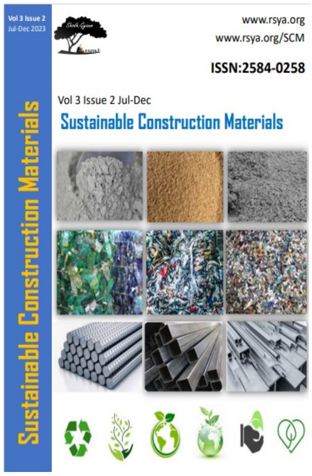

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Examining the Mechanical Characteristics of Environmentally Friendly Concrete with the Incorporation of GGBS and Glass Fibre to Promote Sustainable Development

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Abstract— Concrete has been a crucial component in the construction sector for numerous decades. Cement, fine aggregate, and coarse aggregate are essential components in the manufacturing process of concrete. Cement serves as a cohesive substance in concrete, and the use of this binding element results in a higher emission of carbon dioxide (CO2). In order to reduce carbon emissions, cement is partially replaced by industrial waste materials like fly ash (FACF) and ground granulated blast furnace slag (GGBS), which possess pozzolanic characteristics. The objective of this study is to assess the compressive, tensile, and flexural strength of conventional concrete when fly ash and GGBS are used as partial replacements for cement in three different ratios. The effect of adding 0.5 percent glass fibres to the cementitious material in the proposed mixes was examined. The concrete's output was quantified by analysing cast specimens at intervals of 7, 28, 56, and 90 days. Ultimately, throughout the testing phase, it was determined that a combination of 25% GGBS and fly ash yielded the most optimal outcomes.

Keywords—Green Concrete, GGBS, Metakaolin, Compressive Strength, Flexural Strength

INTRODUCTION

This Concrete has been a crucial component in the construction sector for numerous decades. The concerning issue that arises in this region is the emission of carbon dioxide during the cement production process. Several research have been carried out in recent decades to identify suitable alternatives for reducing the use of cement. In recent decades, several alternate methods for decreasing the amount of cement used have been developed. Construction fabrication contributes about 8% of the total global CO2 emissions [1]. Upcoming research will be carried out to decrease carbon dioxide emissions in construction and to preserve cement-based products. Consequently, there is a requirement for a novel strategy to substitute cement in order to diminish the quantity of cement utilised. Therefore, it is imperative to develop a novel strategy for replacing cement in order to mitigate CO2 emissions. An investigation was conducted to assess the effects of cement with a partial replacement of Ground Granulated Blast Furnace Slag (GGBS) and Fly Ash Class-F (FACF) in three varying quantities. FACF, or fly ash and coal fines, is a residual product generated by thermal power stations, with an annual production of 750 million tonnes. GGBS is a by-product of the iron ore industry. GGBS and FACF are utilised in construction as eco-friendly materials. Moreover, the utilisation of GGBS (Ground Granulated Blast Furnace Slag) and FACF (Fly Ash Concrete Fines) in lieu of cement results in reduced building expenses. The optimum ratio is blended with glass fibres to achieve a significant impact. Within a specific range, glass fibres have the potential to control the cracking, bleeding, shrinkage, and permeability of concrete. Applying additional glass fibres decreases the strength of the concrete. Consequently, we have incorporated the appropriate proportion of glass fibres into the concrete. Presently, the glass fibres constitute a mere 0.5 percent of the entire cementitious material. Chalee and colleagues [2] conducted the substitution test in aquatic conditions. Varying levels of cover concentrations and water/cement ratios in seawaterThe user concluded that an increase in FACF leads to a reduction in corrosion degradation and chloride contamination in concrete. After a period of 7 years, the cement is replaced with a ratio of water to binder (W/B) ranging from 0.45 to 0.65, with the addition of 25 to 50% of fly ash and calcium fume (FACF). In the study of fine aggregate concrete filler (FACF), Tata Power Co. Ltd [3] did an experiment to examine the qualities of both fresh and hardened concrete. The results showed that adding 5%, 10%, and 15% of FACF to the mixture produces a same level of strength as M30 grade concrete. Furthermore, substituting 20% of FACF in the mixture yields concrete strength equivalent to that of M20 grade concrete. In their study, K. Ganesh Babu et al.[4] conducted experiments to examine the use of GGBS as a partial substitute for cement. They examined different proportions of GGBS, ranging from 10% to 80%. At 28 days of age, it was discovered that the strengths of the concrete are similar. To enhance performance, the amount of cementitious material has been augmented by 8.5% and 19.5% respectively, resulting in a 50% increase. Additionally, 65% of the cement has been substituted with GGBS. The research on GGBS and Robo Sand for M30 was undertaken by Venu Malagavelli et al. [5]. The addition of SAVEMIX SP111 was shown to restore the compressive strength of the concrete. A proposed method for partially replacing cement is by using 50 percent GGBS, while robo sand can serve as a substitute material for the fine aggregate. In their study, Yogendra O. Patil et al. [6] examined the impact of partially substituting cement with GGBS by altering the GGBS concentration from 0% to 40%. They reached the conclusion that as the proportion of GGBS increases, the intensity diminishes. The power diminishes from 4 percent to 6 percent of the power at 20% of GGBS to OPC (in terms of compressive and flexural strength).

