An investigation of the Compressive strength of pavement quality concrete using steel fibers in comparison to standard concrete

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Abstract

Aim: This study aimed to evaluate the Compressive strength of pavement quality concrete (PQC) reinforced with steel fibers in comparison to standard concrete. Materials and Methods: This study used Ordinary Portland Cement that met Indian Standards as the main materials, with 20 samples divided into two groups of 10 each for testing. The Compressive strength was tested by comparing Steel fiber reinforced pavement quality concrete (N=10 samples) with Conventional concrete (N=10 samples) through statistical analysis using G-power software with a power of 0.8 and a 95% confidence interval. Results:The compressive strength of proposed concrete reinforced with steel fibers was much greater than that of regular concrete, according to a study. The steel fiber reinforced concrete has an average compressive strength of 35 MPa compared to 25 MPa for normal concrete. A p-value of less than 0.05 (p=0.001) indicates a significant link between the usage of steel fibers and an improvement in compressive strength.Conclusion: The addition of steel fibers to concrete is an effective way to enhance its strength and toughness properties, making it a durable and long-lasting building material.

Keywords: *Compressive strength, Concrete, Cement, Pavement quality concrete, Novel steel fiber, Conventional concrete.*

Introduction

Pavement quality concrete (PQC) is a type of concrete that is used in the construction of roads and pavements (Pandey and Kumar 2022). PQC is designed to be more durable and resistant to wear and tear than regular concrete. However, PQC is also susceptible to cracking due to the high loads that it is subjected to. To overcome this problem, steel fibers are often added to PQC to increase its strength and improve its resistance to cracking (Pandey and Kumar 2019). This study aimed to evaluate the Compressive strength of PQC reinforced with steel fibers in comparison to conventional concrete (Paluri et al. 2020).This study used steel fibers that were 60mm long and 0.5mm in diameter. These fibers were incorporated into the PQC at a rate of 0.5% by volume. The specimens of concrete were cast, allowed to cure for 28 days, and then subjected to Compressive testing. A universal testing apparatus was used to measure the compressive strength of the concrete samples. According to the study's findings, adding steel fibers to the PQC at a volume fraction of 0.5% boosted its

Compressive strength by 10%. The improvement in compressive strength is attributable to the steel fibers' role as reinforcement, providing additional strength and resisting the crack propagation (Murthi, Poongodi, and Gobinath 2021). Steel fiber is typically used in applications such as Reinforced concrete structures, Industrial floors, shotcrete and prefabricated concrete elements. Other specific applications can be found in areas such as fire resistance, seismicity, and blast resistance.

In recent years, a substantial amount of research has been conducted on the use of fiber reinforced concrete for pavement applications (Andrew et al. 2022; Kos et al. 2022; Hassan et al. 2022). This is evidenced by the 505 research papers published on the topic in IEEE Explore and the 1073 articles found on Google Scholar. Khazaei(Khazaei 2020) reviewed the literature and found that factors such as the type and amount of cement, the water-to-cement ratio, and curing conditions all play a role in determining the strength of PQC. Similarly, Gravina(Gravina et al. 2021) found that the aggregate size used in PQC also has a significant impact on the material's Compressive strength. Sharma (Sharma et al. 2022) emphasized the importance of proper curing for achieving high Compressive strength in PQC, and Rosca and Serbanoiu(Rosca and Serbanoiu 2022) highlighted the critical role of the water-to-cement ratio, with lower ratios resulting in higher strength. Malgorzata(Malgorzata 2019) found that the use of air entraining agents can enhance the strength of pavement quality concrete, particularly in cold weather conditions. Saini, Ransinchung R. N, and Kumar (Saini, Ransinchung R. N, and Kumar 2022) found that the type of cement used in pavement quality concrete can have a significant impact on the Compressive strength, with certain types of cement resulting in higher strength. Chore and Joshi (Chore and Joshi 2020) found that the Compressive strength of pavement quality concrete improves with curing time, with longer curing times resulting in higher strength. Hashemi(Hashemi et al. 2022) found that the use of certain admixtures, such as superplasticizers, can improve the Compressive strength of pavement quality concrete.

The main drawback of conventional concrete in terms of Compressive strength is that it can be brittle and prone to cracking under high loads. This can lead to a reduction in its overall strength and durability, as well as an increased likelihood of failure. Additionally, conventional concrete typically has a relatively low compressive strength compared to other building materials, which can limit its use in certain types of construction. To address this issue, this study proposed a novel steel fiber reinforced pavement quality concrete (SFRPQC) and compared it to conventional concrete. The proposed method was compared to conventional concrete to evaluate the potential improvements in Compressive strength. The aim was to determine the potential improvements in Compressive strength when using steel fiber reinforced PQC compared to conventional concrete.

