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***Abstract*— Compressive strength is a crucial factor that influences the longevity and structural integrity of concrete, which is a material that is used extensively in building. The purpose of this study is to contribute several kinds of curing techniques for improved compressive strength. This paper describes how to produce concrete with a higher compressive strength by substituting some cementitious elements, such as fly ash, quartz powder, nano silica, and silica fume, for Portland cement. This concrete mixture had recron fibers measuring 12 mm in length, standard fine aggregate sized 300 µm, and crushed coarse material measuring 4.75 mm. W/b ratio in this mixture is 0.34. The final concrete was allowed to cure for three days at 90^{0}C in hot water, and after 28 days, its compressive strength was measured using a hand mix. With 2.2% of 12 mm length fibers in the hand mix, the experimental concrete including recron fibers had the highest average compressive strengths, reaching 45.89 N/mm2. The results offer significant perspectives on optimizing concrete blends and curing procedures to attain exceptional compressive strength. This research contributes to the ongoing effort in sustainable construction by identifying ways to enhance the mechanical properties of concrete while minimizing resource consumption.**

Keywords*— *binding contents, mixing casting and curing condition, tests procedure.

I. Introduction

The crucial factor affecting the structural integrity and durability of buildings and infrastructure is the compressive strength of concrete. To enhance the performance of structures made with concrete, it is essential to explore and comprehend the factors impacting compressive strength. Blends of concrete offer superior workability, durability, and ultimate strength. Cement, a vital element in construction, plays a significant role. The construction sector utilizes about 75% of natural resources for construction activities, leading to the depletion of these resources [1]. The depletion of natural minerals and the increase in environmental problems related to climate change are attributed to the manufacturing of cement [2]. Portland cement, a widely utilized construction material worldwide, consists predominantly of 3-7% gypsum and anhydride, along with a finely interground blend of clinker [3]. Cement production accounts for up to 18% of total industrial CO_2 emissions [4]. Fifty percent of the CO_2 emissions produced during the cement manufacturing process come from burning limestone, according to reference [5]. Furthermore, 2.54 billion tons of the 36.2 billion tons of human greenhouse gasses produced globally annually, or around 5-7% of all greenhouse gas emissions, are produced during the making of Portland cement [6,7]. Cement also serves as a binding agent, bringing cohesion to the many materials used in construction and infrastructure projects, and is well-known for its versatility and ability to achieve concrete compressive strength. It has been shown that employing cement alone as a binder for other standard concrete components yields a compressive strength of approximately 50 MPa. The interfacial transition zone's weakness would also prevent strength improvement in the presence of coarse aggregate [8]. Concrete production is limited because the $Ca(OH)_2$ produced by cement hydration occupies some space in the concrete microstructure. For this reason, low w/c and high compressive strength are insufficient. To create fine C-S-H compounds that reduce porosity, boost strength, and promote durability, additional components must be able to react with $Ca(OH)_2$ [9]. Concrete's proportions, ingredients, and production techniques are purposefully chosen to meet specific performance and uniformity requirements that cannot always be met by using standard materials such as cement, aggregates, water, and chemical admixtures, or by adhering to standard mixing, placing, and curing procedures. For severe service circumstances, performance criteria may include combinations of high early strength, high strength, low permeability, high workability, and high durability. As a result, the negative effects of cement manufacture have motivated increased investigation into locally available, recycled, and waste materials that could be used as cement alternatives. For this reason, concrete is mostly made using a lot of cement to make up for the absence of coarse aggregate, and we should use some additional cementitious elements with ultrafine particle sizes and a little elevated SiO_2 content to react with the $Ca(OH)_2$ that is created during cement hydration and help to reduce porosity, enhance strength, and also develop the durability of concrete by reacting with $Ca(OH)_2$ and producing C-H-S gel formation such as silica fume. Using cementitious materials is the only option to mitigate the negative consequences of the cement production business. Due to growing environmental concerns about the unsustainable use of cement, cementitious materials have recently been widely used as cement additives or partial substitutes for Portland cement [10,11]. Cementitious materials are inorganic elements that, by pozzolanic or hydraulic activity, contribute to the properties of a cementitious combination (such as paste, mortar, concrete, or grout) [12]. Another reason for their approval is that cementitious materials have been found to greatly improve the durability of cement mortars and concretes [13]. Conversely, lowering the w/cm ratio makes fresh concrete less workable; to address this issue, heavy doses of heavy Range Water Reducing Admixtures (HRWRAs) are used. Another downside of concrete is its quick brittle collapse. To mitigate this disadvantage, fine, high-strength fibres can be added to a concrete mixture [9].

