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Confinement effectiveness of 2900psi concrete using the extract of Euphorbia tortilis cactus as a natural additive

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ABSTRACT

Concrete with cactus is a new type of concrete with high fluidity, strength, and durability with more remarkable advantages. The present paper discusses the role of Euphorbia tortilis cactus (ETC) to achieve the strength, durability, and corrosion resistance properties of concrete specimens. In this work, M_{20} (2900psi) concrete was designed as per Indian standards, and cactus were used as an additive. ETC extracts from Tamilnadu (India) were replaced with water (1%, 3%, 5%, 7%, 9%) by weight. The performance of cactus concrete was analyzed through destructive and non-destructive tests to investigate strength properties. In addition to that, specific tests such as sorptivity, permeability, half-cell potential test, etc. have been performed further for durability and corrosion resistance. ETC concrete improves the fluidity, thereby enhancing the workability of the mixture. Concrete was analyzed through Scanning Electron Microscopy (SEM) to identify the particle distribution. Experimental investigation shows that the strength properties of concrete have been enhanced by 29% due to Polysaccharides at optimum level. However, durability is achieved at a high, which stimulates the effective filling of voids in concrete. It shows that better performance of concrete gives at optimum dosage. On Euphorbia tortilis cactus concrete, no literature has been discovered.

Keywords: concrete; euphorbia tortilis cactos; bio additive; destructive test; non-destructive test.

1. INTRODUCTION

In the construction Division, cement composite is the most extensively utilized construction material. A potential problem with concrete is its strength and durability, which is governed by several factors such as lower values of compressive strength, high chance of clogging, and less resistance to corrosion in severe environments. Various alterations in concrete are made nowadays, like changing mix proportions, adding admixtures, replacing with alternative waste products, and changing composition to achieve good results (Workability, Viscosity of concrete, high performance, and high strength). Present advancement in concrete construction technology demonstrates the possibility of improving concrete quality by altering its composition with fibers. Cement acts as the main role in concrete for binding. While manufacturing cement in industry, more amount of carbon-di-oxide emission happens which is detrimental to the environment. Lime was used as a binding material in ancient times in place of cement, but it was not durable. To modify the properties, Chemical additives are being used in concrete. The use of synthetic polymer additives will emit more toxic species to nature. Moreover, the usage of chemical admixtures is expensive. To cut down these downsides in concrete, the adoption of low-cost natural additives (Euphorbia tortilis cactus) is in the light of current research.

AL-JABRI *et al*. [1] used copper slag with sand and achieved good strength in high-performance concrete. Starch admixtures were tested with cement by AKINDHAET and UZOEGBO [2], an improvement in durability was observed. Bio-superplasticizer had a small impact on porosity said by BEZERRA [3]. As per Chandra's research [4], the cactus extract is giving good plasticity and improves water holding capacity. CARDENAS et. al. [5]

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replaced nanoparticles with cement to modify the properties of concrete but results gradually decreased. The early strength of concrete achieved, when cement reacts with nano-sio$_2$, also reduces the CO_2 emission was reported by CARDENAS et. al. [6]. Another natural admixture namely black gram; enhanced the water holding capacity of cement mortar, but the hydration process was delayed. Cardenas used ficus-indica mucilage in lime mortar to modify the properties, in these admixtures, an improvement in strength was observed. Dwivedi used black gram and superplasticizer in Portland cement to reduce the heat of hydration [7]. The heat of hydration reduced at high was observed. The deterioration of concrete was reduced with low-cost bio admixtures reported by HAZARIKA *et al*. [8] and HANEHARA and YAMADA [9]. Mechanical and durability properties were achieved by using biodegradable natural polymer said by IZAGUIRRE *et al*. [10]. Jensen conducted experimental work with a water-entrained solution to identify the theoretical background [11]. To enhance the durability of concrete, biotech solutions were used by JONKERS *et al.* [12]. As per his experimental improvement in durability was observed. While using beet molasses in concrete, the water holding capacity achieved was reported by JUMADURDIYEV *et al*. [13]. Karandikar et.al. demonstrated with okra extract. Kyomugasho states that compressive strength increased up to 10% with natural biopolymer assessed by experiment [14]. Kizilkanat conducted an experiment using natural polymer to modify the mechanical properties of cement composite. An improvement in the result was observed [15]. Vegetable base biopolymers were used in concrete and strength was increased by 10% in concrete [16]. While adding chitosan ethers with fresh concrete, the heat of hydration was dramatically decreased and concrete workability was enhanced [17–20]. Peschard monitored the hydration of cement using chromatography, and measurement of conductivity [21, 22]. The test results show that retardation increases with polysacradice value. According to POINOT *et al*. [23], cellulose ether degradation and its impact on cement hydration kinetics do not appear to be substantial. While using cactus mucilage as biopolymer in concrete carbonization rate increased and acted as a positive catalyst. [24–26] Sathya observed that lignocellulose in cactus, unsaturated, and saturated fatty acids made this admixture a retardant which eventually improved its strength [27]. The internal curing of concrete was achieved by using super adsorbent polymers [28] and plant extract [29, 30], and the improvement in shrinkage of concrete was enhanced [31, 32]. WOLDEMARIAM *et al*. [33] used the extract to reduce the shrinkage effect in the concrete, improvement in cracking and early age shrinkage was observed. The improvement in physical properties of cement composite and the reduction in cracks is due to the Graphene oxide as reported by Wu. and wei [34–36].