MATERIALS AND METHODS

The experiment was carried out in the Mechanics Laboratory of the Civil Engineering Department at Saveetha School of Engineering, using samples obtained from JsReadymix Concrete in Kanchipuram. A total of 36 cylindrical specimens of Pavement Quality Concrete (PQC) were made, with 0.5% volume fraction of steel fibers added. These specimens were allowed to cure for 28 days before being tested for compressive strength to evaluate the impact of steel fibers on PQC Compressive strength. The research study had a sample size of 20, which was divided into two groups of 10 each. The group1 consisted of conventional concrete, while the group2 used a novel type of Bamboo Fiber reinforced concrete. The sample size for the study was determined on the previous research, as noted by Adesinaet al. (Adesina et al. 2020). The data analysis was conducted 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 consists of cement, water, and aggregates (typically gravel and sand). Cement and water combine to generate a paste that hardens with time and binds the aggregates into a solid mass. The characteristics of traditional concrete can be modified by adjusting the ingredients and the amount of water used in the mix. It is widely used in construction for foundations, floors, walls, and other structures because of its durability and strength. Compressive strength in conventional concrete refers to the ability of the concrete to resist being crushed or compressed under a load. Compressive strength is a crucial property of concrete and is widely used to evaluate the quality and strength of the material. The compressive strength of conventional concrete is affected by a variety of factors, including the design of the mix, the curing method, and the age of the concrete. The mix design, which includes the ratio of cement, water, and aggregates, is an important factor in determining the Compressive strength. A higher ratio of cement to water and aggregates will result in a stronger mix. The curing process, which involves maintaining the concrete at an appropriate level of moisture and temperature, is crucial for the development of the concrete's strength and durability. The age of the concrete also affects its Compressive strength. Concrete gains strength over time, and typically reaches about 80% of its final strength after 28 days. The longer the concrete cures, the stronger it will become. The Compressive strength of concrete can be tested by placing a cylindrical or cubic sample of concrete in a Compressive testing machine and applying force to it until it fails.

Steel fiber reinforced pavement quality concrete

Steel fiber reinforced pavement quality concrete (SFRPQC) is a type of concrete that has been reinforced with steel fibers. These fibers are incorporated into the concrete mixture to increase its overall durability and strength. The fibers serve as reinforcement, similar to steel rebar, and help distribute loads and strains more uniformly throughout the concrete. This can increase the concrete's resistance to cracking and other sorts of damage, as well as its load-bearing capacity. Steel fiber reinforced pavement quality concrete also improves the structural performance of the pavement, reduces the risk of cracking and improves the durability of the pavement, which leads to a longer service life. The procedure for determining the compressive strength of pavement quality concrete using 0.5% volume steel fiber and 36 cylindrical specimens typically involves mixing cement, fine and coarse aggregates, water, and 0.5% volume of steel fiber to prepare the concrete mixture.After that, the material is placed into cylindrical moulds and compacted to ensure that it will properly consolidate. After being cured in a controlled atmosphere for a period of 28 days in order to achieve maximum strength, the specimens are then extracted from the moulds and subjected to testing on a universal testing machine to determine their compressive strength. The procedure is performed 36 times with cylindrical specimens in order to obtain a sample of the concrete mixture that is typical of the whole. After that, the compressive strength of the steel fiber reinforced concrete is contrasted with the compressive strength of a control sample of plain concrete that does not contain any steel fibers.ASTM C1609/C1609M-16 is the standard test method for determining the flexural performance of fiber-reinforced concrete utilizing a beam subjected to third-point loading, primarily for pavement quality concrete. SFRPQC is often used in high-traffic areas, such as roads and highways, as well as in industrial and commercial applications where the concrete will be subject to heavy loads and high stress.

Statistical Analysis

A statistical analysis was conducted using IBM SPSS V26.0 (Hilbe 2004)software tool, specifically to compare two groups. The independent sample t-test was chosen for this purpose because it is appropriate for evaluating the means of two groups when the data are independent and approximately normally distributed. This is the case when using the independent sample t-test. In the statistical analysis, the mean, standard deviation, and variance coefficients for each group of test results were calculated.Additionally, a t-test was carried out to compare the means of the two groups. Dependent variable is Compressive strength. Independent variables are conventional concrete and steel fiber reinforced pavement quality concrete.

RESULTS

Figure 1 illustrates the comparison of compressive strength between conventional concrete and steel fiber reinforced pavement quality concrete through a bar graph. The conventional concrete is represented by a bar with a height of 25 MPa, which is its mean compressive strength. The steel fiber reinforced pavement quality concrete is represented by a bar with a height of 35 MPa, which is its mean compressive strength. From the graph, it is clear that the steel fiber reinforced pavement quality concrete has a higher mean compressive strength compared to the conventional concrete. The X-axis shows the two types of concrete while the Y-axis displays the mean Compressive strength with a 95% Confidence Interval (CI) represented by ±1 Standard Deviation (SD) for the two groups.