The current study, which uses fly ash, quartz powder, nano SiO_2, and silica fume as binder compositions, tries to examine how hand mixing techniques and curing temperatures affect the compressive strength of concrete. Recron fibre was also added to increase compressive strength and corrosion resistance. The strength was greatly boosted by using the procedure of hot water curing for 72 hours at 90°C and 60°C, followed by the ordinary water curing method for 7 and 14 days, and then the open air curing method for 28 days. Next, use a high-content superplasticizer to improve workability at low w/b ratios, and mix with ordinary water.

II. EXPERIMENTAL WORK

A. Binding Contents

Suyog Elements PVT LTD, situated in Baruch, Gujarat, India, offers Class F fly ash that meets IS 3812-2003 [14] specifications with a specific gravity of 2.00 and a lower calcium concentration. With a specific gravity of 2.64, Astra Chemicals in Chennai, Tamil Nadu, India, provides the silica fume. The specific gravity of the nano silica, which is 2.4, is provided by Fiberzone India, located in Ahmedabad, Gujarat, India. The specific gravity of the quartz powder, which is provided by Mumbai, India-based A.J. Corporation, is 2.4. 3.15 specific gravity ordinary portland 53 grade cement from nearby Vadodara, Gujarat was utilized. Table 1 displays the chemical makeup of the binding contents utilized in the investigation.

TABLE 1. The chemical makeup (w%) of cement, fly ash, quartz powder, nano silica, and silica fume

Property	***Cement***	***Fly ash***	***Quartz Powder***	***Nano Silica***	***Silica Fume***
SiO_2	18	62.2	99.14	99	99.96
Al_2O_3	3	19	0.17	-	0.032
CaO	67	-	0.14	-	-
MgO	2.4	1.3	8.76	-	-
Fe_2O_3	0.01	31.56	0.13	-	0.013
Na_2O_3	-	0.46	8.5	-	0.003
CL	0.01	0.0296	-	-	-
SO_3	2.2	0.63	0.024	-	-
LOI	3.3	0.97	0.46	≤1.0	0.001

Sand from the adjacent Vadodara, Gujarat, river was used as the fine aggregate (FA). Upon laboratory testing, it was found to meet the requirements for zone II, as stated in IS 383-2016 [15]. Its maximum size was 300 μm, its specific gravity and fineness modulus values were 2.45 and 3.4, and its water absorption was 1.48. Consistent with the coarse aggregates sourced from the nearby Gujarati River in Vadodara, laboratory testing confirms that each percentage that makes it through a sieve has been successfully processed, in accordance with IS 383-2016 [15]. The maximum size of the coarse aggregate (CA) is 4.75 mm, with a specific gravity of 2.54 and a water absorption of 3.11, respectively.

Recron fiber, a special form of fiber with a length of 12 mm and a straight shape provided by Reliance Industries Limited from Mumbai, India which is employed in this experimental work. It confirms the standards of IS 516: 1959 and IS 516: 1979 [16, 17]. Table 2 shows this type of fiber.

Table 2. Key characteristics of recron fibers

Properties	***Gain over normal mix***
Compressive Strength	14 %
Flexural Strength	10 %
Split Tensile Strength	7 %
Water Absorption	2.14 %
Damping	25 %
Alkali Resistance	90 %

Super plasticizer, also known as Polycarboxylate Ether provided by Kunthunath Enterprise from Vadodara, India, is a very high water-reducing additive that was used in this study and satisfies HS Code: 38244010 [18]. Concrete has several applications. It's a deep brown liquid with a water reduction rate of more than 25% that dissolves in water instantly. Specification is shown in Table 3.

Table 3. Specifications of the Polycarboxylate Ether

Specific gravity	1.110 to 0.02
pH at normal temperature	5.5 ± 0.5
Chloride content	Below 0.02

