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Comparative Study of Strength Parameters for Concrete with Partial Replacement of Fine Aggregates by Basalt Fiber and Glass Fiber

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Abstract: In recent years, high-performance materials have acquire significant attention in civil industrial science due to evolving requirements related to cost efficiency, safety, and environmental concerns. Among these, fiber-reinforced concrete (FRC) has came out as a highly promising material. Its advantages are mainly assigned to properties such as improved toughness (in terms of flexural & compressive strength), greater tensile strength, improved durability, and higher energy absorption capacity. This study investigates the effect of partial replacement of fine aggregate (sand) with basalt fiber and glass fiber on the mechanical properties of concrete. The experimental investigational program was conducted on M25 and M30 grade concrete with diversified replacement percentage of 1%, 2%, 3%, and 4%.

Compressive strength tests were carry out on both M-25 & M-30 grade concrete specimens, while flexural strength tests were carried out on M-30 grade concrete. The results indicated that the insertion of basalt & glass fibers enhance the strength properties of concrete up to a certain limit. The maximum increase in compressive and flexural strength was noted at 3% fiber replacement. Beyond this level, particularly at 4%, a reduction in strength was noted, likely due to poor workability and improper bonding within the concrete matrix.

Keywords: Basalt fiber, Glass fiber, replacement.

I. INTRODUCTION

The popularity of high-performance material is becoming more in civil engineering applications during the past years. It has also complied with new safety, cost, and environmental criteria. Fiber-reinforced concrete (FRC) has emerged as one of the most promising of these materials for use in civil engineering. This is mostly due to the characteristics of FRC, such as toughness (with respect to compressive strength and flexural bending strength), tensile strength, durability, and energy-absorbing capacity. Economic factors are considered when employing fiber reinforcement in concrete. This is because the cost of installing conventional reinforcement is lower than that of ordinary concrete. One of the main benefits of using FRC is that the fibers are already mixed into the concrete during construction. This is especially true for secondary precast concrete components used in civic and industrial buildings as well as infrastructures.

Fiber-reinforced materials play a crucial role in modern engineering applications due to their high strength-to-weight ratio, durability, and versatility. Among these, glass fiber has been widely used for decades, while basalt fiber has emerged as a promising alternative in recent years.

II. OBJECTIVES

The aim of present project is to study the physical, mechanical properties of ingredients of basalt and glass fiber reinforced concrete. Also, to study the structural behavior of basalt fiber concrete Flexural strength , compressive strength and design the concrete mix of this concrete as well as to compare the basalt and glass fiber concrete with conventional cement concrete according experimental analysis. This project work is explained with the help of following points:

1) To study and prepare mix design of M-25 grade concrete.
2) To study and prepare mix design of M-30 grade concrete.
3) To investigate how glass fiber affects both fresh & hardened state of concrete.
4) To investigate how basalt fiber affects both fresh & hardened state of concrete.
5) To determine the optimum dosage of basalt and glass fibers to be added in concrete.
6) To compare increase in strength of concrete for basalt and glass fiber.

III. SCOPE OF STUDY

The present study investigates the effect of partial replacement of fine aggregate (sand) with glass fiber and basalt fiber on the strength characteristics of concrete. The scope is specifically designed based on experimental observations and includes the following:

1) To analyze the behavior of concrete with 1%, 2%, 3%, and 4% replacement of sand using glass fiber and basalt fiber.
2) To evaluate the variation in compressive strength and flexural strength with increasing fiber content.
3) To identify the trend of strength development, where strength increases up to 3% replacement and starts decreasing beyond this level.
4) To determine the optimum fiber content (around 3%) that provides maximum strength and performance.
5) To compare the performance of glass fiber and basalt fiber in terms of strength enhancement and efficiency.
6) To study the possible reasons for strength reduction beyond optimum content, such as poor workability, fiber agglomeration, and improper bonding.

IV. REVIEW OF PREVIOUS STUDIES

Basalt concrete was investigated experimentally as part of the research project. Cubes, cylinders, and beams were used to test the concrete's properties. M40 Grade concrete that was readily accessible in the area was used to cast the examples. The aim of the current study was to measure the ideal percentage of fibers with maximal strength criterion by examining the effects of various fiber proportions in the mix design. Cubes, cylinders, and beams were among the specimens examined for flexural, split tensile, and compressive strength. The experiment's findings demonstrated that basalt fiber improves the qualities of concrete.(Gorde Pravin Jaysing, Joshi, Deepa A., 2012.)

