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A NOVEL INVESTIGATION ON FLEXURAL STRENGTH IN GGBS ENHANCED POLYPROPYLENE FIBER REINFORCED ENGINEERED CEMENT COMPOSITES

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Abstract

Aim: *The main objective of this study is to conduct an experimental analysis of the mechanical characteristics of GGBS Enhanced Engineered Cement Composites reinforced with novel polypropylene fibers.*

Materials and Methods: *The novel Synthetic fiber polypropylene, which had an average length of 40 mm, was blended in at a ratio of 2% with 50% GGBS Enhanced Engineered Reinforced Composite. River sand is used as a fine aggregate.*

Results: *With an increasing proportion of Novel Polypropylene Fiber, the flexural strength of the created concrete samples with polypropylene fiber reinforcement gradually increased. The results might be examined using the independent t-test reports created by the spss program version 25. Using the independent-samples-t-test method, the statistical report of the conventional and modified concrete was compared. G power value $p<0.05$ significant p-value i.e., $p=0.000$ There isn't much of a difference. The mean value (3.7576, 4.1715), standard deviation (0.04798, 0.10707), and mean standard error (.01131, 0.02524) were obtained using group statistics using SPSS version 25.*

Conclusion: *The commercial use of synthetic fiber-reinforced Engineered Cement Composites for constructions, structural repair, seismic activity resistance, impacts and blast resistance, and high strain capacity behaviour as a new building material. Furthermore, this study concludes that new polypropylene GGBS Enhanced fibre reinforced concrete has higher flexural strength than ordinary concrete. This might increase durability and reduce flexural fractures.*

Keywords: *Polypropylene Fiber, GGBS Enhanced Concrete, Flexural Strength, Engineered Cement Composites, Plain Cement Concrete Matrix, Concrete, Fine Aggregate, Fiber Reinforced, PCC, ECC.*

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1. Introduction

Recently, there has been a sharp increase in research and innovation in the field of innovative fiber reinforced Engineered Cement Composites (ECC), which has been motivated by structural challenges related to Flexural Integrity and resistance to tensile failure. The advantages of these methods, as opposed to conventional concrete construction, include minimal environmental impact, cheap cost, and support for their potential in a wide range of applications. Much effort has been invested into enhancing the mechanical performance of this group of materials in order to increase its possibilities and uses. Under varied curing conditions, groups with high volume GGBS mixes improve mechanical, fracture, and durability qualities much more than control mixes.(2019, Ganesh and Murthy) The 50% GGBS replaced RC beam has greater flexural strength in both static and cyclic loading conditions, and the deflection is slightly higher than in the controlled specimen (Mohan and Tabish Hayat 2020). It is most useful for the element that will carry flexural load, as it demonstrates that maximum strength can be achieved at later ages. Replacing cement with GGBS up to 50% without additives is more suited for flexural members than tensile or flexural members. The maximum load capacity of the beam specimens with 50% and 70% GGBS substitution is 3% and 9% greater than that of the control specimen without GGBS (0% GGBS).(2017) (Hawileh et al.) The experimental results demonstrate that the split tensile and compressive strength of ECC increases by 1.5%.n.d. (Neeladharan, Muralidaharan, and Sathish) Previously, ECC was invented in 1993 at the University of Michigan (USA) by Li Victor C. Based on the micromechanics of the fiber-matrix bond, ECC is a separate class of HPFRCC (High performance fibre reinforced cementitious composites). Because coarse aggregates have an influence on the ductility of cementitious composites, ECC does not contain them. When reinforced with a sufficient number of discontinuous polymeric fibres, ECC exhibits remarkable ductility.

Google scholar yielded around 16,100 results for the previous five-year research in this subject by various scholars and scientists (Fallah and Nematzadeh 2017). Concrete is a composite material with a low tensile strength and strain range. The brittle behaviour of concrete, as well as its fragility under stress, which leads to poor ductility, have caused issues for the structural application of standard concrete. In general, the addition of fibres to the concrete mixture can greatly increase the mechanical qualities of the concrete. The existence of many microcracks throughout the concrete body prior to the start of tensile testing precludes the appropriate transfer of tensile stress throughout the test, resulting in crack widening. (2017, Fallah and Nematzadeh) As a consequence, the use of fibres to compensate for tensile and ductile weakness and create a concrete with reduced cracking is obvious, with the level of behavioural change significantly dependent on the kind, shape, and % of fibres. (2017, Fallah and Nematzadeh) Researchers are increasingly interested in macro-polymeric and polypropylene fibres as synthetic fibres due to their cheaper cost and weight, resistance to corrosion and acids, good toughness, and better shrinkage cracking resistance.

