Malaysian Journal
Of Civil
Engineering

Full Paper

EFFECT OF ADMIXTURE ON THE STRENGTH OF SELF-CURING CONCRETE

Article history
Received
22 January 2025
Received in revised form
18 May 2025
Accepted
19 May 2025
Published online
31 July 2025

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Graphical abstract

Abstract

Curing plays an essential role in enhancing the strength and durability of widely used construction materials such as cement concrete. It is imperative for the curing of concrete to have an adequate amount of water to increase the hydration process. In recent years, a new technique for curing concrete that is known as self-curing has been developed, where concrete is capable of curing by itself to preserve the moisture content in it during the absence of proper curing maintenance. An investigation was carried out in this study to examine the impact of self-curing techniques on the strength characteristics of concrete. Using admixtures enables the production of self-curing concrete that can achieve the required strength even in regions where water resources for conventional curing are scarce. During the production of concrete, a modified poly carboxylate (Sikament FF T (VC)) admixture was used as a self-curing agent to justify the investigation. There were two mixing ratios 1:1.5:3 and 1:2:4 implemented on this self-curing concrete investigation with a ratio of water to cement of 0.5. There were different percentages (0.5%, 1.0%, 1.5%, and 2.0%) of admixture (Modified Poly Carboxylate) used in this Self-Curing concrete by weight of Cement. Specimens were assessed to analyze the hardened characteristics (compressive strength and splitting tensile strength) of self-curing concrete following 28 days. Compressive strength tests demonstrated peak values of 30.80 MPa and 27.60 MPa for mix ratios of 1:1.5:3 and 1:2:4, respectively, at a 2% admixture level. In comparison to normal concrete, these results indicate a 46.67% and 44.81% increase in strength. Furthermore, the highest splitting tensile strengths were 13.91 MPa and 12.00 MPa for the same mix ratios and admixtures, representing improvements of 24.20% and 20.00% respectively in comparison to normal concrete. Compressive strength and splitting tensile strength of self-curing concrete were gradually increased with the use of admixtures up to 2%. The incorporation of poly carboxylate into self-curing concrete is demonstrated to significantly improve strength characteristics.

Keywords: Self-curing, hydration, admixture, compressive strength, splitting tensile strength

1.0 INTRODUCTION

As one of the essential components of this growing construction industry, the performance of concrete is crucial to the longevity of structures and is dependent on several factors. A key component of concrete is water. It undergoes a chemical reaction with cement (hydration) to give concrete the desired characteristics. The proportion of water to cement in concrete determines a great deal of its strength and endurance. In contrast to mixing in construction, water is employed extensively in curing. One cubic meter of concrete requires three cubic meters of water for curing (Lokeshwari et al. 2021, El-Dieb 2007). An inadequate curing process or water evaporation can lead to shrinkage cracking and incomplete cement hydration, particularly in mixes with a low water-cement ratio. During curing, maintaining an adequate moisture level enhances strength, reduces permeability, and minimizes cracking, which is imperative for long-term structural durability. Proper curing is crucial for concrete to achieve its intended strength and durability, as over 90% of its final strength is typically developed (Mrudula and Ratnam 2023).

Self-curing concrete is a special concrete that is useful when curing is insufficient, caused by human error, inaccessible locations, or where fluoridation in water will affect the concrete's characteristics (Samdani et al., 2023). A self-curing agent, usually a polymer, lowers the chemical potential of concrete mixes by forming hydrogen bonds with water molecules. In this way, the free energy difference between vapor and liquid phases is minimized, effectively reducing the vapor pressure. As a result, the water evaporation from the exposed concrete surface decreases, ensuring sustained internal moisture availability essential for effective cement hydration (Jasmine et al., 2021).

According to ACI-308 code, self-curing is a technique in which cement hydrates through the availability of extra internal water, which is often not included in mixing water (ACI-308 2001). There are plenty of admixtures are utilized to enhance the mechanical properties (compressive strength, splitting tensile strength, workability) of self-curing concrete, including Superabsorbent polymer (SAP), Polyvinyl alcohol (PVA), Polyethylene glycol (PEG), Liquid paraffin wax (LPW), Sodium lignosulphonate (SL), wood powder (Khan and Gupta 2020), and Polycarboxylate (Yang and Zhang 2023). It is common to use polycarboxylate as a water reduction agent in concrete as a high-range water reducer. As a consequence of the inclusion of polycarboxylate, the concrete workability at lower water-to-cement ratios can be controlled better (Huseien et al., 2019).

