement contented and water cement relation were man-made.

P.S.Kothai, et.al (2014), this work relates the use of Iron ore slag, a waste cheap material used as fine aggregates in M20 grade of concrete and recommends the approval of the material for use in concrete as a replacement material for fine aggregates. The partial substitution of natural aggregates with Iron ore slag aggregates permits a gain of compressive, tensile and flexural strength and modulus of elasticity of concrete up to an optimum value of replacement. The following benefits can also be obtained: Cost reduction, Social benefits & Mass utilization of waste material is possible in construction by using Iron ore slag as a partial replacement material for fine aggregates in concrete.

P. Vignesh Kumar, et.al (2014), in this study of partial replacement of coarse aggregate with iron slag in the cement concrete have greater strength than the conventional concrete. As the self-weight of this concrete is higher. The polypropylene fibres are free from water absorption. With improved understanding of the link between fibre characteristics and composite or structural performance. In 25% iron slag used the compressive strength decreased 1% and split tensile strength also decreased. If the addition of 30% and 35% of the iron slag used. Increased compressive strength in concrete. The compressive strength of the concrete is increased 4% and 5% compared then the conventional concrete. 30 and 35% of the addition of iron slag is 6% increased split tensile strength and flexural strength compared than conventional concrete.

R.Kalpan, et.al (2014), this research has shown that replacing some percentage of natural aggregates by Iron ore slag aggregates causes negligible degradation in strength. It is shown that as the amount of Iron ore slag is increased beyond 75%. The results showed that replacing about 50 to 75% of Iron ore slag aggregates by volume for natural aggregates will not do any harm to concrete and also it will not have any adverse effects on the strength and durability. Whole study was done by both the aggregates were replaced by crystallized & granular aggregates. The coarse aggregate were partially replaced by Iron ore slag of about 10% and 20%. The fine aggregate were partially replaced by Iron ore slag mill scale of about 40% and 50%. This partial replacement of coarse and fine aggregates with Iron ore slag and Iron ore slag mill scale will increase the strength of about 30% to 50%. The main aim of this research was to study the behavior of concrete and changes in the

properties of concrete with Iron ore slag and Iron ore slag mill scale by replacing the use of natural aggregates.

P.Sateesh Kumar, et.al (2015), this paper aims to study experimentally, the effect of partial replacement of fine aggregate by Iron ore slag (ss), on the various strength and durability properties of concrete by using the mix designs the optimum percentage of replacement of fine aggregate by Iron ore slag is found. The compressive strength, flexural strength and split tensile strength of normal concrete and concrete with Iron ore slag as partial replacements are compared and observed that the strength of the normal concrete is slightly lower than the Iron ore slag replaced concrete. The compressive strength increases with increase in percentage of Iron ore slag up to 40% by weight of fine aggregate. The enhancement in compressive strength is about 32% for 7 days curing and 27.2% for 28 days curing. The split tensile strength increases with increase in percentage of Iron ore slag up to 40% by weight of fine aggregate. The enhancement in split tensile strength is about 48.2% for 7 days curing and 31.2% for 28 days curing.

T. Subbulakshmi, et.al (2016), experiments were conducted to study mechanical properties of high-performance concrete with different percentage replacement of mineral admixture and industrial byproducts such as silica fume, bottom ash and Iron ore slag aggregate. Presence of calcium hydroxide layer at the aggregate surfaces as reported extensively for conventional concrete is not seen in high performance concrete because of usage of combination mix of silica fume, bottom ash and slag by-products and presence of partially hydrated cement grains in conventional concrete matrix and the ITZ. It is widely reported that the permeability of concrete reduces drastically with inclusion of silica fume. Iron ore slag aggregate mix of concrete shows that the presence of ettringite indirect contact with aggregate of calcium hydroxide film in the ITZ of normal concrete. A combined model developed using inputs from compressive strength of concrete predicts more accurately and it is recommended to be used alone to predict strength of concrete.

S. Premaet.al., (2017) Makes the findings that; Oil palm shell is a waste from agricultural sector and available in large quantities. It aims at analyzing the compressive strength characteristics of concrete produced using crushed, granular coconut as substitute for conventional coarse aggregate with partial replacement. The experimental programme was to investigate the best mix proportion of combination of CS as coarse aggregate in concrete and feasibility of combination of CS as CA in concrete. As per experimental analysis it was concluded that coconut shell can reduce the material cost, and it is more suitable as low strength giving light weight aggregate in concrete production.