B. Mixing, Casting and Curing condition

This particular experiment involves a rather straightforward mixing procedure. When mixing cement with different cementitious materials, like M1 and M2 start by selecting the percentage of mix proportions. After all trials were finished, the w/b ratio stayed at 0.34. To combine, use ordinary water. To provide a consistent partial replacement, a certain amount of fly ash, quartz powder, nano silica, and silica fume are mixed with cement to create the concrete combinations. First, give the 4.75 mm coarse aggregates a thorough wash and drying. Then, by hand mixing for two minutes, completely blend the 300 µm fine aggregates and the 4.75 mm coarse aggregates. Next, include 0.75% of the entire water content into this blend and thoroughly stir with a hand mixer for five minutes to achieve a saturated surface dry (SSD) state. The liquid was then thoroughly stirred by hand for 10 minutes after the addition of the silica fume binder. The mixture was then given a thorough hand mix for 10 minutes with the addition of the nano silica binder. Subsequently, stir the mixture well by hand for 10 minutes after adding the quartz powder binder. After that, the mixture was thoroughly mixed by hand for 10 minutes with the addition of the fly ash binder. Lastly, the mixture of fly ash, quartz powder, silica fume, nano silica (SiO_2), and aggregates was mixed with the cement binder material. For 10 minutes, the material was thoroughly stirred by hand. Then, combine the water and the Polycarboxylate Ether super plasticizer solution, blending it into the dry mixture in three steps. Lastly, add the recron fibers to the mixture and stir everything well by hand for a maximum of 10 minutes. In the end, this concrete combination's self-consolidation property will become apparent. After this complete blending, the workability of the new concrete was assessed using a slump test. The freshly mixed concrete was then cast into cube specimens measuring 150 x 150 x 150 mm to test the concrete's compressive strength, respectively. Every cast specimen in the mold was given a 72-hour rest time. After being taken out of the mold, the specimens were placed in a hot water curing machine and allowed to cure for 72 hours, or three days, at 90 degrees Celsius. Subsequently, three cubes were allowed to cure in regular water for 14 days, and the final three cubes were allowed to cure for an additional 28 days outside.

The details of the mix proportion of binders are compiled in Table 4. Each of the four distinct specimens in the mix proportions M1, and M2 has 9 cubes that have been kept. For this experiment, which is seen in figure 1(a), (b), (c), are total of 18 cubes were manually mixed and poured. 9 samples were cast for each mix proportion, and as figure 2 illustrates, they were cured at 90 degrees Celsius for 72 hours (3 days). After three days, the samples were taken out of the hot water curing equipment. Three cubes were then cured for 14 days at room temperature (27 ± 2 °C), and the final three cubes were left to cure for an additional 28 days at room temperature before testing.

TABLE 4. The mix proportion criteria for the development of compression strength.

Parameters	***(%) of Materials***						
	Cement (%)	***Fly Ash (%)***	***Quartz Powder (%)***	***Nano Silica (%)***	***Silica Fume (%)***	***Recron Fibers (%)***	***Super plasticizer***
M1 (mix)	50	15.8	20	2.0	10	2.2	1.7 %
M2 (mix)	45.3	20	20	2.2	10	2.5	2.0 %
Fine Aggregates	16 Kg						
Coarse Aggregates	23 Kg						
No. of cubes	18 (each parameters 9)						
Water/Binder Ratio	0.34						
Curing condition	90°C of hot water, Normal water, open air						

TABLE 5. The quantity of mix proportions for concrete mixing

S.No	***Materials***	***Weight in (Kg/m^3)***
1.	Cement	318.53
2.	Fly Ash	269.18
3.	Quartz Powder	179.45
4.	Nano Silica	17.94
5.	Silica Fume	89.72
6.	Recron Fibers	22.43
7.	Fine Aggregates	470.99
8.	Coarse Aggregates	663.18
9.	Super Plasticizer	17.95
10.	Water	190.79

(a)

(b) (c)

Fig.1. Concrete cube casting

Fig.2. Specimen Cubes Subjected to Curing at 90 °C in hot water machine.

C. Test procedure

The cement, fine, and coarse aggregates were tested separately to make sure they were suitable for concrete before mixing the concrete. Slump testing was used in accordance with IS 1199-1959 to determine if experimental concrete was workable, as seen in figure 3(a) [19]. Concrete's cubes were put through a strength test in compliance with IS 516-1959 [16]. Next, the treated cubic samples were placed in the compression testing apparatus seen in figure 3(b), in compliance with the codal requirements. Of the 9 cubes used in the hand mixing experiment, three are assessed after three days of curing in hot water at 90^0C, three more are tested after fourteen days of curing in normal water at 27 ± 20^0C, and the final three are examined after twenty-eight days of curing outside.

