An Experimental Investigation on the Compression Strength of M25 Grade Concrete with Replacement of Quartz Sand and Comparison with Conventional Concrete

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Abstract

Aim: The study aimed to understand the impact of incorporating 10% quartz sand in M25 grade concrete on its compressive strength and workability compared to regular concrete. Materials and Methods: The study tested the properties of two types of concrete, one with a regular mix and one with 10% quartz sand replacement of fine aggregate, using grade 43 cement, a water-cement ratio of 0.5, and 20mm aggregate. The specimens were cast and cured for 28 days before being tested for compression strength using universal testing equipment. The compressive strength of M25 grade concrete (N=10) was compared to normal concrete (N=10) using statistical analysis with G-power 0.8 software and a 95% confidence interval. Results: The analysis found that adding 10% quartz sand as a replacement for fine aggregate in M25 grade concrete improved its compressive strength in comparison to conventional concrete. At 28 days of curing, the compressive strength of concrete containing 10% quartz sand was 27.5 MPa, while that of regular concrete was 25 MPa. Conclusion: The results indicated that using quartz sand as a substitute for fine aggregate in concrete is a realistic option in the building sector. The addition of quartz sand enhances the compressive strength and flowability of concrete compared to standard concrete.

Keywords: *Compressive strength, Concrete, Quartz sand, Novel M25 grade concrete, Conventional concrete, Fine aggregate.*

Introduction

Concrete is the most widely used material of construction all over the world, due to its strength, durability, and versatility (Beushausen, Torrent, and Alexander 2019). A huge quantity of concrete is consumed by the global construction industry. However, the use of conventional concrete has several drawbacks, including high carbon emissions from cement production and a relatively low strength-to-weight ratio (Amran et al. 2020). In recent years, researchers have been exploring alternative materials that can be used to improve the performance of concrete. One such material is quartz sand, which has been shown to have several advantages over conventional concrete when used as a replacement for fine aggregate (Kazanskaya, Isakovsky, and Fadeeva 2019). In this study, a comparison is made between regular concrete and concrete in which 10% quartz sand partially replaces the cement. The testing results demonstrated that concrete containing 10% quartz sand was more workable than normal concrete. Existing concrete structures such as arches, apartment blocks, and roads can be evaluated using compressive strength tests to see if they need to be repaired or rebuilt. (Aslam et al. 2020).

Several studies have explored the use of various materials as partial replacements for cement in M25 grade concrete, with the aim of improving its properties in recent years, as evidenced by the numerous studies published on the subject, including 37 papers found on IEEE Explore and 672 articles found on Google Scholar (Madan et al. 2022; G. Singh et al. 2023; Thajuba et al. 2021). Phul, Memon, and Shah (Phul, Memon, and Shah 2019) observed that replacing cement with fly ash and GGBS increased compressive strength and decreased water absorption. Theja and Pravallika et al. (Theja and Pravallika 2021) discovered that replacing cement with silica fume enhanced the microstructure of the concrete, resulting in an increase in compressive strength and a reduction in water absorption. Dhengarea et al. (Dhengarea et al. 2020) discovered that replacing cement with rice husk ash improved compressive strength and low groundwater absorption. Singh et al. (V. K. Singh et al. 2022) found that using recycled aggregate as a replacement for natural aggregate increased compressive strength, flexural strength, and toughness but decreased workability. Dhanapal and Jeyaprakash (Dhanapal and Jeyaprakash 2020) found that adding steel fibres as reinforcement to M25 grade concrete increased its compressive strength, flexural strength, and toughness. Sanvaliya, Bidare, and Talawale (Sanvaliya, Bidare, and Talawale 2019) found that using microsilica as a replacement for cement in M25 grade high-performance concrete increased compressive strength, flexural strength, and toughness but decreased workability.

The main disadvantage of compressive strength in conventional concrete is that it does not take into account other important properties of concrete such as tensile strength, durability, and workability. Additionally, a high compressive strength may not always be necessary or desirable, as the cost of materials and labor to achieve high compressive strength can be prohibitively expensive. To overcome this, a novel M25 grade concrete with a 10% addition of quartz sand is by increasing the durability and resistance to wear and tear of the concrete. Quartz sand can be used as an aggregate to boost the concrete's overall strength. Quartz sand also enhances the concrete's workability, making it simpler to put and complete. Adding this will also make concrete more resistant to chemical attack and weathering.

