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Research Article

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Comparative Study on the Compressive Strength Performance of Pumice with 30% GGBS and Metakaolin with Conventional Concrete

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Abstract

The scope of the paper is to compare the conventional concrete by employing a mix of M30 grade concrete, a novel pumice aggregate is used to partially replace the coarse aggregate to create lightweight concrete. Both the coarse and fine aggregates are new pumice stone. The curing dates of 28 days were used to make a group of 6 cubes. As usual in our concrete, all groups are composed of 60% cement mix, 30% GGBS (Ground granulated blast furnace slag) modified, and 10% metakaolin. As per the curing date for 28 days, a group of 18 cubes was made. A total of 36 cubes were built in two groups in order to calculate the compressive strength. For typical concrete of grade M30, the average compressive strength test result at 28 days was 30.28 N/mm^2. Concrete's noteworthy 34.53 N/mm^2 compressive strength test result at 28 days for group I and M30 grade concrete in 18 cubes using innovative pumice aggregate stone and partial substitution of GGBS and metakaolin in cement weight. Two-tailed tests had a result of $p = 0.005$, which was lower than $p = 0.05$. A statistically significant difference exists between the two groups as a result. The 28-day M30 grade concrete compressive strength, concrete employing novel pumice aggregate compressive strength test results, and partial substitution of GGBS and metakaolin by weight of cement.

Keywords

Novel pumice aggregate, Metakaolin, Ground granulated blast furnace slag, Compressive strength, Concrete, Lightweight aggregate, Conventional concrete

Introduction

In building projects all across the world, concrete is frequently used. Concrete is a substance that embodies power. 28-day M30 grade concrete compressive strength, concrete employing fresh pumice aggregate compressive strength test results, and partial substitution of GGBS and metakaolin by weight of cement are all examples of concrete [1]. It has become clear that the ability of this construction material to withstand the demands of the current infrastructure may be problematic [2]. Concrete's strength is determined by its ability to resist forces that either decrease or enhance its compressive or tensile strength. The depletion of raw resources is a result of the growing use of concrete in this century [3]. In concrete, the weight of the particles makes up around 70% of the overall weight. Natural resources are being used up faster than they can be replenished, hence it is imperative to use substitute materials that serve the same purpose as natural aggregates. Aggregates make up around 70% of the weight of concrete. The continuous growth in construction activity has increased the need for natural aggregates [4].

A total of 17,000 research subjects from Google Scholar were not accessible in the real-time application. That's why this research was done. Daily resource depletion makes it necessary to introduce some replacement materials that will serve the same purpose as natural aggregates [5]. In a developing country like Nigeria, substituting less expensive local resources or even byproducts like quarry dust for the coarse aggregate can considerably enhance the production of concrete with the necessary properties at a cheap cost [6]. Construction costs will decrease as a result of the much lower production costs. By doing this, quarry dust will be effectively utilized rather than wasted and endanger the environment [7].

The alternative to coarse aggregate is novel pumice aggregate. It is constructed from an aggregate of porous, spherical, and irregularly shaped fresh pumice [8]. A unique pumice aggregate's applicability for a given end-use depends on a variety of physical factors, including Contrarily, the aggregate's porosity makes it simpler for cement paste to enter and form in between the denser interfacial zones [9]. The chemical composition of fresh pumice aggregate is largely the same as that of rhyolite. It is lava, highly cellular, and glassy [10].

Scoria frequently have asymmetrical forms, are heavily vesiculated, and resemble basalt in appearance. Scoria is often more crystalline, darker, and heavier than fresh pumice. New pumice aggregate is a porous and light substance [11]. It may be found all across the world, particularly in developing nations with active volcanic zones. Innovative pumice blends its low weight with insulating properties. The reduced dead weight in the building of structures is one advantage of employing lightweight aggregates to make lightweight concrete. Modern construction is an important and relevant topic.

Materials and Method

The experiment was carried out in the civil engineering department's Saveetha School of Engineering's Concrete Laboratory. The project was to build M30 concrete cubes. To determine the compressive strength of concrete, concrete cubes of the usual dimension of 150 x 150 x 150 mm were made. Figure 1 displays GGBS and figure 2 exhibits metakaolin on a novel pumice aggregate stone (8 - 12 mm thickness). Metakaolin and GGBS are available in powder form.

Figure 1: GGBS.

Figure 2: Metakaolin.

The best grade cement has the standard cement composition of argillaceous and calcareous elements, as well as additional components such as gypsum. Figure 3 depicts a stone made of novel pumice aggregate. Fine aggregate is made from M-sand that has been sieved to a fineness of 4.75 microns. All of the properties are shown in table 1. Table 2 shows the physical features of M-sand, whereas table 3 shows the physical characteristics of novel pumice aggregate.

