Nano World Journal

https://doi.org/10.17756/nwj.2023-s3-045

Research Article

Open Access

Experimental Study on Compressive Strength of M30 Grade of Concrete Using Novel Pumice with 20% Silica Fume and Metakaolin Comparing with Conventional Concrete

Balasubramani Ravi and Lakshmi Thangasamy*

Department of Civil Engineering, Saveetha School of Engineering, Saveetha Institute of Medical and Technical Sciences, Saveetha University, Chennai, Tamil Nadu, India

***Correspondence to:**
Lakshmi Thangasamy
Department of Civil Engineering,
Saveetha School of Engineering,
Saveetha Institute of Medical and Technical Sciences, Saveetha University,
Chennai, Tamil Nadu, India.
E-mail: lakshmits.sse@saveetha.com

Received: July 27, 2023
Accepted: October 05, 2023
Published: October 09, 2023

Citation: Ravi B, Thangasamy L. 2023. Experimental Study on Compressive Strength of M30 Grade of Concrete Using Novel Pumice with 20% Silica Fume and Metakaolin Comparing with Conventional Concrete. *NanoWorld J* 9(S3): S230-S235.

Published by United Scientific Group

Abstract

The objective was to compare the use of M30 grade concrete admixture to partially replace coarse aggregate in lightweight concrete with a novel pumice aggregate using conventional concrete. Two groups prepared in 70% cement mixture and instead of 20% silica fume, 10% metakaolin was fixed in this concrete. Novel pumice was used as coarse aggregate and M-sand as fine aggregate. An independent t-test was calculated using 80% G-power. Metakaolin and silica fume are purchased from scientific institutes and novel pumice is arranged from online traders. Results: The group of 18 cubes was formed according to the curing date for 28 days. A total of two groups were prepared and a total of 36 cubes were prepared to find the compressive strength. The independent sample t-test on two groups showed that there was a statistically significant difference with $p < 0.000$ ($p < 0.05$). This represents group statistics for a sample group of 20% silica fume and 10% of metakaolin and novel pumice stone as coarse aggregate. mean (34.3311, 36.8061), standard deviation (1.65492, 1.58424), and standard error mean (0.39007, 0.37341). The average M30 grade of concrete at 28 days of compressive strength test result of conventional concrete is 34.33 N/mm^2. The M30 Grade of concrete at 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 36.80 N/mm^2 for average result of group 1 and for 18 cubes. The compressive strength of M30 grade of concrete at 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 increased in the percentage of 6.67% over the conventional concrete. It shows better results and performance over conventional concrete.

Keywords

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

Introduction

During the course of history, concrete has been a common building material. Concrete is a material that personifies sturdiness. Investigations have been made into this building material's durability for the present infrastructure needs [1]. Concrete's strength is its capacity to withstand forces that would otherwise diminish or increase its strength [2]. The availability of concrete is beginning to dwindle as a result of its extensive use in this century. Aggregates account for around 70% of the weight of concrete. Because of the daily rise in construction activity, natural aggregates are highly sought. It is essential to create some environmentally friendly materials which will fulfill a similar function as coarse aggregate due to the ongoing depletion of natural resources [3]. Many issues were noted, among which were constrained to: growing high construction supply costs, consumption of non-renewable building materials that raise the price of housing units overall, rejection of local building materials, and inadequate support of localized construction materials empirical investigations [4]. Researchers have been looking into less expensive substitutes that would perfectly replace these materials, keeping the industry standards for concrete because the price of making concrete in Nigeria using conventional materials like river sand for the fine aggregate, granite for the coarse aggregate, and cement has increased [5]. In a developing country like Nigeria, switching out the coarse aggregate with cheaper local alternatives or even materials like quarry dust can greatly boost the production of concrete with the necessary properties at a reasonable price [1]. It will significantly lower production costs, which will lower construction costs as a result. Table 1 shows the coarse aggregate's physical properties [6].

This will allow the quarry dust to be used productively rather than letting it go to waste and posing an environmental risk. Table 2 shows comparison of the chemical constituents of silica fume, metakaolin, and cement.