From all the above literature reviews, it was evident that Iron ore slag can be used as aggregate replacement individually in concrete mix. The optimum percentage of replacement was also identified for all materials individually. But there was no literature available on the utilization of all the above mentioned replacement in the same concrete mix. Hence it is planned to use Iron ore slag as coarse aggregate replacement as an ingredient of the concrete..

III. MATERIALS AND METHODS

The experimental investigation work is started with various tests on the constituent materials. The constituent materials are given below.

- Cement
- Coarse aggregate
- Water
- Iron ore slag
- Sisal fiber
- Conplast sp 430(G)
- Water

1. *Cement*

Ordinary Portland cement of 43 grades manufactured by Shree Ultratech Cement was used throughout the Experimental investigation. The quality of the cement was confirming to IS 8112:1989 was used in the field.

2. *Fine Aggregate*

Fractions from 4.75 mm to 150 microns are termed as fine aggregate. Locally available river sand passed through 4.75mm IS sieve is applied as fine aggregate conforming to the requirements of IS 383:1970.

3. *Coarse Aggregate*

Coarse aggregate shall be of hard broken stone of granite shall be of hard stone, free from dust, dirt and other foreign matters. The stone ballast shall be of 20mm and down and should be retained in 5mm square mesh and well graded such that the voids do not exceed 42 percent. Aggregate most of which is retained on 4.75-mm IS Sieve and containing only so much finer material as is permitted for the various types described in this standard.

4. *Iron ore slag*

At present the use of Iron Slag in concrete gives environmental and economic benefits for concerned industries, especially in places where a considerable amount of Iron Slag is produced. Owing to the scarcity of sand for the

preparation of mortar as well as concrete, partial and fully replacement of Iron Slag with sand have been attempted. Iron Slag are by-products obtained during smelting and refining of Iron Slag. Iron ore is crushed and allowed to pass through various processes in the manufacture of iron in mines and in this process large volume of coarse particles of iron ore is generated. They are known as iron ore slag. The slag obtained has properties similar to that of aggregate and can be used for construction purposes. Ayano T, Sakata K. (2000), proposed a theory on concrete and this theory provides the feasibility of the usage of iron ore as hundred percent substitutes for Conventional Concrete..

5. Sisal fibre

Sisal fiber is gaining popularity in construction as a sustainable, low-cost natural reinforcement for concrete. Derived from the Agave sisalana plant, these fibers are used to address one of concrete's primary weaknesses: its brittleness and tendency to crack.



Fig 3.1 Sisal fiber

IV. MIX DESIGN

The property of workability, therefore, becomes of vital importance. The mix design is done as per IS 10262-2009. Percentage dosage of super plasticizer (high range water reducers) is an additional parameter to be considered for designing an OPC mix. Percentage dosage of super plasticizer was fixed as per the mix design method described in IS 10262- 2009. Mix proportion was arrived through various trial mixes. The grade of concrete prepared for the experimental study was M25 & M40.

V. RESULTS AND DISCUSSIONS

5.1 INTRODUCTION

In this chapter, concepts of experimental work are presented. Objective of testing, i.e. ordinary Portland cement, fine aggregate, coarse aggregate, potable water, Iron Slag, process of manufacturing of concrete, workability of fresh concrete and testing of hardened concrete procedures are explained in

details.

It was proposed to investigate the properties of concrete, cast with partial replacement of coarse aggregate with 20%, 40% and 60% by Iron Slag. In this experimental work, physical properties of materials used in the experimental work were determined. M25 & M45 grade concrete was mixed and cured in potable water. Compressive strength, flexural strength for various mixes then studied the durability with addition of nylon fibres of varied percentages.

5.2 SLUMP TEST

Slump test was carried out to measure the workability of various mixes. The workability of various mixes was assessed as per the IS 1199:1959 specification. The minimum workability for MIX I may be due to the lesser fine particle size of cement which can result in higher water consumption thereby reducing workability.