A potential reduction of up to 14% in the OPC is expected. The study conducted by A. H. L. Swaroop et al. [7] investigated the effects of using FACF (Fine Aggregate Crushing Fines) and GGBS (Ground Granulated Blast Furnace Slag) as partial replacements for OPC (Ordinary Portland Cement) at 20 percent and 40% levels respectively. The researchers determined that the durability of OPC is substituted by 20 percent of GGBS in the marine curing process. When the strength increases to 20% of the Fly Ash Cementitious Fines (FACF), it serves as a partial replacement for cement. Conversely, when the strength decreases to 40% of the FACF, it is considered a partial substitution. To achieve optimal performance, it is recommended to utilise FACF replacement within the range of 20% to 40% of OPC. The combination of GGBS and MK exhibits superior mechanical qualities when used with recycled coarse aggregate[8], [9]. Studies in the literature indicate that the cementitious component is replaced with supplemental cementitious materials in different quantities. This paper aims to investigate the enhanced qualities of M40-grade concrete with the addition of fibres[16-18, 25]. The study enables us to examine the impact of glass fibres on the composition of the concrete mixture.

MATERIALS

CEMENT

The cement grade utilised is OPC-53. As to IS 16415:2015 [10], concrete should consist of a minimum of 40% cement by weight. We utilised the cement specifications given in IS16353 and IS 12269. The specific gravity of cement is 3.15.

GGBS

The We acquired the GGBS and its characteristics from JSW in accordance with IS 16714:2018. GGBS has a specific gravity of 2.86.

FLY ASH

The Fly Ash grade utilised is classified as class F. As per IS 3812 part 1, we obtained the fly ash and its standards from Vijayawada VTPS. The specific gravity of fly ash is 2.3.

COARSE AGGREGATE

The 10 mm and 20 mm aggregates were used, as defined by IS 383:2016[11].

FINE AGGREGATE

The sand of the river is used as fine aggregate. The FA is filtered into a 4.75 m sieve. Fine Aggregate grade according to IS383:2016[11].