About 1190 results from the past five years researchers in Google Scholar. Novel pumice is a volcanic rock that weathering has given a porous, rounded, and irregular appearance. Novel pumice and volcanic materials' physical characteristics, such as density, friability, grain size, grain shape, and roughness determine whether they are suitable for a given end application [7]. Table 3 shows physical properties of novel pumice stone [8]. Yet, the aggregate's porosity encourages the formation of dense, homogenous interfacial zones between aggregate grains [9].

Scoria are basalt-like in nature, have uneven shapes, and are frequently quite vesicular. Novel pumice and scoria typically differ in weight, color, and crystallinity. Novel pumice is a raw material that is very light and porous [10]. It can be found around the world, especially in a number of emerging nations where there are locations where there has been or is currently volcanic activity [11]. Reduced dead weight in constructing structures is a benefit of using aggregates that are lightweight to produce lightweight concrete [6].

Table 1: 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 2: Comparison of chemical properties of the cement, metakaolin and silica fume.

Contents	Cement	Metakaolin	Silica fume
SiO_2 (%)	20.1	54.9	93.38
CaO (%)	63.5	0.06	0.67
Al_2O_3	4.9	41.7	0.15
Fe_2O_3	3.6	1.07	0.21
MgO	1.2	0.84	0.10
TiO_2	-	0.36	-
MnO_2	2.9	-	1.28
LoI	1.7	1.03	1.46
Specific gravity	3.15	2.44	2.25
Color	gray	white	Grey to off-whitish
Bulk density (kg/cc)	830	900	1300

Table 3: Physical properties of novel pumice stone.

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

Materials and Method

The experiment was undertaken in the Saveetha School of Engineering Concrete Laboratory, which is part of the Civil Engineering Department. The project was to be fabricated in M30 design concrete cubes. To determine concrete's compressive strength, 150 x 150 x 150 mm concrete cubes of various sizes were made. Novel pumice stone (8 - 12 mm thickness), Figure 1 shows the silica fume and figure 2 shows the me-

Figure 1: Silica fume.

Figure 2: Metakaolin.

takaolin. Metakaolin and silica fume in powder format. Used materials are nanoscale materials.

The cement of the highest quality is made up of the normal cement content of argillaceous and calcareous materials, as well as other materials like gypsum. Figure 3 shows the novel pumice stone. M-sand was utilized as the fine aggregate, while novel pumice was employed as the coarse aggregate [12]. Fine aggregate is created from M-sand that has been sieved to a fineness of 4.75 microns. This project employed cement that complied with IS: 12269-2013 OPC 53 grade. Silica fume and metakaolin were utilized in accordance with IS: 12089-1987 and Indian Standard Draft Code CED 2(7921), respectively [13].

Table 4 displays the cement's characteristics, while table 5 displays the fine aggregate's physical characteristics. The M30 design was made with the mix proportion of 1:0.75:1.5 (Cement:fine aggregate:coarse aggregate). Using cubes with a standard dimension of 150 mm x 150 mm x 150 mm, compressive strength was determined. The casting of concrete cube specimens of 150 x 150 x 150 mm is seen in figure 4.

Figure 3: Novel pumice stone size of 8 to 10 mm.

Table 4: Physical properties of cement.

S. No.	Properties of cement	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 5: Physical properties of fine aggregate.

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

There were 18 cubes cast for each mix design for a total of 72 cubes. The cubes were maintained for 24 h after casting before being demolded, and the curing period was taken to the compression strength of 28 days. Figure 5 shows the curing of concrete cube specimens. The specimen was obtained to determine the compressive strength once the curing procedure was finished [14]. The compressive strength in N/mm^2 was calculated using the compression testing apparatus. The ultimate load was taken and calculated by using the stress formula and known about the maximum load resistance by the concrete cube specimen.

Statistical analysis

Software SPSS (Statistical Package for the Social Sci-

Figure 4: Casting of concrete.

Figure 5: Curing of concrete.

ences) version 26 was used to evaluate experiment results. To determine the statistical significance between the study and control groups, an independent sample t-test was conducted. With this tool, the mean, standard deviation, and standard error of the mean were also computed for compressive strength. The bar graph of the conventional concrete and lightweight concrete comparison is shown in figure 6. T-test on an independent sample of significant values is 0.000, which is $p < 0.05$. Represents group statistics for a sample group of 20% silica fume and 10% of metakaolin and novel pumice stone as coarse aggregate. Mean (34.3311, 36.8061), standard deviation (1.65492, 1.58424), and standard error mean (0.39007, 0.37341).