As presented in the literature, the quality of the concrete improved through many methods using polymer. However, success depends upon the availability of the material, ease of preparation, cost-effectiveness, and optimum performance [37]. As presented elsewhere, Natural additives are interesting and challenging for improving the mechanical and corrosion resistance of concrete specimens. In this present investigation, cactus extract (Euphorbia Tortilis) is used in cement composite as a natural additive to achieve better results in strength, durability, and properties of corrosion. As no result, based on Euphorbia tortilis cactus concrete are available in the literature. The effect of Euphorbia Tortiis extract on fresh and hardened cement concrete was addressed through various interesting experimental work like sorptivity, porosity test, etc... Finally, to identify the possibility of corrosion in ETC concrete, the half-cell potential method was performed.

2. MATERIALS AND SAMPLE PREPARATION

In this research, sulphate-resistant ordinary Portland cement was used as per IS 8112(part 1):2013 with a specific gravity of 3.15. Locally available river sand conforming to zone III and crushed aggregates of 20mm size were used as fine aggregates and coarse aggregates with a specific gravity of 3.13 and 2.64 respectively. The properties of the materials are listed in Table 1. All mixes were prepared with portable water. A natural organic additive of Euphorbia Tortilis cactus was collected from Pallakapalayam nearby komarapalayam area, Namakkal district, Tamilnadu. The euphorbia tortillas gel was directly extracted from the leaves of the cactus. After extraction, the gel was filtered through 1.18mm sieve (Sieve No. 16). The extract properties are analyzed and listed in Table 1. The extracts were added to the water by weight at the concentration of 1%, 3%, 5%, 7%, and 9%.

As per IS:7874-1975(R2014), a Crude fat test was conducted on a dried gel to find the number of proteins, polysaccharides, and fats, also find the quantity of protein present in the Euphorbia Tortilis cactus. Polysaccharide amount was calculated based on the percentage of protein and fat, and the results are listed in Table 1. 5.2% of polysaccharides and 1.9% of proteins present in Euphorbia tortilis. According to IS: 4031-1988, standard consistency of cement, setting time (initial and final) was conducted with various dosages (1%, 3%, 5%, 7%, and 9%) and 100% water added in a base sample.

3. EXPERIMENTAL STUDY

As per IS456:2000, the mix is prepared for 2900psi (M_{20} Grade) concrete compressive strength with 1:1.5:3 mix proportion. The molecular formula of concrete is $3CaO.Al_2O_3.6H_2O$. Using 0.5 water-cement ratios, six concrete

Table 1: Physical properties of materials.