Numerous research have been conducted to investigate the fresh and hardened state characteristics of concrete including GGBS (Ganesh and Murthy 2019). The use of slag industry byproducts at a greater replacement level in cement can drastically lower the price of concrete and pave the way for cost-effective environmentally friendly concrete. The usage of GGBS as a cement replacement successfully reduces GHG emissions by 47.5%. The influence of GGBS in cement generates new and hardened concrete features such as workability, delay bleeding of fresh concrete, lower heat of hydration, long term strength, corrosion resistance, decreased porosity, and permeability.

n.d. (Ganesh Babu, Sree, and Kumar) This study was primarily concerned with evaluating the efficiency of GGBS in concrete using standard Portland cements based on the findings of current studies. The replacement amounts in the concrete investigated ranged from 10% to 80%, and the strength efficiencies were measured after 28 days. The following are the key conclusions.

(1) The previously described approach for assessing the efficiency of pozzolans such as fly ash and silica fume was found to be appropriate for assessing GGBS. This technique understands that the pozzolan's "overall strength efficiency factor (k)" is a mixture of two components, the "general efficiency factor (ke)" and the "percentage efficiency factor (kp)."
(2) The analyses revealed that the "overall strength efficiency factor (k)" ranged from 1.29 to 0.70 at 28 days for percentage replacement levels ranging from 10% to 80%.
(3) It was also discovered that the "overall strength efficiency factor (k)" was an algebraic sum of a constant "general efficiency factor (ke)" with a value of 0.9 at 28 days and a "percentage efficiency factor (kp)" varying from +0.39 to?0.20 for the cement replacement levels studied ranging from 10% to 80%.
(4) Overall, this technique predicted the strength of concretes ranging from 20 to 100 MPa with GGBS levels ranging from 10% to 80%, yielding a regression coefficient of 0.94, which was also obtained for normal concretes.
(5) Finally, it was discovered that in order to achieve equal strength in concretes at 28 days using the efficiencies evaluated in this study, an additional 8.5% and 19.5% increase in total cementitious materials will be required at 50% and 65% cement replacement levels, which agrees well with the 10% and 20% additional material reported previously.

(McNally, O'Connell, and Richardson) The use of large volumes of GGBS increases the resilience of Portland cement binders against sulphate attack. The GGBS combination created a binder that was similar to or surpassed the sulfate-resistant Portland cement concrete in tests. The CEM II-A/L lime-stone cement employed in this study was shown to have a higher sulfate-resistance than CEM I Portland cement, which may be advantageous in 'Moderate' or 'Severe' conditions. The production of gypsum on the exterior surfaces of the concrete specimens was discovered to be the predominant deteriorating process in the sulfuric acid testing programme, followed by surface delamination and minor spalling.

Expansion was discovered to be unimportant in sulfuric acid-based deterioration. The most severe circumstances that the concrete will face in service are represented by a 1% sulfuric acid solution (pH? 1.5), and the rate of visual degradation of a 1% solution of sulfuric acid attack substantially exceeded that of a 5% sodium sulphate solution. In practise, however, pH levels can change depending on time, temperature, and bacterial activity. There was no discernible difference between the cements tested when subjected to sulfuric acid tests, while specimens containing GGBS outperformed all other mixtures independent of cement type.

Due to the exceptionally severe nature of this type of assault, it was clear that these concretes could not sufficiently handle the durability threat to all components of wastewater infrastructure over a substantial life period (e.g., 100 years).