The concrete's compressive strength was observed to increase by increasing superplasticizer/admixture dosages of 0.8%, 1.0%, 1.5%, and 2%. In the 28 days, the concrete's maximum compressive strength (35.32 MPa) was observed at 2% superplasticizer compared to normal concrete (19.96 MPa) (Guruswamygoud et al., 2021). Further research was conducted to assess the effect of admixture (PEG-400) on self-curing concrete. An admixture (PEG-400) was used at various percentages of 0.8%, 1.6%, 2.4%, and 3.2% . In the absence of admixture, loss of compressive strength was observed at 11.35% and 12.24% for M20 and M25 grade concrete respectively. Additionally, the optimum tensile strength was observed at 1.6% and 2.4% PEG-400 for M20 and M25 grade concrete respectively (Mandiwal and Jamle 2019). The optimum dosage of PEG-4000 varies by concrete grade, and concrete with the optimum amount of the admixture shows an enhancement in terms of hardened strength compared to normal concrete (Jaha et al., 2022).

In order to obtain the high-strength concrete needed for high-rise construction, superplasticizers are frequently utilized. Controlling the cement hydration rate is essential in mass concreting to avoid a high-temperature (500°C above) upsurge that might cause fissures and structural damage. Retarding superplasticizers enhances the strength of concrete by delaying the hydration process (Verma and Nigam 2017). However, the performance of concrete behavior depends on some factors such as water-cement ratio, curing process, concrete mix ratio, etc. This study aims to assess the optimum strength characteristics (compressive and splitting tensile strength) of self-curing concrete utilizing optimum admixture [Sikament FF-T (VC)] content as a self-curing agent for varying mix ratios.

2.0 METHODOLOGY

2.1 Materials Used

A number of materials were employed in the experiment. Before starting the experimental investigation, the features of materials were defined.

2.1.1 Binding material

In this experiment, the binding material was regular Portland cement. On regular Portland cement, there were two tests conducted. Compressive strength testing and setting time testing are these. Table 1 summarizes the physical properties of Portland cement.

Table 1 Test for binding material

Types of cement	Normal consistency (%)	Setting time (min.)		Compressive strength (MPa)		
		Initial	Final	3 days	7 days	28 days
Regular Portland Cement	28	86.25	150	16.52	29.65	40.23

2.1.2 Fine aggregate (FA)

Sylhet sand was collected for the experimental inquiry. The sand was cleaned to get rid of any remaining dirt and then sieved through a 4.75 mm sieve to eliminate any larger particles. The test procedure for fine aggregate sieve analysis complies with ASTM standard specification (ASTM C136-06 2006). In this work, dry saturated surface aggregate was used to determine the specific gravity of fine aggregate. The specific gravity and water absorption capacity test methods adhere to the guidelines provided in (ASTM C128 2012). According to this test method, voids that contain one particle, whether permeable or impermeable, are excluded from the definition of voids. This test procedure complies with the requirements of ASTM C29, (2009). The properties of the fine aggregate availed in the experiment are listed in Table 2 & Table 3.

Table 2 Fine aggregate's physical characteristics

Test	Condition	Result
Bulk Sp. Gravity	SSD	2.36
Bulk Sp. Gravity	OD	2.23
Apparent Sp. Gravity	-	2.55
Absorption Capacity (%)	-	5.6
Fineness Modulus (FM)	-	2.77

SSD = Saturated Surface Dry; OD = Oven Dry

Table 3 Percent of voids in fine particles

Test	Result (%)
Shoveling	39.65
Rodding	35.26
Jigging	32.94

Figure 1 displayed the fine aggregate gradation curve, it provides a clear visual representation of the particle size distribution.