The mechanical characteristics and microstructure of high performance fiber reinforced concrete (HPFRC), which contains as much as 3% chopped basalt fibers, are presented in this work. Concrete was produced in three different varieties, the first of which contained only cement. 10 % of the cement in the other 2 types of concrete was replaced with locally generated metakaolin and condensed silica fume. Every kind of concrete was used to create twelve different HPFRC concrete mixes, four of which had basalt fibers mixed in the range of 0–3%. To ascertain the material behavior of the HPFRC, twelve examples were cast from all the twelve concrete mixes.such as compressive strength, splitting tensile strength, and flexural strength. In this way, a total of 108 specimens were cast and analyzed for this study. Test findings showed that the addition of basalt fibers significantly increased the HPFRC's flexural and tensile splitting strengths, but only marginally increased its compressive strength. The interfacial transition zone (ITZ) between the aggregates & the paste was determined by analyzing the microstructure of HPFRC using a field emission scanning electron microscope. The findings showed how the ITZ was enhanced by the inclusion of basalt fibers (Tehmina Ayub, Nasir Shafiq, and M. Fadhil Naruddin, 2014).

Glass's promise as a building material was recognized in the 1940s, and in the 1960s, zirconium dioxide was added for hard alkali conditions. The latest generation of glass fibers is focused on improving the technique to increase the durability of materials. Glass fiber reinforced concrete (GFRC) was thus introduced to meet various needs. The standard of the materials and the precision of the production techniques affect the GFRC's mechanical and physical characteristics, according to scientific research and testing. Anywhere a lightweight, durable, impermeable, fire-resistant, and weather-resistant material is required, GFRC can be utilized. As technology develops, it may be possible to construct intricate freeforms and entire buildings at a minimal cost. The impacts of glass fibers in hybrid mixtures for high-performance concrete (HPC), a cutting-edge technology that has gained popularity in the building sector, have been studied recently. (Bekir KARASU, Muhammad iSKENDER, 2018)

Because of the absence of reinforcement in its constituent parts, The tensile strength of concrete is really low.. Basalt fiber is one kind of fiber used to strengthen and reinforce concrete.This essay explores the necessity of this fiber to improve the basic characteristics of the concrete. Additionally, fibers filament have a tendency to alter both the hardened and physical characteristics of concrete. Because basalt fibers come from igneous rocks, they aren't affected by chemical or heat processes. The mechanical properties of concrete have been found to be enhanced by the addition of basalt fibers. As the % of fiber volume rises, it has been observed that the concrete's physical properties, such as workability and dry shrinkage, decrease. It has been exhibited that basalt fiber is an effective reinforcing material for concrete, giving it a long lifespan.At a glance, this publication will greatly benefit future researchers working on fiber-reinforced concrete and enhance the field of structural engineering.(Pushpendra Kumar Sharma and Rashmi Pantawane, 2014)

When basalt rock is melted at a high temperature, basalt fiber—a non-metallic fiber—is created. Concrete with basalt fibers is strong, lightweight, and resistant to fire. These characteristics will be very beneficial to the construction industry in the future. Basalt fiber has a wide range of uses, including residential, commercial, bridge, and highway applications. Fibres of basalt rock are used to make Basalt fibre, is cheaper and have improved physicomechanical properties which is very similar to the fibre glass and the carbon. They can take the place of numerous costly materials, leading to a variety of uses in the industry. All nations have access to the raw ingredients, which makes manufacture extremely easy. The use of basalt fibers can help the concrete & cement industries overcome their greatest challenges. Additionally, it is utilized as a composite in the automotive, aerospace, and fiber-proof textile industries. Basalt fibers are non-combustible, explosion-proof, and do not react dangerously with water or air. When in touch with other substances, no chemical reaction that could harm the environment or human health will occur. The basalt foundation composites may take the place of steel and reinforced polymers. 9.6 kg of steel is equivalent to one kilogram of basalt reinforcement. This paper examines the differences in compressive & split tensile strength of concret with and without basalt fiber utilizing cubes & cylinders.(Seena Simon, Dhilip Kumar R G., Arun Prathap, and Sharanya Balki, 2021)

V. RESULTS & DISCUSSION

A. Compressive Strength Results of Basalt fiber & Glass fiber

Table 1. shows summary of the results when sand is replaced by glass fiber. Figure 1. shows the effect of replacement of glass fiber on compressive strength in the concrete. It is observed that, at 3% replacement the strength is maximum. Hence, the replacement recommended is 3% glass fiber.