MATERIALS AND METHODS

The experiment was carried out in the Mechanics Laboratory of the Civil Engineering Department at Saveetha School of Engineering. The materials used in this experiment were cement, water, coarse aggregate, and quartz sand. The study was conducted using two types of concrete using conventional concrete and a novel M25 grade concrete containing 10% quartz sand. Except for the substitution of quartz sand for fine aggregate, the concrete mixtures of the two forms of concrete remained unchanged. The cement used is a standard portland cement of grade 43, the water-cement ratio was 0.5, and the coarse aggregate was sourced from Js Readymix Concrete in Kanchipuram and measured 20 mm in diameter. The concrete specimens were cast and cured for 28 days. Compressive strength was determined using a universal testing machine. This research had a sample size of 20, divided into two groups of 10 each. The first group consisted of regular concrete, while the second group utilized a new type of M25 grade concrete that incorporated 10% quartz sand as a replacement for fine aggregate. The sample size was determined based on previous studies done by (Kanamarlapudi et al. 2020). The data was analyzed using G-power software with a significance level of 0.05 and a power of 0.20. The results are reported with a 95% confidence interval.

Conventional concrete

Conventional concrete is a type of concrete that is created with traditional materials such as cement, water, coarse aggregate (typically crushed stone), and fine aggregate. The ingredients are mixed together in specific proportions to achieve the desired strength, workability, and durability of the final product. The coarse aggregate is typically made of crushed stone, such as limestone or granite, while the fine aggregate is typically made of natural sand. The mixture is then placed into forms, compacted and cured over time to achieve the desired strength and durability. Conventional concrete is widely used in construction projects such as buildings, bridges, roads, and other infrastructure. The compressive strength of conventional concrete is determined by the proportions and quality of the ingredients used in the mix, as well as by the curing conditions. For normal weight concrete, the compressive strength is usually measured at 28 days after casting, at that point the strength is considered to have reached 90% of its final strength. However, in practice, the compressive strength of concrete is not uniform throughout the structure, and it may vary from point to point.

M25 grade concrete

The term "M25 grade concrete utilising 10% quartz sand" refers to a form of concrete that is distinguished by its compressive strength as well as the substitution of quartz sand for fine aggregate. The letter "M" in "M25" stands for "mix," and the number "25" denotes the compressive strength of the concrete in megapascals (MPa) at the end of the 28-day curing period. Concrete of the M25 grade has a medium strength and is frequently utilised in construction projects including the building of structures, bridges, highways, and other forms of infrastructure. It is a versatile concrete mix that is suited for a wide variety of applications, including slabs, columns, beams, and foundations, among other things. When talking about M25 grade concrete, the term "usage of 10% quartz sand" refers to the substitution of quartz sand for 10% of the fine aggregate in the mix of concrete that is being used. Quartz sand is a type of natural mineral that can be found in large quantities and is not overly expensive. It has been determined that it can function adequately in the role of fine aggregate in concrete. It has been discovered that adding quartz sand to concrete can improve the material's strength as well as its durability and its capacity to be worked. The compressive strength test, sometimes called the cube test or the concrete cylinder test, is a standard method that is used to assess the compressive strength of concrete. Other names for this test include the concrete cylinder test and the cube test. It is a crucial indicator of the concrete's general quality and longevity, and it is used to evaluate the concrete's capacity to withstand loads that may cause compression. Tests of a concrete structure's compressive strength can be utilised to ascertain why the structure failed in the first place and what actions should be taken to mitigate the risk of failures of a similar nature in the future. In a laboratory context, testing of compressive strength are carried out on novel concrete mixes, additives, and other types of materials in order to evaluate their effectiveness. In order to guarantee that the concrete used in a structure satisfies the minimum strength standards, building laws and regulations will often mandate that compressive strength tests be performed on the concrete.

Statistical Analysis

The independent samples t-test was conducted using IBM SPSS V26.0 (Hilbe 2004) to compare the means, standard deviations, and standard errors of compressive strength between the two groups. The dependent variable of the study was compressive strength, while the independent variable was the type of concrete (regular or M25 grade). The goal of the statistical analysis was to accurately determine the mean and standard deviation of compressive strength for each group and to identify any significant differences between the two groups of regular and M25 grade concrete.

RESULTS

The data is presented in the form of a bar graph in Figure 1, which compares the compressive strength of conventional concrete and M25 grade concrete. The graph shows the mean compressive strength on the Y-axis, with a 95% confidence interval represented by ±1 standard deviation. The X-axis represents the types of concrete. The mean compressive strength for conventional concrete is 25 MPa and for M25 grade concrete is 27.5 MPa.