2. Materials and Methods

Figure 1: Cement

The entire project work has been carried out in the Department of Civil Engineering at Saveetha School of Engineering, Chennai. The conventional concrete material is cement 53-grade OPC, river sand as fine aggregate, Ground Granulated Blast Slag (GGBS) as alternative cement material, polypropylene fiber as fiber reinforcement. Figure 1 shows the Cement and Figure 2 shows the novel polypropylene fiber and Figure 3 shows the ggbs. A total of 36 samples were prepared such as 150 x 150 x 700mm concrete beams. The prepared beams are oiled well and poured concrete in the cube. After casting, 24 hours need to dry and placed in the curing pond for 28 days. The heat hydration process will be done at that stage. Figure 4 shows the beam Mould. The same procedure is for novel concrete specimens of polypropylene fiber added to concrete. The Polypropylene Fiber added in concrete is 2% in that mass of cement and m sand is used as a fine aggregate. After 28 days of concrete beam storage, a test for flexural strength was conducted. This test was done by using the flexural testing machine. Figure 5 shows the preparation of concrete beams. The Engineered Cement Composites are essentially a Plain Cement Concrete Matrix and hence a mix ratio of 1:2 is incorporated for this study. Figure 6 shows the Flexural Strength testing using the Flexural Testing Equipment. Following sample preparation, the specimens are removed from the mould after 24 hours and cured in a 100% H2O solution (water) for 28 days.

It is the process of managing the pace and amount of moisture loss from concrete during cement hydration. Both regular concrete and GGBS Enhanced Polypropylene ECC were evaluated utilizing Flexural testing equipment after 28 days of curing. The Flexural strength should be assessed by gradually increasing the load until the specimen collapses.

Figure 2: Novel Polypropylene Fiber

Figure 3: GGBS

Figure 4

Figure 5

Figure 6

3. Statistical Analysis

SPSS version 25 software was used to examine the experiment's findings. To determine the statistical significance between the study and control groups, an independent sample t-test was conducted. Flexural strength, concrete quality, water-to-cement ratio, cement quality, and curing days are all independent factors in the study; there are no dependent variables. This tool was used to compute Flexural strength and calculate the mean, constant deviation, and constant error of the mean. Figure 7 shows the Bar chart analysis of mean flexural strength of Conventional concrete and Modified Concrete.

4. Results

The Flexural strength of conventional Plain cement concrete is 3.75 N/mm2. Additionally, the ECC's Flexural strength for the polypropylene fiber concrete is 4.17 N/mm2. Table 1 shows the Flexural Strength Result of Conventional Plain Cement Concrete. Table 2 shows Flexural Strength Result of GGBS Enhanced Polypropylene Reinforced ECC Concrete. This performance gives the 10.07 % increment value while comparing the flexural strength result of conventional concrete. Table 3 shows the Independent-samples-t-test from the spss software statistical analysis and the comparative statistical report of the conventional and modified concrete. The significance p-value greater than 0.05 i.e., p=0.000. There is significant difference. Table 4 shows the Group Statistics derived from the spss version 25 and the Mean value(3.7576,4.1715), standard deviation (.04798,.10707) and the standard error mean(.01131,.02524) Group Statistics derived from the spss version 25.

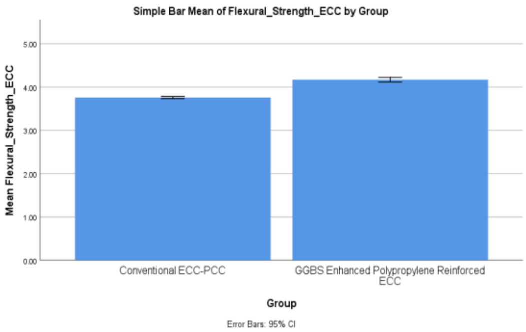

Figure 7

Table 1: Flexural Strength Result of Conventional PCC Concrete

Mix Type	**Flexural Strength (N/mm^2)**	
	Load	**28 Days**
Conventional PCC Concrete	17.85	3.70
	18.43	3.82
	18.4	3.81
	17.85	3.70
	18.21	3.77
	18.24	3.78
	18.38	3.81
	17.96	3.72
	17.92	3.71
	18.22	3.77
	18.31	3.79
	18.3	3.79
	18.33	3.80
	17.9	3.71
	17.88	3.70
	18.31	3.79
	17.86	3.70
	17.8	3.69

Table 2: Flexural Strength Result of GGBS Enhanced Polypropylene Reinforced Concrete