Fig. 1. A bar graph that illustrates the comparison of the Compressive strength between conventional concrete and steel fiber reinforced pavement quality concrete. The conventional concrete has a mean Compressive strength of 25 MPa while the steel fiber reinforced pavement quality concrete has a mean Compressive strength of 35 MPa. The X-axis shows the two types of concrete while the Y-axis displays the mean Compressive strength with a 95% Confidence Interval (CI) represented by ±1 Standard Deviation (SD) for the two groups.

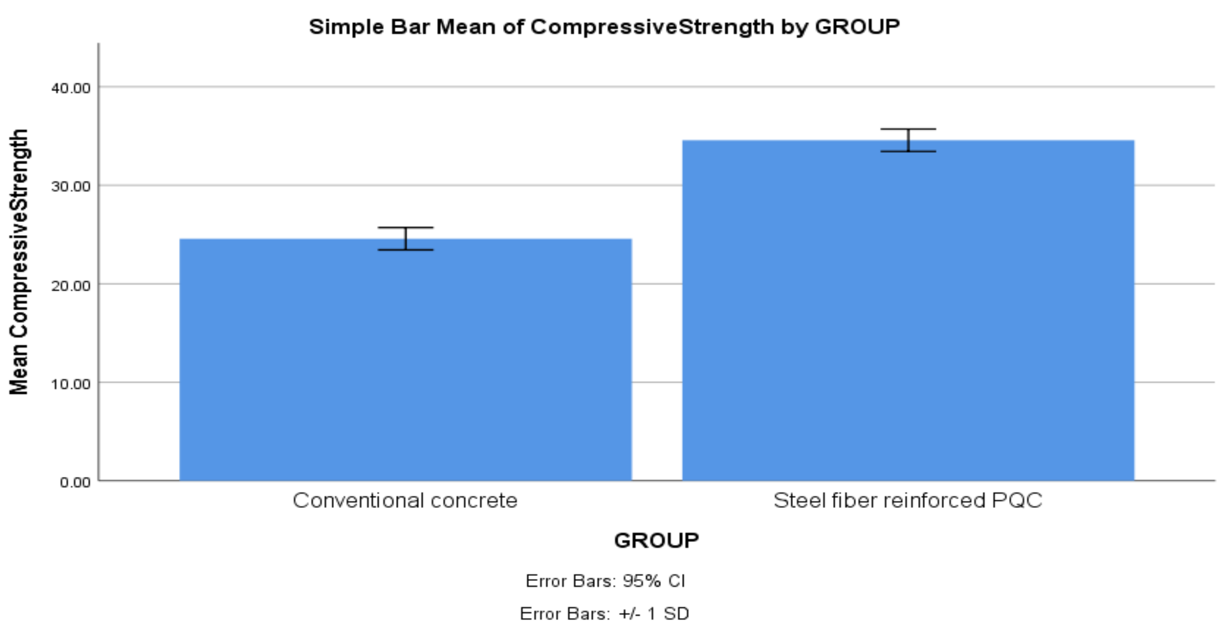

Table 1. The Compressive strength of the conventional concrete is 25 MPa, while the steel fiber reinforced PQC has a Compressive strength of 35 MPa. This indicates that the steel fiber reinforced PQC has a higher Compressive strength than the conventional concrete.

SI.No.	Test Size	Compressive Strength	
		Conventional concrete	Steel Fiber Reinforced Pavement Quality Concrete
1	Test1	25	35
2	Test2	24	34
3	Test3	22	32
4	Test4	24	34
5	Test5	25	35
6	Test6	24	34
7	Test7	25	35
8	Test8	26	36
9	Test9	27	37
10	Test10	28	38

The results of a compressive strength test on conventional concrete and steel fiber reinforced pavement quality concrete are presented in Table 1. The test was performed on 10 specimens, and the findings are shown in a table along with the test size and compressive strength for both types of concrete. The compressive strength of standard concrete is 25 MPa, while the compressive strength of PQC (Pavement Quality Concrete) reinforced with steel fiber is 35 MPa.

Table. 2. The statistical calculations, including mean, standard deviation, and standard error mean, for both conventional concrete and steel fiber reinforced PQC. The Compressive strength parameter was used in the t-test. The mean Compressive strength of the conventional concrete is 25 MPaand that of the steel fiber reinforced PQC is 35 MPa. The standard deviation of the conventional concrete is 0.527 and that of the steel fiber reinforced PQC is 0.250. The standard error mean of the conventional concrete is 0.176 and that of the steel fiber reinforced PQC is 0.083.