Figure 1. A bar graph is used to compare the compressive strength of conventional concrete and M25 grade concrete. The X-axis represents the types of concrete, and the Y-axis shows the mean compressive strength, with a 95% confidence interval represented by ±1 standard deviation. The conventional concrete has a mean compressive strength of 25 MPa, and the M25 grade concrete has a mean of 27.5 MPa.

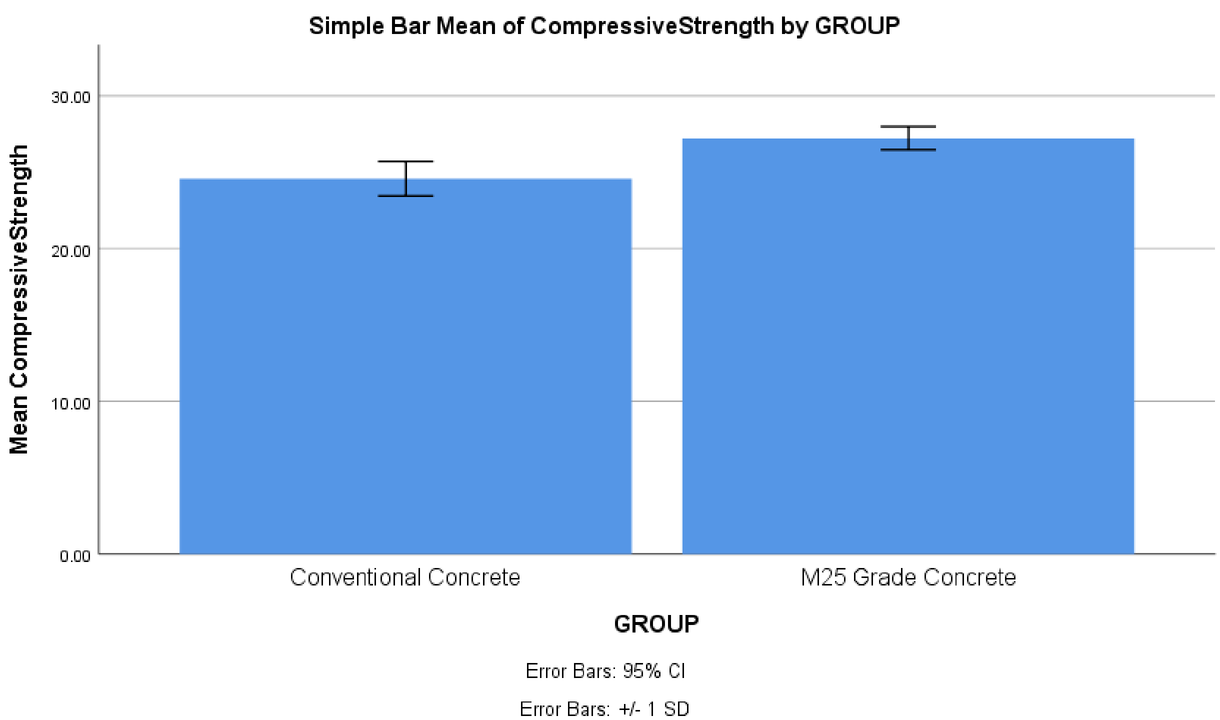

Table 1. The compressive strength of M25 grade concrete with 10% replacement of fine aggregate with Quartz Sand is 27.5 MPa, which is 2.5 MPa higher than the compressive strength of conventional concrete (25 MPa). This indicates that the addition of Quartz Sand as a replacement for fine aggregate has improved the compressive strength of the concrete.

SI.No.	Test Size	Compressive Strength	
		Conventional concrete	M25 grade concrete
1	Test1	20	21
2	Test2	22	25

3	Test3	24	29
4	Test4	26	23
5	Test5	28	27
6	Test6	30	31
7	Test7	20	19
8	Test8	24	23
9	Test9	28	27
10	Test10	32	29

Table 1 illustrates that the compressive strength of M25 grade concrete using 10% Quartz Sand as a replacement for fine aggregate is 27.5 MPa, which is 2.5 MPa greater than the compressive strength of conventional concrete (25 MPa). This implies that replacing fine aggregate with Quartz Sand increases the compressive strength of the concrete.

Table. 2. The compressive strength of the conventional concrete is 25 MPa, while that of the M25 grade concrete is 27.5 MPa. The compressive strength of the M25 grade concrete is 10% higher than that of the conventional concrete at 28 days. The standard deviation of the conventional concrete is 0.415, and that of the M25 grade concrete is 0.190. The standard error mean of the conventional concrete is 0.337, and that of the M25 grade concrete is 0.078.