M30 design was developed using cement: fine aggregate: coarse aggregate ratio of 1:0.75:1.5. Compressive strength was calculated using cubes of constant size. Table 4 shows the comparison of properties of cement, metakaolin, and GGBS.

Figure 3: Pumice stone size of 8 to 10 mm.

Table 1: Physical properties of cement.

S. No.	Properties	Result
1	Fineness	90 microns
2	Specific gravity	3.1
3	Standard consistency	30%
4	Initial setting	30 min
5	Final setting	600 min

Table 2: Physical properties of the fine aggregate.

S. No.	Properties	Result
1	Size	4.75
2	Sieve analysis	2.59
3	Water absorption	3%
4	Specific gravity	2.65

Table 3: Physical properties of the coarse aggregate.

S. No.	Name of the test	Result
1	Size	20 mm
2	Sieve analysis	20 mm
3	Water absorption	3.14%
4	Specific gravity	2.68

Table 4: Comparison of the properties of cement, metakaolin, and GGBS.

Contents	Cement	MK	GGBS
SiO_2 (%)	20.1	54.9	35.26
CaO (%)	63.5	0.06	38.77
Al_2O_3	4.9	41.7	8.2
Fe_2O_3	3.6	1.07	1.23
MgO	1.2	0.84	4.1
TiO_2	-	0.36	-
MnO_2	2.9	-	11.7
LoI	1.7	1.03	0.74
Specific gravity	3.15	2.44	2.77
Color	Grey	White	Off whitish
Bulk density (kg/cc)	830	900	1060

Figure 4 depicts the casting of concrete cube examples. Table 5 shows the properties of novel pumice. A total of 72 cubes were cast, with each mix design requiring 18 cubes. Following the casting process, the cubes were held for 24 h before being demolded, and the curing period was extended to a compression strength of 28 days. Figure 5 depicts concrete specimen curing. The specimen was obtained once the curing procedure was done.

The resisting strength in N/mm^2 was calculated using compression testing equipment. The ultimate load was measured and computed using the stress formula, and the maximum load resistance of the concrete cube specimen was determined. The comparison of modified concrete and conventional concrete was calculated and found the performance of the concrete.

Figure 4: Casting of concrete.

Table 5: Properties of pumice.

S. No.	Properties	Values
1	Specific gravity	2.75
2	Water absorption	2.27%

Figure 5: Concrete specimen curing.

Statistical analysis

The statistical report was generated through the SPSS (Statistical Package for the Social Sciences) software and analyzed the results. The mean was also computed for compressive strength. Represents a group of statistics for a sample group of 30% of GGBS and 10% metakaolin and novel pumice aggregate stone as coarse aggregate. Mean (30.28, 34.53). There is a statistically significant difference and p = 0.000 as it is lesser than p = 0.05. Figure 6 shows the chart derived from SPSS for compressive strength of a sample group of 30% of GGBS and 10% of metakaolin and novel pumice aggregate stone as a coarse aggregate mixture of concrete and conventional concrete.

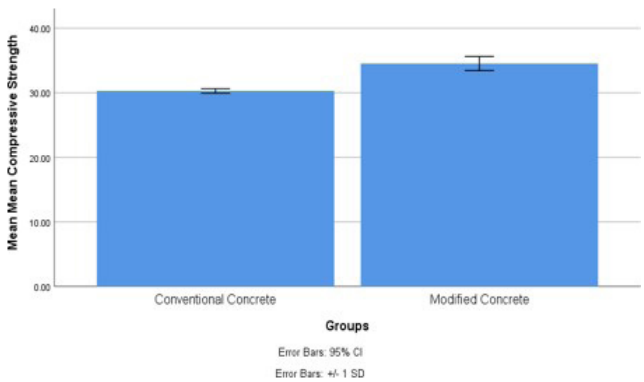

Figure 6: Bar chart analysis of mean compressive strength of sample group of 30% of GGBS and 10% of metakaolin and pumice stone as coarse aggregate mixture of concrete and conventional concrete. Lightweight concrete shows better accuracy compared to conventional concrete. Mean accuracy of detection +/-1 standard deviation.

Results

The average 28 days of compressive strength test result of conventional concrete is 30.28 N/mm². Table 6 shows the compressive strength result of conventional concrete. The compressive strength test result of concrete with novel pumice aggregate stone and partial replacement of GGBS and metakaolin by the weight of cement is 34.53 N/mm² for average result of group I and for 18 cubes.