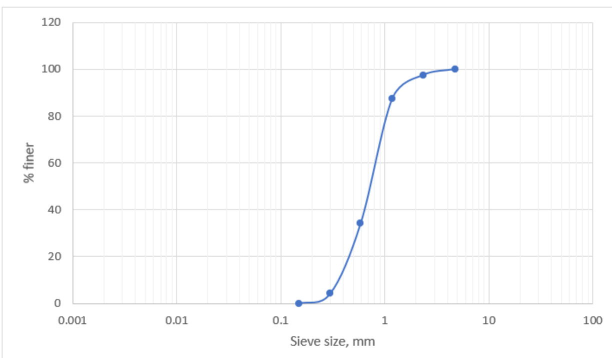


Figure 1 Gradation curve of fine aggregate

2.1.3 Coarse aggregate (CA)

According to ASTM C136-06 (2006), the test procedure for sieve analysis of coarse aggregate (stone chips) complies with those standards. The test method for specific gravity and absorption capacity of coarse aggregate conforms to the ASTM standard requirement of specifications (ASTM C127-12 2012). Unit weight values of aggregate must be utilized for different methods of determining proportions for concrete mixes. Additionally, they can be utilized to assess the proportion of voids in aggregate and to establish the mass/volume relationship for conversion. According to this test method, voids that contain one particle, whether permeable or impermeable, are excluded from the definition of voids. This test procedure complies with ASTM standard specifications (ASTM C29/C29M-09 2009). The features of the stone chips employed for the testing are illustrated in Table 4 & Table 5.

Table 4 The features of stone chips

Test	Condition	Result
Bulk Sp. Gravity	SSD	2.71
Bulk Sp. Gravity	OD	2.70
Apparent Sp. Gravity	-	2.72
Absorption Capacity (%)	-	4
Fineness Modulus (FM)	-	7.12

Table 5 Percent of voids in coarse aggregates

Test	Result (%)
Shoveling	51.60
Rodding	45.25
Jigging	44.70

Figure 2 displays the coarse aggregate grain size analysis curve, which provides a clear visual representation of the particle size distribution.

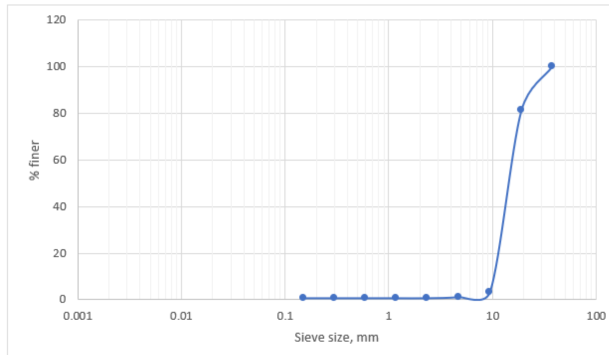


Figure 2 Particle size distribution curve for coarse aggregate

2.1.4 Admixture

Sikament FF-T (VC), a superplasticizer (Modified poly carboxylate), was added to the mixture in this investigation. While it improves the performance of the mix, it also signifies a new development in the formulation of concrete. Sikament FF T (VC) superplasticizer is ideal for thermoplastic or super-feasible concrete processes. Optimum concrete mixes can include those with low water content for semi-dry or no-slump concrete. This concrete component has a low water-fold proportion, long-lasting liquefaction, no segregation, and high early. This plasticizer will produce a Rheodynamic material capable of self-curing and strengthening without the use of vibration. In this study, admixtures were used at 0.5%, 1%, 1.5%, and 2% by weight of cement. Detailed properties of admixture used in this study are presented elaborately in Table 6 below for better understanding.

Table 6 Properties of admixture used

Item name	Chemical base	Relative density	Application dosage
Sikament FF-T (VC)	Modified Poly Carboxylate	~1.02 kg/l at 25°C	0.5 - 2.0% by weight of cement

2.2 Preparation of Specimens

In this study, the volume batching method was used for measuring the materials and concrete mixing had been done by hand. Hand compaction of concrete was done following the ACI code 318-02 for the investigation. A standard tamping bar (16 mm in diameter) was used for compaction and void removal when casting was done using cylindrical molds with dimensions of 100 mm in diameter and 200 mm in height. Typically, structural designs are based on 28-day strengths, which are available in the first week after placement in approximately 70% of cases. In this investigation, a certain number of cylinder specimens made with no additives (0%) have been used. The remaining cylindrical specimens incorporating (0.5%, 1%, 1.5%, 2%) the admixture "Sikament FF-T (VC)" were prepared and tested to evaluate the effects of the admixture on concrete performance, including strength characteristics. To ensure adequate hydration and the development of strength properties, all concrete specimens took a 28-day curing process. The cylindrical specimens were placed in the curing tank for proper hydration as Figure 3 illustrates.

