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Experimental Study on Compressive Strength of Concrete in M30 Grade Utilizing Novel Pumice with 30% Silica Fume and Metakaolin Comparing with Conventional Concrete

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Abstract

Aim: The purpose is to contrast traditional concrete with lightweight concrete, which is created by utilizing a mixture of M30 grade of concrete and using pumice aggregate in place of coarse aggregate to some extent.

Method: For this investigation, two groups totaling 18 samples were created. All groups were prepared at the composition of 60% cement and replacing 30% silica fume, 10% metakaolin is kept constant in this concrete. M-sand was utilized as the fine aggregate, while novel pumice stone was employed as the coarse aggregate. Metakaolin and silica fume are procured from scientific company and pumice are arranged from online traders.

Results: The group of 18 cubes was formed according to the 28 days of curing period. To determine the compressive strength, a total of 36 cubes were manufactured in two groups. A t-test on an independent sample yielded $p = 0.118$, which is higher than $p = 0.05$. Represents group statistics of 30% silica fume and 10% of metakaolin and novel pumice stone as coarse aggregate. Mean (34.3311, 37.6489), standard deviation (1.65492, 2.30843), and standard error mean (0.39007, 0.54410). The result of a 28-day test for compressive strength on concrete of grade M30 is 34.33 N/mm^2, on average. The average result for group 1 and 18 cubes for the M30 28 days of concrete: Concrete grade with novel pumice stone and partial replacement of silica fume and metakaolin by the weight of cement is 37.65 N/mm^2.

Conclusion: Compressive M30 grade concrete's strength after 28 days of testing of concrete with novel pumice stone and partial replacement of silica fume and metakaolin by the weight of cement is an increase in the percentage of 9.67% over the conventional concrete. It performs and produces better results than conventional concrete.

Keywords

Novel pumice stone, Metakaolin, Silica fume, Compressive strength, Lightweight concrete, M30 grade of concrete, Water

Introduction

Since the late 1960s, with the advent of nanotechnology, the concept of producing nanomaterials has evolved significantly [1]. Nanoparticles, due to their extremely small size, exhibit a greater impact on fillers compared to materials at the micro level. It has been noted that all materials can potentially be transformed into nanoparticles, with the success of nanoparticle formation being dependent on its ability to influence the purity or fundamental chemical composition of the parent materials [2-4]. This led to the development of two main methods: the top-down approach and the bottom-up approach. The choice between these methods is based on factors such as suitability, cost, and expertise in nano behavior [5].

One technique employed in the top-down approach is milling, which is chosen due to the availability of milling machines and its practicality, requiring no additional chemical or electronic devices [6]. In this approach, larger structures are reduced to the nanoscale while retaining their original properties or chemical composition, without altering the atomic level control. Essentially, bulk materials are broken down into nanoparticles through mechanical attrition and etching techniques [7]. Although widely used in various industries, this method may result in inconsistent uniformity and quality of the final product [8-10]. However, modifications to milling techniques, such as adjusting the number and type of balls, milling speed, and jar type, can enhance the quality of nanoparticles [11].

High energy ball milling is a commonly employed method for synthesizing nanoparticles, including nanomaterials, nanograins, nanoalloys, nanocomposites, and nano quasi-crystalline materials [12, 13]. For instance, it has been used to modify and strengthen alloy components for applications in high thermal structures.

Materials and Method

The experiment was undertaken in Saveetha School of Engineering's Concrete Laboratory, which is part of the Civil Engineering Department. The project was to be fabricated in M30 design concrete cubes. A range of concrete cubes measuring 150 x 150 x 150 mm were produced to test the compressive strength of the material. Novel pumice stone (8 - 12 mm thickness), figure 1a shows the silica fume and figure 1b shows the metakaolin. Metakaolin in powder and s crushed granulated blast furnace slag, also known as silica fume, in powder form. Figure 1c shows the novel pumice stone.

Table 1 and table 2 cement's physical properties and fine granular. The cement of the highest quality is made up of the typical cement content of gypsum and other materials, along with argillaceous and calcareous minerals.

The coarse aggregate used was pumice, whereas the fine aggregate used was M-sand. M-sand that has been sieved to a fineness of 4.75 microns is used to make fine aggregate. Cement that met the IS: 12269-2013 OPC 53 grade was used in this project. Metakaolin and silica fume were used in compliance with Indian Standard Draft Code CED 2(7921) and IS: 12089-1987, respectively.