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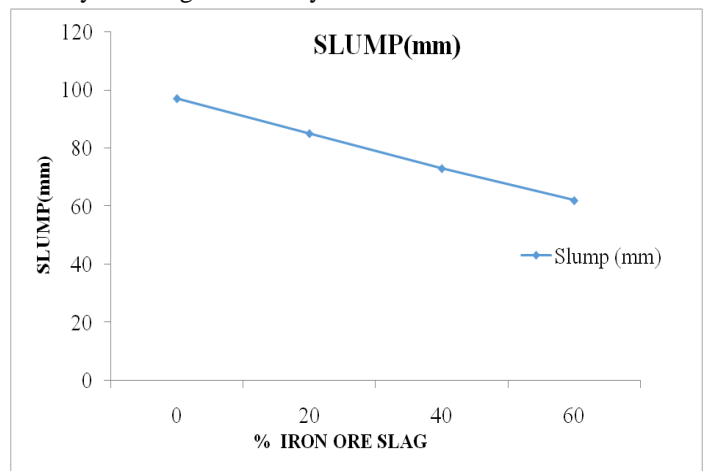


Fig 5.1: Plot shows the Variation of Slump Values for % replacement of Iron Slag

5.3 COMPRESSIVE STRENGTH

The main function of the concrete in structure is mainly to resist the compressive forces. When a plain concrete member is subjected to compression, the failure of the member takes place, in its vertical plane along the diagonal. The vertical cracks occur due to lateral tensile strain. A flow in the concrete, which is in the form of micro crack along the vertical axis of the member will take place on the application of axial

compression load and propagate further due to the lateral tensile strain.

Cubes are prepared of size 150 mm x 150 mm x 150 mm are checked for compressive strength. The specimens tested for 7, 14 and 28 days. The specimen were tested for compressive strength parallel to the plane of the board by applying increasing compressive load until failure occur. The arrangement of load is applied to the specimen by placing the specimen length vertical between the surfaces of the testing machine. Prior to that, measurement for the thickness and width was carried out in order to get the values of cross section area for the test specimens.

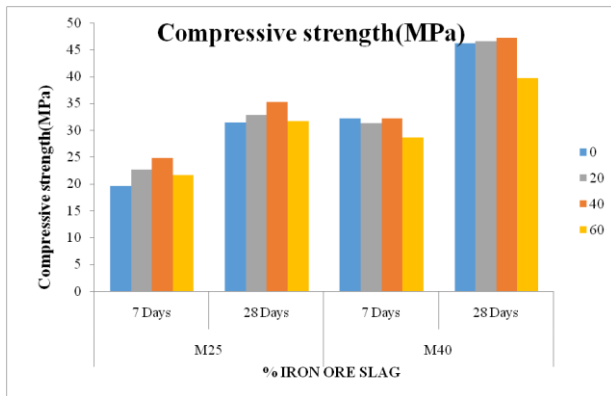


Fig 5.2 Plot shows the summarized results of variation in compressive strength for M25 & M40 Grade.

5.4 SPLIT TENSILE STRENGTH

The cylinder specimen is of the size 150 mm diameters and 300mm height was cast to determine the split tensile strength of concrete. The test is carried out by placing a cylindrical specimen horizontally between the loading surfaces of compression testing machine and the load is applied until failure of cylinder, along its longitudinal direction.

The size of specimens 150 mm dia and 300 mm length was used and the specimens were cured in normal water. Concrete specimen cubes are used to determine split tensile strength of concrete and were tested as per as per IS 516 (1959) and IS 5816 (1999). Split tensile test is also used to determine the tensile stress in concrete; this method is also called as Brazilin test. In this we place the cylindrical specimen of size 300 mm height and 150 mm diameter is placed in horizontal between the loading surfaces of compression test machine and load is applied until the failure of the specimen along the vertical diameter. This test is performed as per IS: 5816 code.

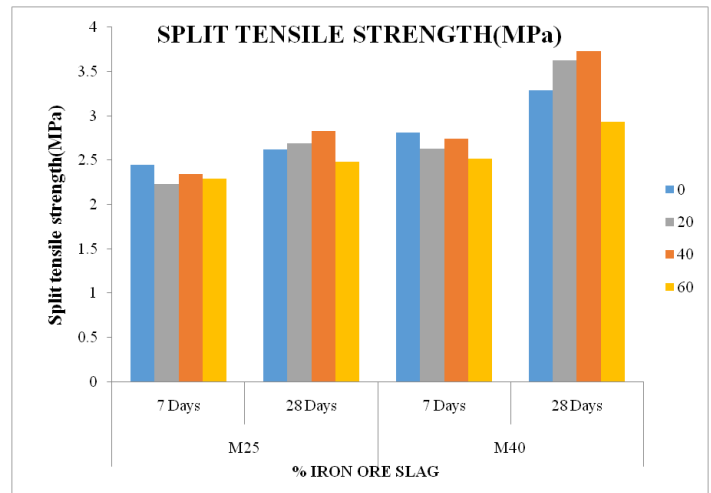


Fig 5.4 Fig 5.8: Plot shows the summarized results of variation in Split tensile strength for M25 & M40 Grade

5.5 FLEXURAL STRENGTH

The size of specimens 100 mm x 100 mm x 500 mm was used and the specimens were cured in water. Concrete specimen beams are used to determine flexural strength of concrete and were tested as per as per IS 516 (1959).