Results

The average M30 grade of concrete at 28 days of compressive strength test result of conventional concrete is 34.33 N/mm^2. Table 6 shows the M30 grade of concrete at 28 days of compressive strength test result of conventional concrete. The M30 grade of concrete at 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 36.80 N/mm^2 for average result of group 1 and for 18 cubes.

Table 7 shows the M30 grade of concrete at 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. There is statistical significance dif-

Table 6: M30 grade of concrete at 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

Table 7: M30 grade of concrete at 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.

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	840	37.33
2	8.543	852	37.87
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	812	36.09
11	9.043	840	37.33
12	8.798	855	38.00
13	8.675	865	38.44
14	8.793	842	37.42
15	9.045	874	38.84
16	8.894	842	37.42
17	9.406	854	37.96
18	9.654	865	38.44

Table 8: Independent samples t-test results for sample group of 20% of silica fume and 10% of metakaolin and novel pumice stone as coarse aggregate: this study shows the statistical significance difference observed for compressive strength in an independent sample t-test significant value is 0.000, which is ($p < 0.05$).

		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	Upper
Compressive strength	**Equal variance assumed**	0.052	0.822	-4.583	34	0.000	-2.47500	0.53999	-3.57239	-1.37761
	Equal variance not assumed	-	-	-4.583	33.935	0.000	0.53999	0.53999	-3.57246	-1.37754

Table 9: Represents group statistics for a sample group of 20% of silica fume and 10% of metakaolin and novel pumice stone as coarse aggregate. Mean (34.3311, 36.8061), standard deviation (1.65492, 1.58424), and standard error mean (0.39007, 0.37341).

	Groups	N	Mean	Std. deviation	Std. error mean
Compressive strength (N/mm^2)	Conventional concrete	18	34.3311	1.65492	0.39007
	Lightweight concrete	18	36.8061	1.58424	0.37341

ference between the compressive strength in an independent sample t-test significant value is $p < 0.000$, which is ($p < 0.05$). Represents group statistics for a sample group of 20% silica fume and 10% of metakaolin and novel pumice stone as coarse aggregate.

Table 8 shows the independent t-tests comparison for compressive strength test results. Mean (34.3311, 36.8061), standard deviation (1.65492, 1.58424), and standard error mean (0.39007, 0.37341). The group statistics obtained from the SPPS statistical analysis are displayed in table 9.

Figure 6 bar chart analysis of mean compressive strength of sample group of 20% 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 compared to conventional concrete. Mean accuracy of detection = +/- 1 standard deviation.

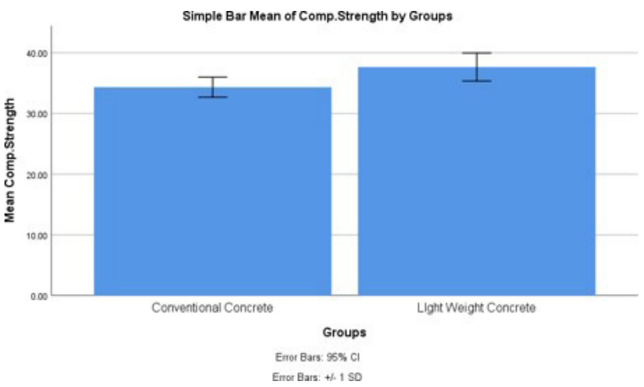

Figure 6: Bar chart analysis of mean compressive strength of sample group of 20% of silica fume and 10% of metakaolin and novel pumice stone as coarse aggregate mixture of concrete and conventional concrete. Lightweight concrete shows better accuracy compared to conventional concrete. Mean accuracy of detection = +/- 1 standard deviation.

Discussion

The ideal concentrations of silica fume and metakaolin together led to better performance to increase the strength, durability, and hardness respectively. This mineral admixture was the best alternate material for cement and reduced the CO_2 emission from cement industry [15]. With its special chemical and physical characteristics, silica fume, a high-performance pozzolan, helps mix designs reach better levels of workability. When metakaolin is used in concrete as a partial replacement for cement, it combines with $Ca(OH)_2$, one of the by-products of the hydration process of cement, to produce more C-S-H [16] gel and hence more strength. The experimental study evaluated the corrosion impact of metakaolin on a few concrete sample samples [17]. By analyzing the concrete pore solution, this was accomplished.