(a) (b)

Fig.3. Slump test of concrete and cube test in CTM machine

III. RESULTS AND DISCUSSION

It was noted that freshly mixed concrete had a high degree of cohesion and viscosity along with a medium to high slump. When mixing concrete by hand, the workability of the material decreases as a result of concrete grade. The main reason for this is that adding more water causes the water to binder ratio which is supposed to be roughly 0.21 according to the mix design to decline, resulting in a workable water/binder ratio of 0.34. An increase in the water to binder ratio enhances the slump value for all classes of concrete because more water is supplied to the mixture during the hand mixing process. However, if we hadn't added superplasticizer, the water to binder ratio wouldn't have been sufficient; as a result, the workability at 0.34 w/b ratio was greatly increased. More water is needed since adding recron fibers also reduces the flow of the concrete. Thus, it may be said that using concrete results in a more difficult to mix mixture when mixing concrete by hand. Even after tamping thoroughly, this rigidity increases the chance of voids in the concrete during cube casting, which prevents the necessary packing density from being achieved and also lowers workability, which ultimately gives lowers strength.

The study's goal was to investigate the effects of varying the binder content concrete's compressive strength. Specifically, the study examined the following ranges for all hand-mixed mixes: 40% to 50% for cement, 10% to 25% for fly ash, 20% for quartz powder, 2.0% to 2.2% for nano silica, 10% for silica fume, and 2.2% to 2.5% for recron fibers. Moreover, the study included 1.7% to 2.0% of super plasticizer. focusing on 90°C hot water curing for a full 3 days, then ordinary water curing for 14 days, and lastly, open-air curing for manual mixing. The study considered two distinct mix proportions for two distinct mix proportions for hand mixing.

The results demonstrated that the M1 mix in the hand mixing case, which is cured at open air for 28 days, had the maximum strength among the various mix proportions, reaching approximately 45.89 N/mm². The matching numbers and table 6 findings for the various hand-mixed mix proportions are displayed below. The compressive strength test results for the concrete that was cured for three, fourteen, and twenty-eight days under parameters M1 and M2 are displayed in Figure 4.

TABLE 6. Cube testing results mixed by hand

Parameters	Total cube cast	No. of cube test	Days	Curing types	Strength in N/mm^2		
					3 days	14 days	28 days
M1	9	3	At 3 days	90^0C hot water	36.34	-	-
		3	At 14 days	Normal water	-	43.39	-
		3	At 28 days	Open air	-	-	45.89
M2	9	3	At 3 days	90^0C hot water	36.15	-	-
		3	At 14 days	Normal water	-	39	-
		3	At 28 days	Open air	-	-	42.31

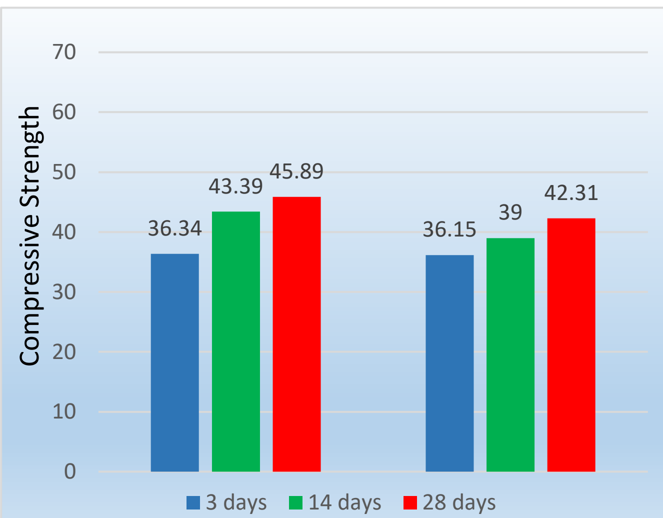

Fig. 4. Compressive Strength of Concrete at 3, 14, 28 Days for Mixes M1 and, M2

After a 28-day curing period, the M1 blend ratios at the hand mixing settings produced an optimal compressive strength of 45.89 N/mm2. Conversely, with a compressive strength of 42.31 N/mm2, the M2 mix yielded the lowest result and was below the values corresponding to each of the two parameters.