Table 1. Summary for results for Glass fiber

SN	% glass fiber added	Grade	Strength	Grade	Strength
1	Conventional	M25	27.75	M30	36.90
2	1		28.93		38.45
3	2		29.90		39.20
4	3		31.00		40.90
5	4		29.35		37.30

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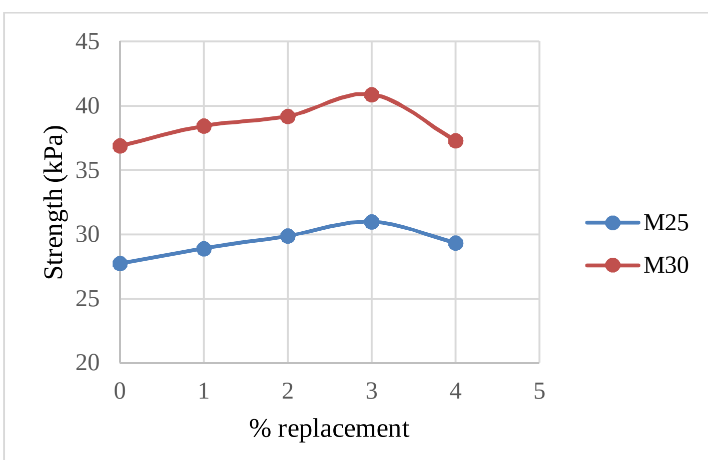

Fig.1.Replacement of Fine aggregate (sand) by Glass Fiber in Concrete

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Table .2 Summary for results for replacement of sand by Basalt Fiber

SN	% basalt fiber added	Grade	Strength	Grade	Strength
1	Conventional	M25	27.75	M30	36.90
2	1		29.40		38.85
3	2		30.95		40.40
4	3		32.05		41.40
5	4		29.95		37.90

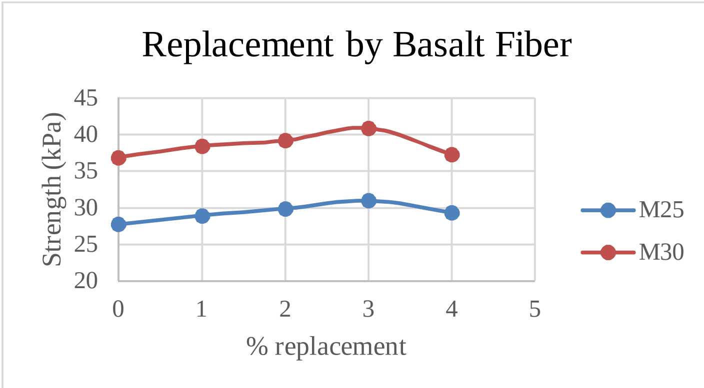

Fig 2.Replacement of fine aggregate (sand) by Basalt Fiber in Concrete

Figure 2. shows the effect of replacement of sand by basalt fiber on compressive strength in the concrete. It is observed that, at 3% replacement the strength is maximum. Hence, the replacement recommended is 3% basalt fiber.

B. *Flexural Strength Results of Basalt fiber & Glass fiber*

Table .3 Summary of results for replacement of cementitious material by basalt fiber for flexural strength

SN	% basalt fiber added	Grade	Strength (N/mm^2)
1	Conventional	M30	5.05
2	1		5.37
3	2		5.50
4	3		5.56
5	4		5.13

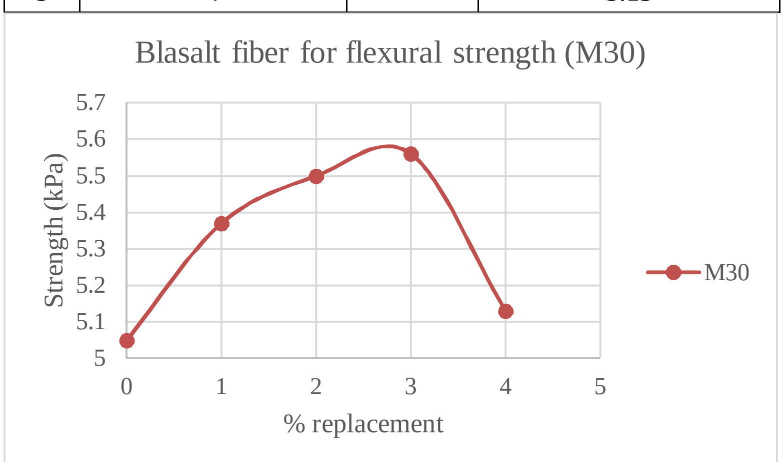

Fig. 3 : Flexural strength Vs % replacement by Basalt Fiber

Table 4. Summary for results for glass fiber for flexural strength

SN	% basalt fiber added	Grade	Strength (N/mm^2)
1	Conventional	M30	5.05
2	1		5.27
3	2		5.39
4	3		5.48
5	4		5.16