METHODOLOGY

W. Chalee [2] claims that 25–50% FACF with a W/C of 0.65 provides the strongest results in terms of longevity. J.M. GAO [12] believes that GGBS may be used to replace up to 40% of cement. It totally vanishes from the concrete's vulnerable region. The cement composite combinations were chosen within the ranges specified in IS 16415:2015 [10] according to the requirements. Starting with a typical mix (CM) of 100 percent cement and 0 percent FACF and GGBS, the mix proportions arecalculated. The next three blends were made with progressively lower cement content and higher FACF and GGBS content. The proportional mix-1 (PM-1) was made with 60% cement and 20% FACF and GGBS, respectively. The proportional mix-2 (PM-2) was made with 50% cement and 25% FACF and GGBS, respectively. The proportional mix-3 (PM-3) was made with 40% cement and 30% FACF and GGBS, respectively[19-24]. Experiments were carried out on concrete of the M40 standard. IS 10262:2009 [13] and IS 456:2000 [14] Codes are used to build the combination. Based on a literature survey and the number oftrails, the W/B ratio for M40 is 0.38. The admixture has been used in the majority of laboratory experiments to improve the concrete's workability and power. The optimal percent of admixture for M40 is 0.5 percent of the cement weight, and we achieved the necessary slump, which is 100 mm, as per the mix specification. The term "coarse aggregate" comes from IS 10262:2009 [13]. The coarse aggregate is divided into two sizes: 20 mm and 10 mm, which account for 60% and 40% of the overall aggregate, respectively. FA is made from river sand. Table-2 lists the amounts for 1 cubic meter of CM, PM-1, PM-2, and PM-3. In terms of mechanical properties at 7, 28, 56, and 90 days, the experimental procedures and testing are absolutely dependent on IS 516 [15] and IS 5816 [16]. Glass fibers of 0.5 percent are applied to the ideal blend in addition to the cementitious content, and mechanical properties are checked for 7 and 28 days.

RESULT AND DISCUSSUION

Compressive Strength

Figure 1 illustrates the impact of three different mix proportions (M-1, M-2, and M-3) in comparison to the standard mix (CM) for M40. It is evident that CM yields the most optimal outcomes. An further finding revealed that both M-1 and M-3 had a significant impact on 87% of the compressive strength of the fck value. Consequently, the findings from M-2 can be considered equivalent to CM. When we equate the data to some of the literature, we notice a 20–25 percent rise in strength. The ideal ratio of glass fibres, specifically M-2 for M40, is utilised as indicated earlier. The current findings demonstrate that the addition of glass fibres leads to a reduction in compressive strength by 4%. We propose that this can be attributed to the water absorption of glass fibres in concrete, as well as the time required for chemical reactions involving fly ash to attain the required strength of the concrete.

Table 1 Quantities for one cubic meter

M40 for 1 Cubic Meter			
Material(Kg/m^3)	CM	PM-1	PM-2
Cement	416.23	239.044	217.537
Fly Ash	0.000	82.15	113.768
GGBS	0.000	84.25	113.768
C A 20 mm	680.00	680.00	680.00
C A10 mm	465.00	465.00	465.00
Water	147.738	147.738	147.738
Fine Aggregate	745.123	745.123	745.123
Chemical Admixture	2.175	2.175	2.175

Flexural Strength

The research findings, as depicted in Figure 5, indicate a consistent outcome where M-2 surpasses both M-1 and M-3. As depicted in Figure 6, glass fibres are included in the ideal ratio, specifically M-2 for M40. The latest findings validate that the inclusion of glass fibres leads to a reduction in flexure strength by 13%.