Mix Type	Flexural Strength (N/mm^2)	
	Load	28 Days
GGBS Enhanced Polypropylene Reinforced ECC Concrete	19.27	3.99
	20.14	4.17
	19.5	4.04
	19.86	4.11
	20.38	4.22
	20.07	4.16
	20.96	4.34
	20.75	4.30
	19.54	4.05
	19.98	4.14
	20.25	4.20
	20.85	4.32
	19.59	4.06
	20.68	4.28
	19.65	4.07
	20.58	4.26
	20.32	4.21
	19.72	4.09

Table 3: Independent-samples-t-test from the spss software statistical analysis and the comparative statistical report of the conventional and fiber reinforced concrete. The significance p-value lesser than 0.05 i.e., p=0.000. There is statistically significant difference.

Independent-samples-t-test									
Load	Levene's Test for Equality of Variances		t-test for Equality of Means						
								95% Confidence Interval of the Difference	
	F	Sig.	T	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Equal Variances Assumed	11.296	.002	-14.966	34	.000	-.41389	.02765	-.47009	-.35769
Equal Variances Not Assumed			-14.966	23.562	.000	-.41389	.02765	-.47102	-.35676

Table 4: Group Statistics derived from the spss version 25 and the Mean value (3.7576, 4.1715), standard deviation (0.04798, 0.10707) and the standard error mean (0.01131, 0.02524)

Group Statistics					
Description	Group	N	Mean	Std. Deviation	Std. Error Mean
Flexural Strength	Conventional ECC_PCC	18	3.7576	.04798	.01131
	GGBS Enhanced Polypropylene Reinforced ECC	18	4.1715	.10707	.02524

5. Discussion

The mechanical performance of ECC reinforced with polypropylene fibres enhanced up to a specific limit for fibre loading. As the fraction of natural fibre loading increases, the tensile, bending, flexural, and impact performance decreases. The flexural strength, splitting tensile strength, and flexural strength of HPC rose when the fibre volume fraction of single basalt fibre or polypropylene fibre increased, although the rise in flexural strength was not substantial. Flexural strength and splitting tensile strength were greatly enhanced when the volume percentage of a single fibre was less than 7.2%. The flexural strength of HPC reinforced with a single fibre was increased by 1.1%-24.5% compared to HPC without fibre, and the splitting tensile strength was increased by 21.9%-44.5%; the effect of polypropylene fibre on the flexural strength and splitting tensile strength of HPC is superior to that of basalt fibre. (2019, Wang et al.) Because of superior dispersion of cementitious particles and surface properties of GGBS particles, the flowability of UHPC mix improves dramatically as cement substitution by GGBS increases.

Flexural and split tensile strength are greatly increased with an increase in GGBS level of up to 40% when compared to raised curing and 20% when compared to ordinary water curing. Under higher temperature curing, the direct and indirect tensile characteristics of UHPC with large volumes of GGBS up to 40% exhibit enhanced strength. This is most likely owing to the increased binding strength between the fibre and matrix during elevated curing conditions. (2019, Ganesh and Murthy) The maximum load capacity of the beam specimens with 50% and 70% GGBS substitution is 3% and 9% greater than that of the control specimen without GGBS (0% GGBS).

The stiffness of the G50B and G70B specimens was 10% and 4% greater than that of the control G0B specimen, respectively. However, the control G0B specimens outperformed the G90B specimens with 90% GGBS substitution by 16%. Reinforced concrete beams cast with up to 70% GGBS substitution to cement would perform similarly to beams built with ordinary concrete mixtures including no GGBS (0% GGBS) (Hawileh et al. 2017).

6. Conclusion

This study is based on a comparison of flexural strength tests for the ECC Concrete Matrix. As a consequence, the GGBS-Polypropylene ECC concrete flexural strength provides excellent performance. Furthermore, this study reveals that Polypropylene Fibre reinforced concrete has higher flexural strength than traditional PCC concrete. This may prevent shrinkage cracks and improve durability.

7. Declaration

Conflicts of Interest

No conflict of interest in this manuscript.

Author Contribution

Author JV is involved in data collection, experimental study, and manuscript writing. Author GBRK was involved in the conceptualization, guidance, and critical review of the manuscript.

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