Figure 3 Curing process of specimens

2.3 Test on Specimens

2.3.1 Strength Test For Compressive

The compressive strength of concrete constructed with various ratios of cement, sand, and coarse aggregate (stone chips) was determined in accordance with ASTM C39 (1996). A total number of 60 specimens from these 30 specimens were used for assessment of compressive strength. Several findings were found for each tested sample during the evaluation of the compressive strength utilizing a Universal Testing Machine (UTM) for imposing the load. Test values were taken thoroughly during the loading procedure. Using different percentages of admixtures in cement concrete significant changes were found in the results. An evaluation of the maximum load applied to the specimen was conducted. In Figure 4, the process for determining compressive strength is demonstrated.

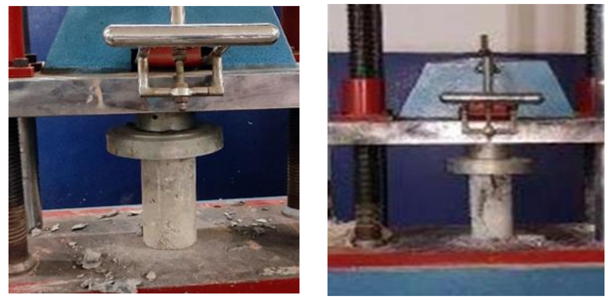
$$P = F/A \tag{1}$$

Where,

P = Compressive strength, MPa

F = Crushing load, N

A = Cross-sectional Area, mm^2



(a) (b)

Figure 4 Compressive test for specimens

2.3.2 Strength test for Splitting Tensile

The experiment was carried out following the Standard Test Method specifically designed for concrete specimens with cylindrical shapes, with the objective of measuring and determining their tensile strength (ASTM C496/C496M-17 2017). An additional 30 cylinders, selected from the total batch of specimens, were used to assess the splitting tensile strength. Placing each specimen horizontally between the machine's loading platens allowed the load to be delivered along the cylinder's vertical diameter. To eliminate stress concentrations and distribute the load evenly, a thin strip of plywood, about 3 mm in thickness, was placed between the specimen and the loading platens. For uniform loading, the weight was applied at a uniform rate. The test was carried out repeatedly until the specimen split along the vertical plane that went across the cylinder's diameter. An evaluation of the maximum load applied to the specimen was conducted. Figure 5 displays the splitting tensile strength test conducted on the concrete specimens, illustrating the procedure used to evaluate their tensile performance.

$$\delta = 2P/\pi DL \tag{2}$$

Where,

δ = Splitting tensile strength, MPa

P = Crushing load, N

D = Diameter of concrete cylinder, mm

L = Length of the concrete cylinder, mm

(a) (b)

Figure 5 Splitting tensile strength test for specimens

3.0 RESULTS AND DISCUSSION

3.1 Compressive Strength Of Self-Curing Concrete

There were considerable variations in results when admixtures were added at different percentages to cement concrete. The experimental strength values are highlighted in Table 7, and Figure 6 provides a corresponding graphical illustration. The evaluated results for both mix ratios lead to significant improvement. Strength has been increased to 30.80 MPa at 2% over time using a 1:1.5:3 mix ratio. As well, the strength increased from 19.06 MPa with 0% admixture to 27.60 MPa with 2% admixture for the 1:2:4 mix ratio. Considering different mix ratios, this results in an overall increase of 46.67% and 44.81%, respectively.