PHYSICAL PROPERTY	CEMENT	FA	CA	CACTUS EXTRACT
Specific Gravity	3.15	2.67	2.75	–
Fineness Modulus (%)	2.31	3.72	7.41	–
Water Absorption (%)	–	0.6	0.5	–
Consistency (%)	30.5	–	–	–
Initial Setting Time (Minutes)	34	–	–	–
Final Setting Time (Minutes)	600	–	–	–
Fats (%)	–	–	–	0.10
Protein (%)	–	–	–	1.9
Polysaccharides (%)	–	–	–	5.2
Water (%)	–	–	–	92.85

mixes were prepared for all experimental works. Totally 126 cubes were prepared along with reference concrete. The concrete workability was examined with a help of the slump Cone apparatus according to IS:1199-2018 [38]. A cube of concrete measuring 150mm × 150mm × 150mm was tested to find compressive strength according to IS:516-1959(R2018) [39] which was performed under 140 kg/cm^2/min. loading rate in the compressive testing machine. After hardening, the compressive strength was determined at 7 days, 28 days, 5 6days, and 90 days. By using Equation (1), the strength of the hardened cement composite was calculated.

$$Compressive\ strength\ =\ \frac{P}{A} \tag{1}$$

IS:5816-1999(R2004) [40] standard was used to test the concrete splitting tensile strength. 150mm diameter and 300mm long cylinders are used for testing at the age of 7 days, 28 days, 56 days, and 90 days. Failure loads were noted and calculated using Equation (2). Where P denotes Ultimate load, A is cross-sectional area, L is Cylidrical length, and D is Cylindrical Diameter.

$$Spliting\ tensile\ strength = \frac{2P}{\pi LD} \tag{2}$$

As per IS 516-1959(R2018), the Flexural strength of hardened beams was conducted on 100mm × 100mm × 500mm prism after 28 days, 56 days, and 90 days curing. The flexural test was conducted with 4-point loading at the rate of 180kg/min and strength was calculated by using the following Equation (3). In equation (3), l denotes Span length of prism support, b is Prism width, and d is Prism measured depth.

$$Flexural\ strength = \frac{Pl}{bdd} \tag{3}$$

Durability tests are done after the curing period of hardened concrete (like 28 days and more). The hardened concrete specimens are made with desired sizes for different durability tests based on their procedures. At the age of 28 days and 90 days curing, a saturated water absorption test was conducted on 150mm cube specimen according to ASTM C642 [41]. Saturated water absorption refers to how much of the pore volume or porosity of hardened concrete is taken up by water when it is saturated. It refers to the amount of water that may be removed from a saturated specimen after drying. Effective porosity is defined as the porosity derived from absorption tests. It is calculated using Equation (4).

$$Effective\ porosity = \frac{\text{Volume of voids}}{\text{Bulk volume of specimen}} \times 100 \tag{4}$$

A Sorptivity test was carried out as per ASTMC642 [41]. Sorptivity is a measurement of the rate at which water percolates into the pores of concrete by capillary pressure. Using a hammer and a ball mill, the crushed portions of the tested specimens were re-broken into small bits and pulverized. After grinding, the powders were tested for alkalinity test according to ASTM C1202 [42].

4. RESULTS AND DISCUSSION

4.1. Test on fresh concrete

The workability or consistency of fresh concrete was tested using a slump cone equipment. Consistency of the concrete is increased when the slump is increased because both are directly proportional to each other. The slump cone, consistency, and setting time of fresh concrete results are shown in Table 2. The values indicates that the workability and consistency of concrete increased with ETC dosage value. The obtained results show that biopolymer additive enhances the workability of modified concrete. Also, the biopolymer enhances the hydration process of cement, as Ca^{2+} is less in water. The plasticity of concrete is increased because of polymeric chains of pectin. Cactus extract clearly improves the workability and consistency of cement composites.

4.2. Scanning Electron Microscope (SEM) analysis with various specimens

The details about particle sizes and mix proportions are taken through SEM images. Scanning electron microscope images started from reference concrete and studied. Figure 1(a) shows a microstructure view of reference concrete particle distribution and sizes at the range of 50µm Figure 1(b) shows the 1% ETC moderated concrete particle distribution and sizes at the range of 5nm where more voids. Figure 1(c) shows the 3% ETC moderated concrete particle distribution and sizes at the range of 1µm. Figure 1(d) shows the 5% ETC moderated concrete particle distribution and sizes at the range of 15nm. Figure 1(e) shows the 7% ETC moderated concrete particle distribution and sizes at the range of –5µm. Figure 1(f) shows the 9% ETC moderated concrete particle distribution and sizes at the range of 25nm where fewer voids and very tight to water movement.