Group		**N**	**Median**	**Standard Deviation**	**Standard Error Median**
Compressive Strength	M25 grade concrete	10	27.5	0.190	0.078
	Conventional Concrete	10	25	0.415	0.337

Table 2 depicts that the compressive strength of standard concrete is 25 MPa, while that of M25 grade concrete is 27.5 MPa. M25 grade concrete has 10% better compressive strength than normal concrete after 28 days. Normal concrete has a standard deviation of 0.415%, while M25 grade concrete has a standard deviation of 0.190%. Normal concrete has a mean standard error of 0.337, while M25 grade concrete has a mean standard error of 0.078.

Table 3: The statistical calculations for independent samples comparing conventional concrete and M25 grade concrete. The significance value for Compressive strength is 0.001. An independent sample T-test was used for the comparison, with a confidence interval of 95% and a level of significance of 0.183. The test includes information such as the significance (2-tailed), mean difference, standard error difference, and lower and upper interval difference.

Group		Levene's Test for Equality of Variances		t-test for Equality of Medians						
		F	Sig.	t	df	Sig. (2-tailed)	Median Difference	Std. Error Difference	95% Confidence Interval (Lower)	95% Confidence Interval (Upper)
	Equal variances assumed	1.309	0.176	1.591	13	0.001	0.284	0.183	-0.146	0.730

Compressive strength	Equal variances not assumed			1.591	6.088	0.001	0.284	0.183	-0.148	0.732

Table 3 provides the statistical analysis comparing the compressive strength of regular concrete and M25 grade concrete using separate samples. The analysis used a 95% CI independent sample t-test with a significance level of 0.183. A p-value of 0.001 was considered statistically significant. The results of the test are reported as a two-tailed p-value, the mean difference, the standard error of the difference, and the range of the difference interval between the two groups.

DISCUSSION

When 10% quartz sand is added to M25 grade concrete, it can increase the compression strength of the concrete. Quartz sand is a strong, abrasion- and erosion-resistant mineral that can enhance the overall stability and durability of the concrete. It has been demonstrated that concrete constructed with quartz sand has various advantages over regular concrete. For example, it has a higher compressive strength and a higher modulus of elasticity. This means that concrete made with quartz sand is stronger and more resistant to cracking and deformation. Additionally, concrete made with quartz sand has a lower water absorption rate, which means that it is less susceptible to damage from freeze-thaw cycles and salt attacks. This research also found that the environmental impact of using quartz sand in concrete is lower than that of traditional concrete. After 28 days of curing, the compressive strength of concrete with 10% quartz sand was found to be 27.5 MPa, while the compressive strength of regular concrete was 25 MPa.

Some similar studies are Jamenraja and Ravichandran (Jamenraja and Ravichandran 2022) and Malathy et al. (Malathy et al. 2022) found that the use of quartz sand in M25 grade concrete improves its compressive and flexural strengths, as well as its durability in various environmental conditions. On the other hand, a study by Jagan and Neelakantan (Jagan and Neelakantan 2021) found that the use of quartz sand improves workability of the concrete. However, a study by Manohar Reddy, Prasad, and Kumar Balguri (Manohar Reddy, Prasad, and Kumar Balguri 2022) found that the use of egg shell and copper slag in M25 grade concrete increases its setting time, which can make it harder to work with. This contradicts the findings of Michael Johnson's study which claimed that the use of egg shell improves the workability of M25 grade concrete.

The limitation of the proposed study is that it may not result in a significant increase compared to conventional concrete. The increase in compressive strength may be minimal and may not be enough to justify the added cost and potential negative effects of using quartz sand. In terms of future research, it would be interesting to investigate the optimal percentage of quartz sand to use in M25 grade concrete in order to achieve the highest compressive strength while also considering other factors such as cost and sustainability. Additionally, looking into the long-term effects of using quartz sand in concrete and how it affects the durability and longevity of the concrete could also be valuable.

CONCLUSION

According to this research, using 10% quartz sand as a replacement for fine aggregate in M25 grade concrete improves its compressive strength. It is anticipated that the compressive strength of concrete containing 10% quartz sand will be greater than that of standard concrete. Therefore, quartz sand can be considered as a viable alternative to natural river sand as a fine aggregate in concrete.

DECLARATION

Conflicts of Interest

No conflict of interest in this manuscript

Authors Contributions

Jaleezur rahman was involved in data collection, data analysis and manuscript writing. Ganeshan was involved in conceptualization, data validation, and critical review of manuscripts.

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