The addition of silica fumes will significantly improve the strength and decrease the permeability of concrete, which will boost its durability in terms of chemical resistance, chloride attack, sulfate attack, and abrasion resistance. The alternative material for coarse aggregate is novel pumice stone [15]. Rocks of volcanic origin, such as novel pumice stones, are found all over the planet. A natural lightweight aggregate called novel pumice stone is thin enough and robust enough to be utilized in thin concrete [18].

Limitation in the usage of conventional material by alternate materials from industrial waste: The compressive strength and tensile strength of conventional concrete and concrete that had different percentages of novel pumice from 5% to 30% replaced it were tested to determine the physical, mechanical, and durability aspects of concrete. Shotcrete and self-consolidating concrete applications benefit from increased cohesiveness when silica fumes are used. Engineers and specifiers can achieve and even surpass design and performance requirements with the help of silica fumes in the next research.

Conclusion

The compressive strength of M30 grade of concrete at 28 days of compressive strength test results 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 7.19% over the conventional concrete. Compared to traditional concrete, it exhibits greater outcomes and performance.

Acknowledgements

None.

Conflict of Interest

None.

References

1. Li Z, Zhou X, Ma H, Hou D. 2022. Advanced Concrete Technology. John Wiley & Sons.
2. Taranath BS. 2009. Reinforced Concrete Design of Tall Buildings. CRC press.
3. Dvorkin L, Zhitkovsky V, Lushnikova N, Ribakov Y. 2021. Metakaolin and fly ash as mineral admixtures for concrete. CRC Press, Boca Raton.
4. Alaoui YJ. 2021. Ultra-high strength concrete: effect of supplementary cementitious materials and their proportions. Department of Civil Engineering, Pennsylvania State University. (Graduate Thesis)
5. Pimienta P, McNamee RJ, Mindeguia JC. 2019. Physical properties and Behaviour of high-Performance Concrete at high Temperature. RILEM State-of-the-Art Reports. Springer Cham.
6. Yilmaz S, Ozmen HB. 2016. High Performance Concrete Technology and Applications. IntechOpen.
7. Cas R, Wright J. 2012. Volcanic Successions Modern and Ancient: A Geological Approach to Processes, Products and Successions. Springer.
8. Reddy KR, Kalia S, Tangellapalli S, Prakash D. 2022. Recent Advances in Sustainable Environment. Springer, Singapore.
9. Gupta R, Deshmukh D, Patil AP, Shrivastava NK, Giri J, et al. 2023. Recent Advances in Material, Manufacturing, and Machine Learning. CRC Press, London.
10. Wu S, Hoff I, Amirkhanian S, Xiao Y. 2019. Environment- Friendly Construction Materials. MDPI.
11. Kumar VV, Raja K, Ramkumar T, Selvakumar M, Kumar TSS. 2021. Studies on mechanical property and wear behaviour of AA7075 hybrid composites prepared by a conventional casting method. *Proc Inst Mech Eng Part E J Process Mech Eng* 235(6): 2180-2188. https://doi.org/10.1177/09544089211034939
12. Balasubramanian B, Udayakumar T, Kumar VVK, Raja K. 2022. Study of natural cellulose fiber's characters in *Holoptelea integrifolia* tree bark. *J Nat Fibers* 19(16): 13574-13581. https://doi.org/10.1080/15440478.2022.2101576
13. Clarke JL. 1993. Structural Lightweight Aggregate Concrete. CRC Press, London.
14. Yokeswaran R, Vijayan V, Karthikeyan T. 2020. Study of various types cladding and the evolvement of the techniques through years and the future scope–a review. *Mater Today Proc* 21: 773-776. https://doi.org/10.1016/j.matpr.2019.06.756
15. Kodeboyina GB. 2018. High Performance Self-consolidating Cementitious Composites. CRC Press, Boca Raton.
16. Barnes P, Bensted J. 2002. Structure and Performance of Cements. CRC Press.
17. Duggal SK. 2017. Building Materials. Routledge, London.
18. Chandra S, Berntsson L. 2002. Lightweight Aggregate Concrete. Elsevier.