Table 7 Compressive strength variations

Admixture, %	Compressive strength, MPa	
	1:1.5:3	1:2:4
0	21.00	19.06
0.5	23.50	21.00
1	26.00	23.40
1.5	28.40	25.31
2	30.80	27.60

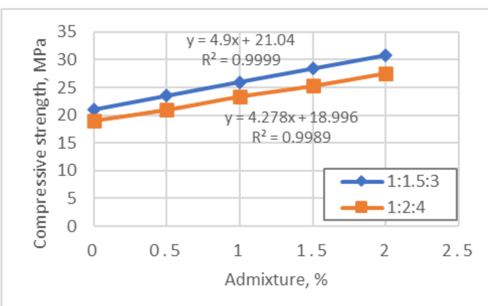


Figure 6 Compressive strength variations

3.2 Splitting TENSILE STRENGTH OF SELF-CURING CONCRETE

The results of the splitting tensile strength tests for varying percentages of admixture are summarized in Table 8 and in graphical representation Figure 7 for two concrete mix ratios. The evaluated results for both mix ratios lead to significant improvement for splitting tensile strength. Using 0% admixture resulted in 11.20 MPa tensile strength for the 1:1.5:3 mixture, which increased to 13.91 MPa at 2%. Likewise, the 1:2:4 mix increased from 10.00 MPa to 12.00 MPa during the same time period. This represents an approximate 24.20% improvement for the 1:1.5:3 and 20% for the 1:2:4, highlighting that utilizing optimum admixture content (2%), optimum strength was achieved at varying mix ratios.

Table 8 Splitting tensile strength variations

Admixture, %	Splitting tensile strength, MPa	
	1:1.5:3	1:2:4
0	11.20	10.00
0.5	11.80	10.50
1	12.50	11.00
1.5	13.20	11.50
2	13.91	12.00

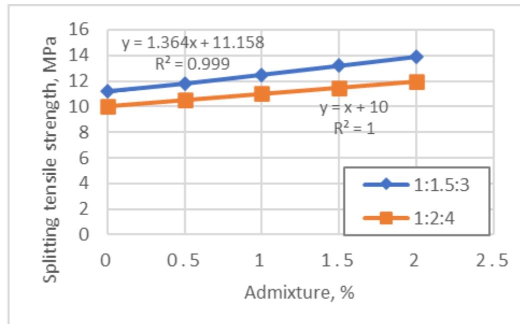


Figure 7 Splitting tensile strength variations

3.3 Investigate the Strength Characteristics of Self-curing Concrete Between Various Mix Designs

3.3.1 Evaluation Of Compressive Strength

According to the previous study, Ananthi et al. (2017) conducted a study to assess the strength characteristics of self-curing concrete utilizing polyethylene glycol (PEG-400) as an admixture/superplasticizer. The authors incorporated varying percentages of PEG-400 (1%, 2%, and 3%) into the concrete mix, which had a ratio of 1:1.89:3.6. The results observed that the optimum strength of 42.06 MPa was achieved at 28 days with 2% PEG-400. This represented a 12.76% increase in strength compared to conventional concrete. The compressive strength decreased when 1% and 3% admixture contents were used, relative to the optimum strength observed at the 2% dosage. Additionally, Ganesan and Meyyappan (2024) measured a peak strength 26.2 MPa, which is 5.64% improved compared to conventional concrete following 28 days. Using 1% admixture (PEG-400) maximum strength was obtained for a 1:1.5:3 mix ratio. Compared to optimum strength at 1% dosage, strength was decreased when another 2% and 3% dosages were used. Graphical variation between the present study and the previous research is demonstrated in Figure 8.

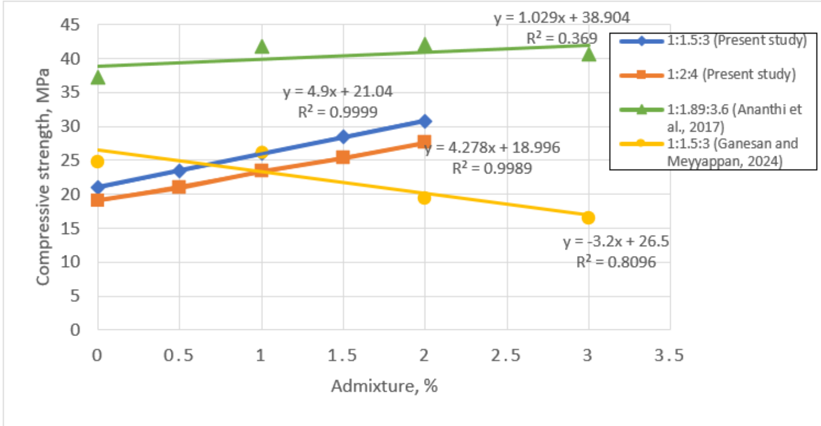


Figure 8 A comparison of the compressive strength of concrete with different mix designs