Table 7 shows M30 grade concrete 28 days of compression strength test result of concrete with novel pumice aggregate stone and partial replacement of GGBS and metakaolin by the weight of cement. There is a statistically significant difference and p = 0.000 as it is lesser than p = 0.05. Table 8 shows results of the independent samples t-test for a sample group of 30% of GGBS and 10% of metakaolin and novel pumice aggregate stone as coarse aggregate. Table 9 Shows the group statistics derived from the SPSS statistical analysis.

Discussion

By examining the above findings, it is clear that novel pumice aggregate stone is used as a coarse aggregate and GGBS is used as a fine aggregate. Using GGBS as a substitute has detrimental effects on concrete strength (reduced strength) [12]. Lastly, lightweight aggregate concrete has a density of 1600 Kg/m³, which is lower than standard concrete [13]. When fine aggregate is replaced with GGBS, better results are obtained as compared to normal cement aggregate [14]. According to the independent t-test analysis performed using the SPSS statistical program, the significance of the two-tailed test findings was p = 0.000, which was smaller than p = 0.05. It depicts how adding additional novel pumice aggregate reduces the density of the concrete, resulting in lightweight aggregate concrete. Natural aggregate can be used in place of innovative pumice aggregate to minimize the self-weight of concrete [15]. New pumice aggregate absorbs more water and loses strength as a result of having more pores than conventional coarse aggregate. Superplasticizers are used in this manner [16]. According to testing of novel pumice aggregate LWAC with 20%, 80%, and 100% substitution, 30% replacement provides the best value [17]. It depicts how the strength of concrete decreases as the amount of novel pumice aggregate increases [18]. This form of concrete can be used to make lintels, sunshades, and partition walls for non-load bearing wall panels in precast structures.

Table 6: M30 grade of concrete at 28 days at compressive strength test result of conventional concrete.

Strength (kN)	Compressive strength (N/mm²)	Mean compressive strength (N/mm²)
683	30.34	30.28
690	30.67	
681	30.25	
672	29.87	
685	30.45	
670	29.78	
696	30.92	
693	30.78	
675	29.98	
687	30.52	
673	29.92	
686	30.47	
688	30.58	
672	29.87	
684	30.38	
672	29.87	
679	30.16	
680	30.21	

Table 7: Represents the compressive strength of M30 grade of concrete using pumice with 30% GGBS and metakaolin.

Strength (kN)	Compressive strength (N/mm²)	Mean compressive strength (N/mm²)
736	32.71	34.53
782	34.76	
785	34.89	
787	34.98	
810	36.00	
790	35.11	
765	34.00	
740	32.89	
758	33.69	
798	35.47	
762	33.87	
745	33.11	
821	36.49	
748	33.24	
787	34.98	
792	35.20	
794	35.29	
783	34.80	

Table 8: Independent samples t-test results for sample group of 30% of GGBS and 10% of metakaolin and pumice stone as coarse aggregate: This study shows the statistical significance difference. And it was observed for compressive strength in an independent sample t-test p = 0.000 as it is lesser than p = 0.05.

		Levene's test for equality of variances		T-test for equality of means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean difference	Std. error difference	95% CI of the difference: Lower	95% CI of the difference: Upper
Flexural strength	Equal variance assumed	20.661	0.000	-15.826	34	0.000	-4.24778	0.26841	-4.7932	-3.7023
	Equal variance not assumed			-15.826	20.417	0.000	-4.24778	0.26841	-4.8269	-3.6886

Table 9: Represents group statistics for a sample group of 30% of GGBS and 10% of metakaolin and pumice stone as coarse aggregate.

	Groups	N	Mean	Std. deviation	Std. error mean
Compressive strength (N/mm²)	Conventional concrete	18	30.2789	0.34573	0.08149
	Lightweight concrete	18	34.5267	1.08503	0.25574

Novel's boundaries pumice is a lightweight aggregate that is commonly used in construction. Precast and prestressed constructions commonly use lightweight concrete [19]. Pumice is a one-of-a-kind lightweight concrete component. a type of lightweight concrete utilized since the beginning [20]. The cause is volcanic activity. The fundamental benefit of lightweight concrete is that it has a low heat conductivity. Future scope will reduce overall construction weight while boosting strength and durability, as well as lowering structural behavior of the concrete.

Conclusion

The M30 grade of concrete at 28 days of compressive strength test result of concrete with novel pumice aggregate stone and partial replacement of GGBS and metakaolin 14.03% increase the percentage of over the conventional concrete. It shows better results and performance over conventional concrete.

Acknowledgements

None.

Conflict of Interest

None.

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