The mix ratio used to manufacture the M30 design was 1:0.75:1.5 for water, fine aggregate, coarse aggregate, and cement, respectively. The water to cement ratio was established at 0.45. Using cubes Compressive strength measures 150 mm x 150 mm x 150 mm as the usual dimensions. was determined. The casting of cube specimens of 150 x 150 x 150 mm is seen in figure 2. There were 18 cubes cast for each mix design for a total of 72 cubes. The cubes were stored for 24 h after the casting process, demolded, and the curing period was extended to 28 days for the compression strength.

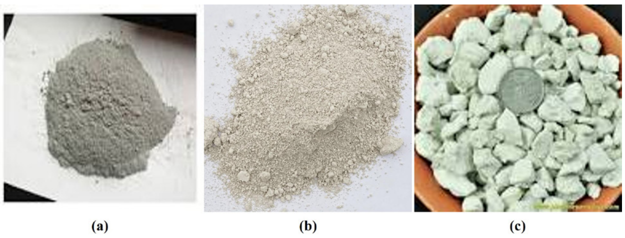
(a) (b) (c)

Figure 1: **(a)** Silica fume, **(b)** Metakaolin, and **(c)** Novel pumice stone size of 8 to 10 mm.

Table 1: Physical properties of cement.

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

Table 2: Physical qualities of fine grain concrete.

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


Figure 2: Casting of concrete.

Figure 3 shows the testing of concrete cube specimens. The specimen was acquired to determine the compressive strength once the curing phase was concluded. Using the compression testing device, the compressive strength in N/mm^2 was determined. The concrete cube specimen's maximum load resistance was known, and the ultimate load was measured and calculated using the stress formula.

Statistical analysis

The test results were evaluated using SPSS software, version 26. To ascertain using an independent sample t-test, the statistical significance between the study and control groups was determined. The study does not contain any dependent variables; the independent variables were curing days, compressive strength, cement quality, and the ratio of water to cement. This tool was used to calculate the mean, standard deviation, and standard error of the compressive strength. The

Figure 3: Testing of concrete.

bar chart comparing conventional and lightweight concrete is displayed in figure 4. The standard deviation is taken as ± 1 standard deviation. A t-test on an independent sample yielded p = 0.118, which is higher than p = 0.05. depicts group data for a thirty percent sample group of silica fume and 10% of metakaolin and novel pumice stone as coarse aggregate. Mean (34.3311, 37.6489), standard deviation (1.65492, 2.30843), and standard error mean (0.39007, 0.54410).

Results

The average compressive strength test result for conventional concrete in the M30 grade of concrete after 28 days is 34.33 N/mm^3. The M30 grade of concrete @ 28 days of compressive strength test results for conventional concrete are displayed in table 3. The M30 grade of concrete @ 28 days of compressive strength test result of concrete with novel pumice stone and partial replacement of silica fume and metakaolin by the weight of cement is 37.65 N/mm^2 for average result of group 1 and for 18 cubes.

Table 4 shows the M30 grade of concrete @ 28 days of compressive strength test result of concrete with novel pumice stone and partial replacement of silica fume and metakaolin by the weight of Cement. P = 0.118 for the independent sample t-test because it is higher than p = 0.05. Depicts group statistics for a sample group using novel pumice stone as coarse aggregate and 30% silica fume and 10% metakaolin.

Table 5 shows the independent t-tests comparison for compressive strength test results. Mean (34.3311, 37.6489), standard deviation (1.65492, 2.30843), and standard error mean (0.39007, 0.54410). Table 6 displays the group statistics obtained using the statistical analysis of the SPSS.

Discussion

The recommended dosages of metakaolin and silica fume together resulted in improved performance. to increase the strength, durability, and hardness respectively. This mineral admixture was the best alternate material for cement and reduced the carbon dioxide emission from cement industry. High-performance pozzolan silica fume helps systems and mix designs based on cement achieve higher performance and durability levels thanks to its unique chemical and physical properties. When metakaolin is utilized in concrete as a partial substitute for cement, it reacts with calcium hydroxide, one of the by-products of cement hydration, to increase the amount of C-S-H gel and hence the strength. The experimental investigation assessed how metakaolin affected a few concrete sample samples' susceptibilities to corrosion. This was achieved by investigating the concrete pore solution.