IV. CONCLUSIONS

This study tested the compressive strength of concrete under a range of mixing conditions and curing temperatures. As a result, the findings are briefly summarized as follows:

- This study examined the possibility of lowering the water-binder ratio in order to increase the compressive strength of concrete. Therefore, in this instance, a super plasticizer percentage of more than 2.0% is required to guarantee the flowability and flexibility of the combination.
- Concrete's compressive strength rises after 28 days of ambient curing after placing in the temperature of the hot water curing process. where the strongest proportions and design mix are at their best.
- It was demonstrated that the hand-mixed concrete's compressive strength gaining very slowly and strength does not increase after a while. It is therefore suggested to utilize a mixing machine for the mix to provide a better result.
- Further investigation into the mechanical characteristics of concrete's durability is advised. More research is needed on the use of GGBS in place of fly ash, especially because fly ash reduces the initial strength of concrete. More research is needed to fully replacement of recron fibers with the steel fibers, because steel fiber will gives better strength as compare to recron fibers.
- The compressive strength of concrete is greatly affected by changing in mixing proportion and curing condition.

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REFERENCES

[1] Lin, L. K., Kuo, T. M. and Hsu, Y. S. (2016) “The application and evaluation research of coffee residue ash into mortar,” *Journal of Material Cycles and Waste Management*. Springer-Verlag Tokyo, 18(3), pp. 541–551.

[2] Imbabi, M. S., Carrigan, C. and McKenna, S. (2012) “Trends and developments in green cement and concrete technology,” *International Journal of Sustainable Built Environment*. Elsevier B.V., 1(2), pp. 194–216.

[3] van Oss, H. G. (2005) *Background Facts and Issues Concerning Cement and Cement Data Open-File Report 2005-1152*. Available at: http://www.usgs.gov/pubprod.

[4] Pooler, M. (2019) *Cleaning up steel is key to tackling climate change | Financial Times*. Available at: https://www.ft.com/content/3bcbcb60-037f-11e9-99df-6183d3002ee1 (Accessed: December 30, 2019).

[5] Pade, C. and Guimaraes, M. (2007) “The CO2 uptake of concrete in a 100-year perspective,” *Cement and Concrete Research*. Pergamon, 37(9), pp. 1348–1356.

[6] Celik, K. *et al.* (2014) “High-volume natural volcanic pozzolan and limestone powder as partial replacements for portland cement in selfcompacting and sustainable concrete,” *Cement and Concrete Composites*, 45, pp. 136–147.

[7] Our World in Data (2017) *CO_2 and Greenhouse Gas Emissions – Our World in Data*. Available at: https://ourworldindata.org/co2-and-othergreenhouse- gas-emissions#annual-co2-emissions (Accessed: December 2, 2019).

[8] Mehta P k, Monteiro P J M 2006 *Concrete, Microstructure, Properties and Material* 3rd edition McGraw-Hill Company.

[9] Jabbar, A. M., Hamood, M. J., & Mohammed, D. H. (2021). Ultra High Performance Concrete Preparation Technologies and Factors Affecting the Mechanical Properties: A Review. In IOP Conference Series: Materials Science and Engineering (Vol. 1058, Issue 1, p. 012029). IOP Publishing. https://doi.org/10.1088/1757-899x/1058/1/012029.

[10] Paris, J. M. *et al.* (2016) "A review of waste products utilized as supplements to Portland cement in concrete," *Journal of Cleaner Production*, 121, pp. 1–18.

[11] Khaliq, W. and Mujeeb, A. (2019) "Effect of processed pozzolans on residual mechanical properties and macrostructure of high-strength concrete at elevated temperatures," *Structural Concrete*, 20(1), pp. 307–317.

[12] ASTM C125-19 (2019) "Standard Terminology Relating to Concrete and Concrete Aggregates," in *Annual Book of ASTM standards 2019*. West Conshohocken, PA: ASTM International, pp. 78–86.

[13] Sabir, B., Wild, S. and Bai, J. (2001) "Metakaolin and calcined clays as pozzolans for concrete: A review," *Cement and Concrete Composites*, 23(6), pp. 441–454.

[14] IS 3812-1: 2013. Specification for Pulverized Fuel Ash, Part 1: For Use as Pozzolana in Cement, Cement Mortar and Concrete.

[15] IS 383- Specification for Coarse and Fine Aggregate from Natural Sources for Concrete 2016.

[16] IS 516-1959. Methods of Tests for Strength of Concrete. New Delhi, India: Bureau of Indian Standards, 1999.

[17] IS 516 (1979): Specialization for testing and strength of concrete, Part 1: Compressive, Flexural and Split Tensile Strength.

[18] HS: 38244010 – Prepared additives for cement, morter or concretes: Damp proof or proof compounds HS Code and Indian Harmonised System Code.

[19] IS 1199-1959. Methods of Sampling and Analysis of Concrete. New Delhi, India: Bureau of Indian Standard, 2004.