4.3. Test on Mechanical properties

4.3.1. Compressive strength

Compressive strength is used to determine the concrete's strength. The test was conducted at 7 days, 28 days, 56 days, and 90 days curing period with a help of a Universal Testing Machine [43]. The compressive strength of reference concrete and modified concrete (1% to 9%) are shown in Figure 2 and Table 3. From the obtained result, the strength during 7-day curing period was decreased with increasing ETC dosage. After 28, 56, and 90 days curing period, the strength of modified concrete is increasing with ETC dosage. The addition of ETC has the most important impact on concrete properties. 9% of ETC additive shows 80 ± 2% of target strength. ETC concrete's low reactivity and slow pozzolanic reaction may be the cause of its early strength decline. The primary advantage of ETC is known as the "pozzolanic effect," which asserts that unfixed Polysaccharides in ETC can be activated by CaOH, a byproduct of cement hydration, and produced more hydrated gel. Because the gel created by pozzolanic activity can fill up the concrete's capillaries, it greatly enhances the strength of the material. While adding 1%, 3%, 5%, 7% and 9% ETC; the strength of concrete enhanced 3.9%, 15%, 19.5%, 24.1%, and 28.8% respectively at 28 days curing as compare to reference concrete. At 56 days, 3.9%, 4.8%, 10%, 13.9%, and 21.3% strength increased as compared to reference concrete. After 90 days of curing, 4.1% , 7.8%, 14.4%, 19.8%, and 25.5%.

Table 2: Fresh concrete properties.

MIX INDEX	SLUMP VALUE (mm)	CONSISTENCY (%)	INITIAL SETTING TIME OF CONCRETE (MIN.)	FINAL SETTING TIME OF CONCRETE (MIN.)
Reference Concrete	29	29.3	34	590
ETC 1%	31	28.7	41	605
ETC 3%	34	28.1	44	618
ETC 5%	37	27.8	48	627
ETC 7%	39	27.2	50	640
ETC 9%	42	26.5	53	655