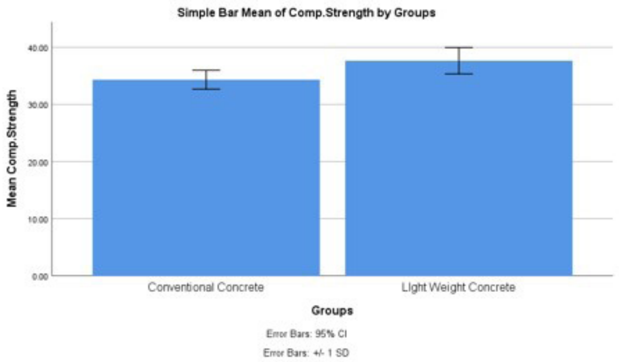

Figure 4: Bar chart analysis of mean compressive strength of sample group of 30% of silica fume and 10% of metakaolin and novel pumice stone as coarse aggregate mixture of concrete and conventional concrete. Lightweight concrete shows better accuracy in contrast to traditional concrete. The average detection accuracy is ± 1 standard deviation.

Table 3: M30 grade of concrete @ 28 days of compressive strength test result of conventional concrete.

S. No.	Weight of the concrete cube specimen (kg)	Ultimate load of the concrete cube specimen (kN)	Compressive strength for 28 Days (N/mm^2)
1	8.132	590	30.67
2	8.543	672	34.31
3	8.231	659	33.73
4	8.987	680	34.67
5	9.011	674	34.40
6	8.654	685	34.89
7	8.256	725	32.22
8	8.987	689	35.07
9	9.231	617	31.87
10	8.765	693	35.24
11	9.043	662	33.87
12	8.798	653	33.47
13	8.675	696	35.38
14	8.793	699	35.38
15	9.045	720	36.44
16	8.894	650	33.33
17	9.406	597	35.42
18	9.654	746	37.60

By greatly increasing concrete's strength and lowering its permeability, silica fume boosts the material's durability in terms of systems and mix designs based on cement achieve higher performance and durability levels. Novel pumice stone is a substitute for coarse aggregate. All across the world, volcanic rocks called fresh pumice stones may be found. Novel pumice stone is a natural lightweight aggregate that is robust enough and thin enough to be utilized in thin concrete.

Table 4: M30 grade of concrete @ results of a 28-day test for compressive strength of concrete using new pumice stones and a partial substitution of cement weight for metakaolin and silica fume.

S. No.	Weight of the concrete cube specimen (kg)	Ultimate load of the concrete cube specimen (kN)	Compressive strength for 28 Days (N/mm^2)
1	8.132	832	37.00
2	8.543	892	39.64
3	8.231	820	36.44
4	8.987	847	37.64
5	9.011	800	35.56
6	8.654	802	35.64
7	8.256	780	34.67
8	8.987	757	33.64
9	9.231	760	33.78
10	8.765	852	37.87
11	9.043	840	37.33
12	8.798	907	40.31
13	8.675	920	40.89
14	8.793	862	38.31
15	9.045	900	40.00
16	8.894	917	40.76
17	9.406	880	39.11
18	9.654	872	38.76

Limitation in the usage of conventional material by alternate materials from industrial waste by measuring the standard concrete's tensile and compressive strengths and concrete that had been substituted with various amounts of pumice, ranging from 5% to 30%, the physical, mechanical, and concrete's durability attributes were examined. Shotcrete and self-consolidating concrete applications benefit from increased cohesiveness when silica fumes are used. Engineers and specifiers may meet and surpass design and performance objectives with silica fumes.

Conclusion

The compressive strength of concrete of M30 grade after 28 days of testing test result of Concrete with novel pumice stone and partial replacement of silica fume and metakaolin by the weight of cement is increase in the percentage of 9.67% over the conventional concrete. It shows better results and performance over conventional concrete.

Acknowledgements

None.

Table 6: Represents group statistics for a sample group of 30% of silica fume and 10% of metakaolin and novel pumice stone as coarse aggregate. Mean (34.3311, 37.6489), standard deviation (1.65492, 2.30843), and standard error mean (0.39007, 0.54410).

	Group	N	Mean	Std. deviation	Std. error mean
Compressive strength (N/Mm^2)	Conventional concrete	18	34.3311	1.65492	0.39007
	Lightweight concrete	18	37.6489	2.30843	0.54410

Conflict of Interest

None.

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Table 5: Results of the independent samples t-test for the 30% sample group of silica fume and 10% of metakaolin and novel pumice stone as coarse aggregate: In an independent sample t-test, no there was a statistically significant difference discovered. for compressive strength (p = 0.118), as it is bigger than p = 0.05.

Compressive strength	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	Upper
Equal variance assumed	2.572	0.118	-4.956	34	0.000	-3.31778	0.66948	-4.67832	-1.95724
Equal variance not assumed	-	-	-4.956	34	0.000	-3.31778	0.66948	-4.68350	-1.95205

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