3.3.2 Evaluation Of Splitting Tensile Strength

The effect of mix design ratios on splitting tensile strength utilized by admixture is illustrated in Figure 9 for present study and the previous study. According to the previous study assessment, at 2% admixture (PEG-400), the maximum value of 7.23 MPa is shown by the 1:1.89:3.6 mix design, which is 11.23% higher than conventional concrete. Utilizing another two dosages (1% and 3%) of admixture, strengths fell gradually (Ananthi et al. 2017). Ganesan and Meyyappan (2024) evaluated the 1:1.5:3 mix ratio with polyethylene glycol (PEG-400) and found that the highest tensile strength (2.13 MPa) was at 1% admixture dosage across all admixture (PEG-400) percentages. In comparison with conventional concrete, the results showed a 17.68% increase. On the other hand, tensile strength further declined with the use of another 2% and 3% admixture dosages.

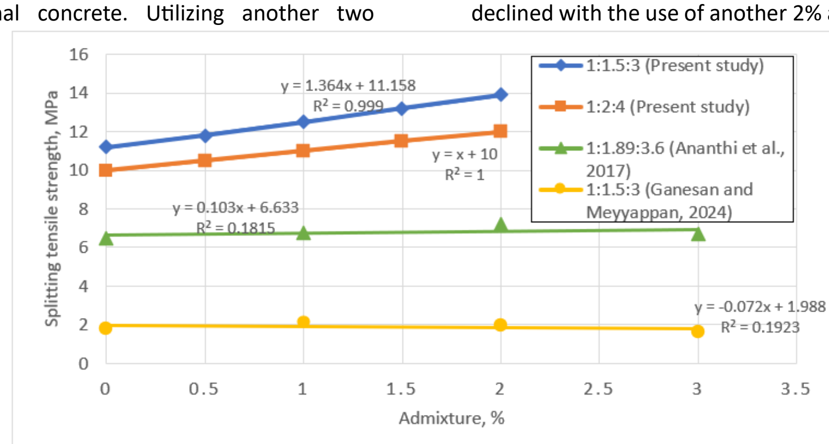


Figure 9 A comparison of the splitting tensile strength of concrete with different mix designs

4.0 CONCLUSIONS

This study explored utilizing admixture/superplasticizer [Sikament FF-T (VC)] in varying percentages for 1:1.5:3 and 1:2:4 mix ratios to evaluate the strength properties of concrete.

The maximum compressive strength was assessed to be 46.67% larger than that of conventional concrete when the mix ratio was set at 1:1.5:3. It was found that the strength of a 1:2:4 mix ratio was 44.80% larger than that of conventional concrete. As a result of the investigation, the strength increased to 30.80 MPa and 27.60 MPa, respectively. Strength was considerably improved while superplasticizer up to 2% was incorporated in self-curing concrete.

The application of superplasticizer in concrete with a certain mix ratio considerably raises the splitting tensile strength. The tensile strength of the 1:1.5:3 mix portion was 13.91 MPa, much higher than that of conventional concrete. Likewise, a tensile strength of 12.00 MPa was noted at a 1:2:4 mix percentage. Optimal improvements in strength were found to be 24.19% and 20% for both ratios, incorporating 2% of admixture.

In this investigation, admixtures/superplasticizers used up to 2% in 1:1.5:3 and 1:2:4 mix ratios were shown to achieve optimum strength characteristics throughout a 28 period.

The use of Sikament FF-T (VC) maintained the water-cement (w/c) ratio on self-curing concrete.

This study recommends the use of Sikament FF-T (VC) in concrete in order to reduce water scarcity while maintaining concrete curing to achieve optimum strength characteristics.

Graphical presentation provides clear knowledge about data trends for strength properties. Trends showed the behavior of self-curing concrete strength to the optimum level with the use of optimum admixture [Sikament FF-T (VC)] dosages.

Acknowledgments

I would like to deeply gratitude my co-authors for their dedication, encouragement, and astute advice during this research effort. The field investigation for this work was conducted in the civil engineering laboratory of Uttara University. It's important to note that neither the laboratory nor the authors received any funding for the study.

Conflicts of Interest

The author(s) declare(s) that there is no conflict of interest regarding the publication of this paper

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