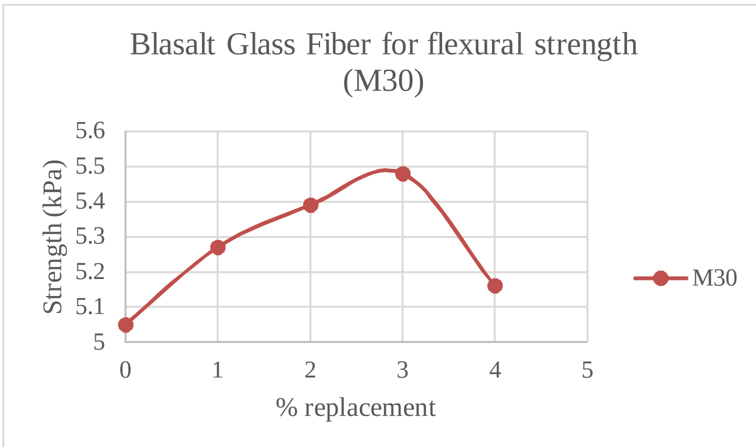

Fig. 4. : Flexural strength Vs % replacement by Glass Fiber

C. *Flexural test Results*

It is observed from the test results that, the replacement of glass fiber at 3% is giving maximum strength in flexural for M30 grade of concrete with replacement of both glass fiber and basalt fiber.

VI. CONCLUSIONS

From the experimental investigation ,it was observed that the partial replacement of the aggregate (sand) with glass fiber and basalt fiber significantly influenced the mechanical properties of concrete. The compressive strength of concrete increased with the increase in fiber content up to a certain percentage and the slightly decreased byond the optimum level.

For M25 grade concrete with glass fiber replacement ,the compressive strength increased from 28.75 N/mm^2 at 1% replacement to 29.90 N/mm^2 at 2% ,reaching a maximum value of 31 N/mm^2 at 3% replacement. However, further increase in fiber content to 4% resulted in a slight decrease in compressive strength to 29.35 N/mm^2.

Similarly , For M25 grade concrete with basalt fiber replacement ,the compressive strength increased from 29.40 N/mm^2 at 1% replacement to 30.95 N/mm^2 at 2% ,reaching a maximum value of 32.05 N/mm^2 at 3% replacement. However, further increase in fiber content to 4% resulted in a slight decrease in compressive strength to 29.95 N/mm^2

For M30 grade concrete with glass fiber replacement ,the compressive strength increased from 38.45 N/mm^2 at 1% replacement to 39.20 N/mm^2 at 2% ,reaching a maximum value of 40.90 N/mm^2 at 3% replacement. However, further increase in fiber content to 4% resulted in a slight decrease in compressive strength to 37.30 N/mm^2.

Similarly , For M30 grade concrete with basalt fiber replacement ,the compressive strength increased from 38.85 N/mm^2 at 1% replacement to 39.80 N/mm^2 at 2% ,reaching a maximum value of 41.40 N/mm^2 at 3% replacement. However, further increase in fiber content to 4% resulted in a slight decrease in compressive strength to 37.90 N/mm^2

For M30 grade concrete with glass fiber replacement ,the flexural strength increased from
5.37 N/mm^2 at 1% replacement to 5.50 N/mm^2 at 2% ,reaching a maximum value of 5.56 N/mm^2 at 3% replacement. However, further increase in fiber content to 4% resulted in a slight decrease in flexural strength to 5.16 N/mm^2.

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Similarly , For M30 grade concrete with basalt fiber replacement ,the flexural strength increased from 5.27 N/mm^2 at 1% replacement to 5.39 N/mm^2 at 2% ,reaching a maximum value of 5.48 N/mm^2 at 3% replacement. However, further increase in fiber content to 4% resulted in a slight decrease in compressive strength to 5.13 N/mm^2

Despite the reduction in slump value, the workability of concrete remained within acceptable limits. The results indicate that up to 3% fiber replacement provides adequate workability along with improved strength properties. Therefore , 3% fiber content can be considered as the optimum dosage for balanced workability and strength performance of concrete.

The addition of basalt fiber and glass fiber helps in improving the mechanical performance of concrete, particularly in terms of crack resistance and durability.

According to the findings, fiber-reinforced concrete outperforms traditional concrete in terms of strength qualities.

From the overall experimental results, the optimum fiber content was found to be approximately 3% replacement of the sand ,which provides maximum compressive and flexural strength with acceptable workability.

When compared to regular concrete, the cost investigation indicates that adding glass and basalt fibers to concrete increases its overall cost. The price rise is due to the fact that fibers are more expensive than natural sand.

Because basalt fibers are more expensive than glass fibers, basalt fiber concrete was shown to be more costly than glass fiber concrete. In structural applications, however, the increased cost can be justified by the enhanced mechanical qualities and crack resistance.

From the experimental results, 3% fiber replacement was found to be the optimum percentage ,providing improved strength with reasonable cost increase

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