Flexural strength of concrete keeping 40% iron ore slag as constant and with different percentages of sisal fibre for curing period of 7-days, 14-days and 28-days respectively and table shows the summarized Split tensile strength Results for different curing periods– M30 grade.

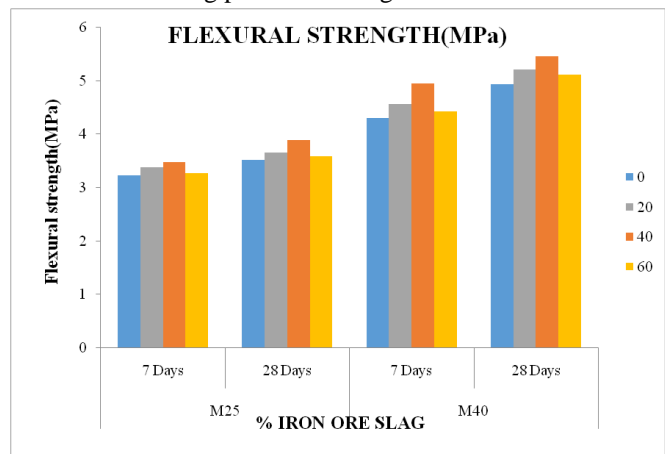


Fig 5.5: Plot shows the summarized results of variation in flexural strength for M25 & M40 Grade

As the percentage of iron ore slag increases the strength properties of concrete tends to increase up to certain percentage and then start's decreasing with the increase of iron ore slag content.

The strength of 40% iron ore slag concrete is more than 20% iron ore slag concrete and strength of 40% iron ore slag concrete is slightly more than normal concrete. This shows that till 40% iron ore slag concrete the strength increases while

percentage of iron ore slag increases.

5.6 EVALUATING THE OPTIMUM PERCENTAGE OF SISAL FIBER

Strength properties of concrete keeping 40% iron ore slag as constant and with different percentages of sisal fibres for curing period of 7-days and 28-days respectively for M40 grade.

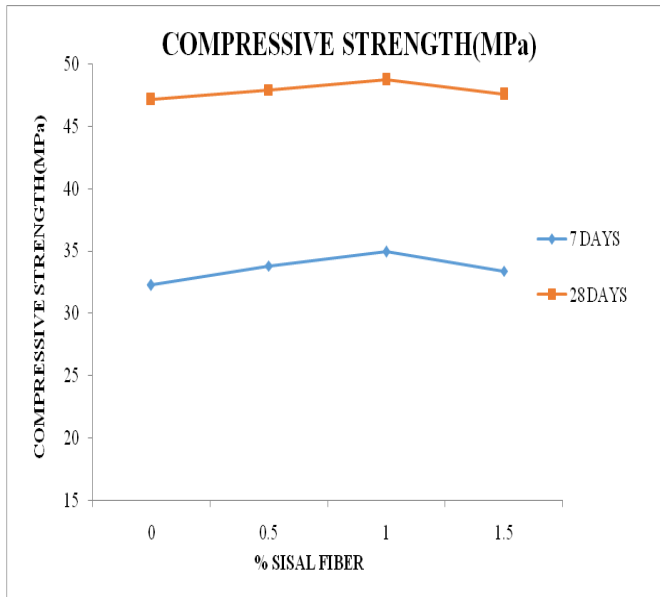


Fig 5.6: Plot shows the variation in compressive strength for different percentages of sisal fiber-M40 Grade