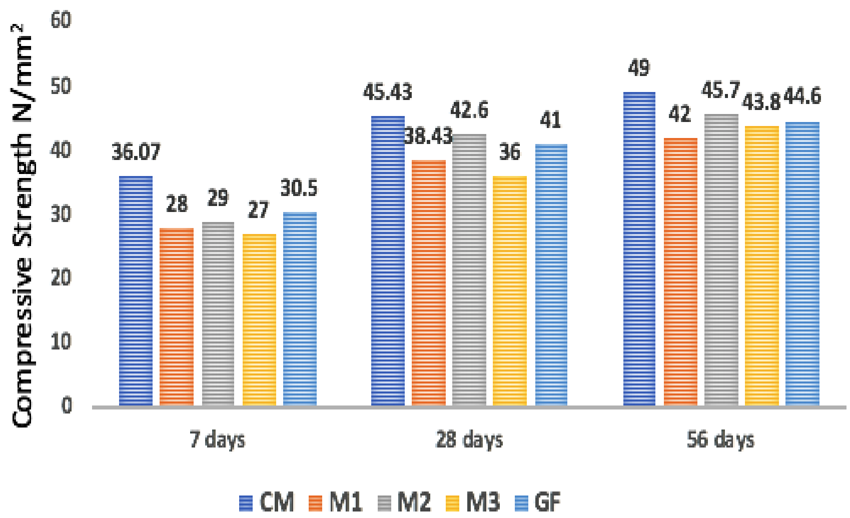

Fig 1. Compressive Strength

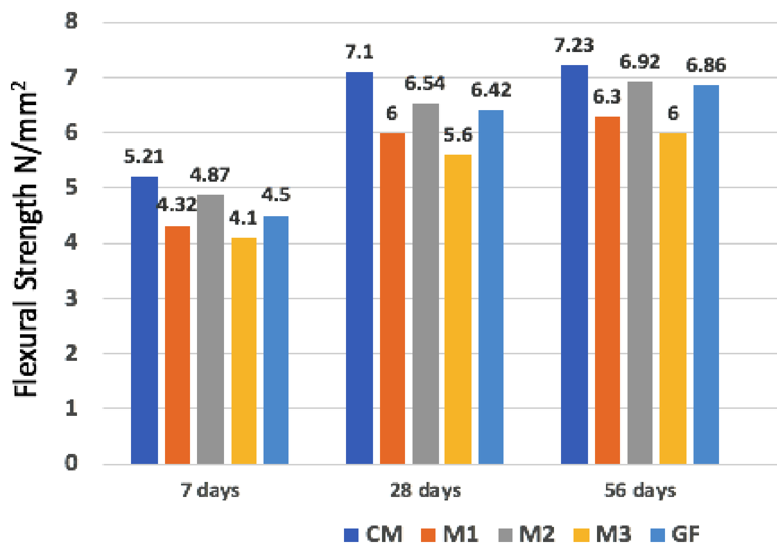

Fig 2. Flexural Strength

Split Tensile Strength

This analysis verified the split tensile strength results of three alternative mix proportions (M-1, M-2, and M-3) compared to a controlled mix (CM) for M40. The results may be observed in Fig. 3. As a result of M-2, this leads to significantly enhanced performance. The tensile strength of concrete typically falls between 8% and 15% of its compressive strength. As depicted in Figure 4, glass fibres are included in the ideal ratio, specifically M-2 for M40. The latest findings indicate that the inclusion of glass fibres leads to a reduction in the tensile strength at the point of fracture by a significant margin of 14%.

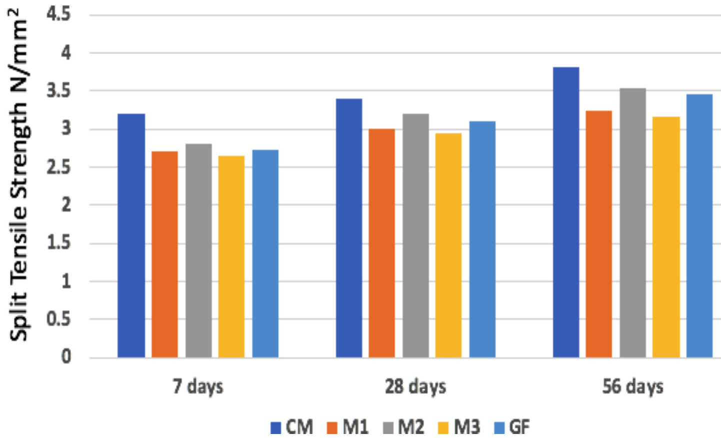

Fig 3. Split Tensile Strength

CONCLUSION

The 90-day compressive, tensile, and flexural strengths of M-2 with 25% GGBS and fly ash were observed to be decreased when compared to the standard blend. Nevertheless, this reduced strength surpasses the target average strength. The addition of fly ash and GGBS at 20%, 25%, and 30% results in a reduction of compressive strength of 0.14%, 0.076%, and 0.23%, respectively. The addition of glass fibres (0.5%) has been found to decrease the toughened characteristics. Based on this analysis, the optimal mix proportion in terms of cost is a 25 percent combination of fly ash and GGBS.

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