Group		N	Median	Standard Deviation	Standard Error Median
Compressive Strength	Steel Fiber Reinforced Pavement Quality Concrete	10	35	0.250	0.083
	Conventional Concrete	10	25	0.527	0.176

Table 2 presents the results of a statistical analysis of compressive strength data for two groups namelySFRPQC and Conventional Concrete (CC). The table shows the number of observations (N), Median, Standard Deviation, and Standard Error Median for both groups. The SFRC group has a median of 35 MPa, which is higher than the median of 25 MPa for the CC group. The standard deviation of SFRPQC is 0.25 MPa, while the standard deviation of CC is 0.527 MPa, indicating that the SFRPQC has a smaller spread of values around the median. The standard error median of SFRPQC is 0.083 MPa, while the standard error median of CC is 0.176 MPa, indicating that the SFRPQC has a smaller uncertainty around its median than the CC.

Table 3: The statistical calculations for independent samples comparing conventional concrete and steel fiber reinforced PQC. 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 0.194. 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)
Compressive strength	Equal variances assumed	2.463	0.136	1.429	16	0.001	0.278	0.194	-0.134	0.690
	Equal variances not assumed			1.429	11.427	0.001	0.278	0.194	-0.148	0.704

Table 3 shows the statistical calculations that were used to compare the compressive strength of regular concrete to that of PQC that was reinforced with steel fibers. The comparison was made using independent samples. The result of 0.001 indicates that the comparison is statistically significant. The data were analyzed using the independent sample T-test, with a significance level of 0.136 and a confidence interval of 95%. Information such as the significant level (two-tailed), the variation in mean, the standard error difference, as well as the lowest and maximum interval difference limits are provided by the test findings.

DISCUSSION

In this work, the compressive strength of traditional concrete and the proposed PQC reinforced with steel fibres is compared and contrasted. According to the findings, incorporating steel fibres into concrete can improve both the material's tensile strength and its resistance to plastic deformation. The matrix of the concrete is made more robust by the addition of the steel fibres. The compressive strength of standard concrete is 25 MPa, whereas the compressive strength of PQC that has been reinforced with steel fibres is 35 MPa. According to the findings of the study, the addition of steel fibres at a volume fraction of 0.5% strengthens the compressive strength of PQC by 10%, resulting in enhanced resistance to cracking and deformation under large loads. The increased Compressive strength of steel fiber reinforced concrete makes it a suitable choice for pavement construction as it can withstand heavy loads and high traffic volumes commonly found on roadways and highways.

Some similar studies are Arafa(Arafa et al. 2021) performed a systematic review on the Compressive strength of PQC and observed that aggregate type, cement-to-water ratio, and curing conditions influence the concrete's strength. The study also identified areas of research that were not well explored and recommended them for future investigation. Marathe(Marathe et al. 2021) examined the impact of various types of aggregate on the Compressive strength of PQC. The results showed that the use of crushed stone as the aggregate resulted in the highest Compressive strength, followed by gravel and then sand. Shinde(Shinde and K. 2020)proposed a method for determining curing periods for pavement-grade concrete based on its compressive strength. The results revealed that the use of steam curing resulted in the highest Compressive strength, followed by water curing and then air curing. Kavyateja, Guru Jawahar, and Sashidhar(Kavyateja, Guru Jawahar, and Sashidhar 2020) compared the Compressive strength of traditional concrete mixes with self-compacting concrete mixes. The results indicated that self-compacting concrete had higher Compressive strength values than traditional concrete mixes.

The limitation of steel fiber reinforced pavement quality concrete (SFRC) is that it can be more expensive than traditional concrete due to the added cost of the steel fibers. Additionally, controlling the distribution of steel fibers throughout the concrete can be difficult, which can have effects for the concrete's overall strength as well as its durability. In terms of future work, research is needed to optimize the design and mix proportions of SFRC in order to improve its strength and durability while reducing costs. Additionally, more research is needed to better understand the long-term performance of SFRC and to develop methods for more effective quality control during construction.

CONCLUSION

The use of steel fibers in pavement quality concrete results in a significant increase in Compressive strength compared to conventional concrete. This makes it a more suitable option for pavement construction, as it can better withstand the heavy loads and high traffic volumes typically seen on roadways and highways. The compressive strength of novel PQC reinforced with steel fibres is considerably greater than that of normal concrete. The compressive strength of PQC reinforced with steel fibres is 35 MPa, compared to 25 MPa for normal concrete.

DECLARATION

Conflicts of Interest

No conflict of interest in this manuscript

Authors Contributions

Author name was involved in data collection, data analysis and manuscript writing. Author guide name was involved in conceptualization, data validation, and critical review of manuscripts.

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