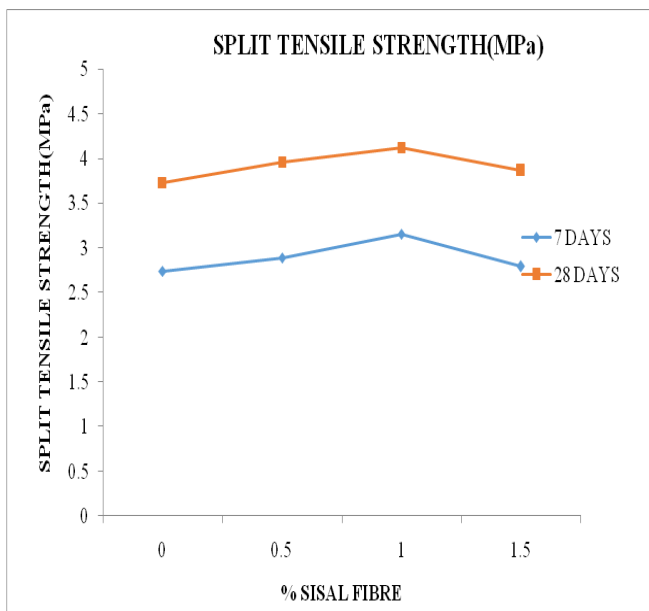


Fig 5.7: Plot shows the variation in split tensile strength for different percentages of sisal fiber-M40 Grade

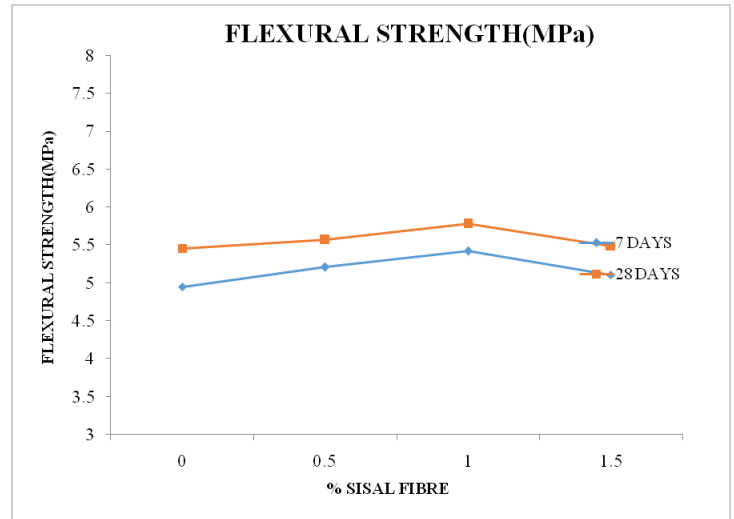


Fig 5.8: Plot shows the variation in flexural strength for different percentages of sisal fiber-M40 Grade

From the results it is evident that with the increase of fibre content the tensile nature of the concrete also increases results in higher values compared to that of Plain concrete. The figure shows that the test results of splitting tensile strength and flexural strength of specimens after water curing, it is concluded that the percentage increase in strength increases with the increase in percentage of fiber content. Also, from the results it is evident that compressive and flexural strength also increases with the increase of fiber content.

VI. CONCLUSIONS

- After completion of total experimental methodology, from the above investigations and from the test results some variations observed in workability and in strengths results of different concrete mixes having different percentages of replacing materials (Iron ore slag in place of coarse aggregate) and sisal fiber addition as reinforcement as mentioned below.

Based on the experimental investigations, the conclusions regarding the use of iron ore slag as a coarse aggregate replacement and sisal fiber as reinforcement in concrete are as follows:

Effects of Iron Ore Slag Replacement

- **Workability:** Increasing the percentage of waste iron ore slag in the concrete mix leads to a decrease in the workability of the fresh concrete.
- **Optimum Replacement Level:** The study indicates that strength properties tend to increase as the percentage of iron ore slag increases up to a certain point, after which they begin to decrease.
- **Performance at 40% Replacement:** A 40% replacement of coarse aggregate with iron ore slag resulted in an increase in compressive strength compared to the

conventional mix (0% replacement) after both 7 and 28 days of curing.

- **Performance at 60% Replacement:** When the iron ore slag replacement was increased to 60%, the compressive strength decreased for both the 7 and 28-day curing periods.

Effects of Sisal Fiber Reinforcement

- **Strength Enhancement:** The addition of 1% sisal fiber as reinforcement, while keeping 40% iron ore slag constant, further improves the strength properties of the concrete.
- **Tensile and Flexural Gains:** Due to the high elastic modulus and stiffness of sisal fibers, there was a significant enhancement in both split tensile and flexural strength. Specifically, the study noted a 25% increase in tensile strength and a 17% increase in flexural strength.

Summary of Optimum Strengths (28 Days)

- M25 Grade: The compressive strength for the optimum mix (40% iron ore slag and 1% sisal fiber) reached 35.24 MPa.
- M40 Grade: The compressive strength for the optimum mix (40% iron ore slag and 1% sisal fiber) reached 48.71 MPa.

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