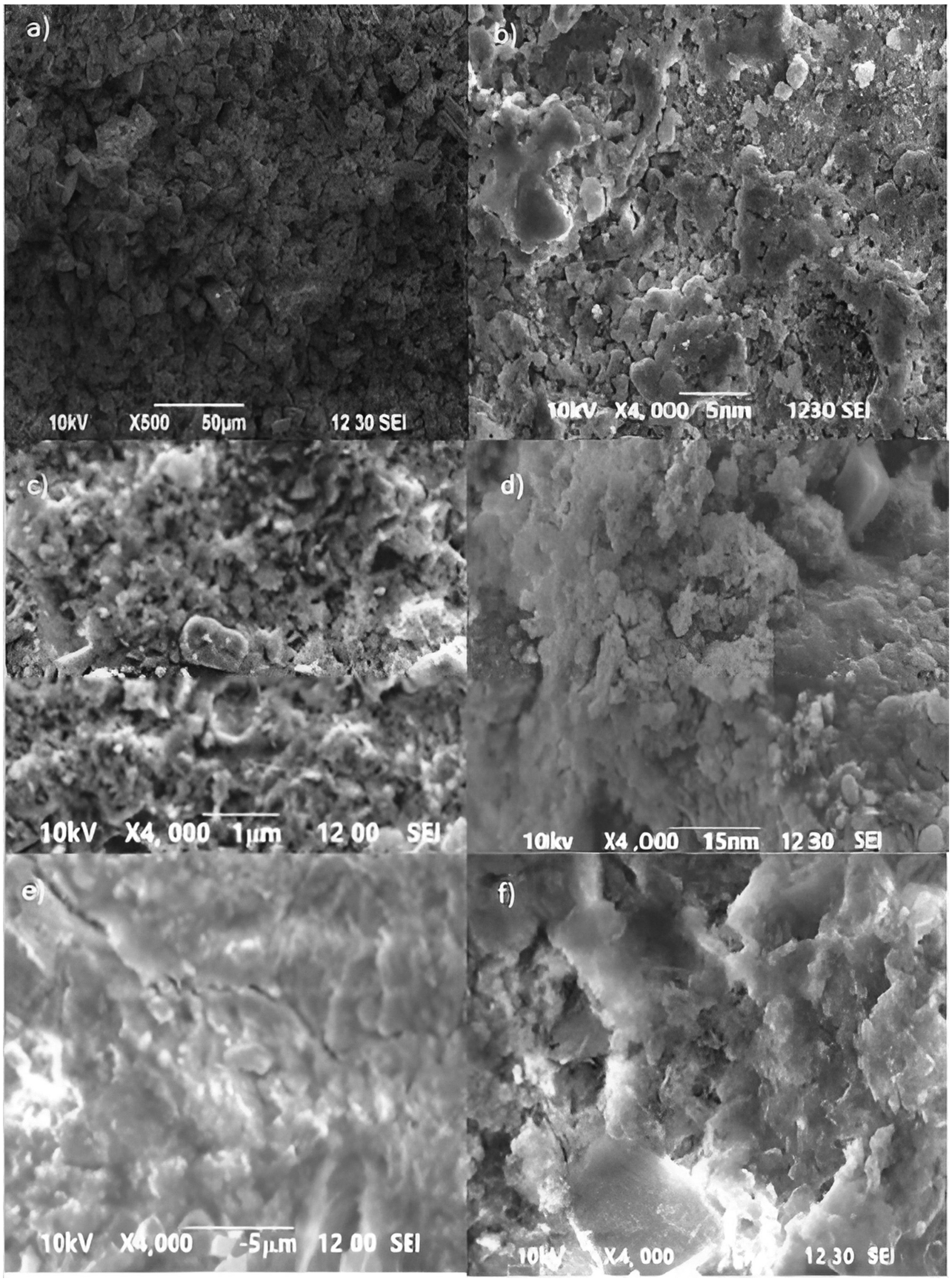

Figure 1: SEM images of with and without ETC in concrete (a). Reference concrete at 50µm range; (b) Concrete with 1% ETC at 5nm range; (c) Concrete with 3% ETC at 1µm range; (d) Concrete with 5% ETC at 15nm range; (e) Concrete with 7% ETC at –5µm range; (f) Concrete with 9% ETC at 25nm range.

4.3.2. Split tensile strength test

The concrete yield capacity is the ability of cement composite to withstand forces without breaking. Traditionally tensile strength is defined as a function of compressive strength. Normally the split tensile strength of cement composite is 8 to 14% of the compressive strength [44]. Cylindrical specimens were made to test the tensile strength of concrete after 7 days, 28 days, 56 days, and 90 days. The obtained results are listed in Table 4. The concrete split tensile strength is increasing with an increasing percentage of dosage (ETC), in comparison to the reference concrete. As a result, they provide a better bond, and hence the strength is increased. As per the tensile strength test result and graph, it is observed that the optimum tensile strength obtained is 3.95 N/mm^2 at 28 days of curing with 9% ETC addition. The tensile strength of 9% ETC concrete is 4.51 N/mm^2 at the end of 90 days. The graph of spilt tensile strength vs percentage of ETC at different curing periods is shown in Figure 3. While adding 1%, 3%, 5%, 7% and 9% ETC; the tensile strength of concrete enhanced 5.6%, 17.8%,

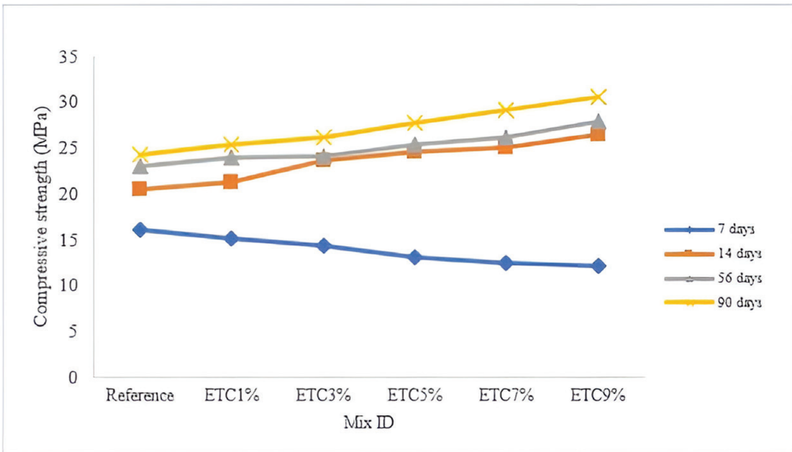

Figure 2: Compressive strength of concrete with & without ETC.

Table 3: Average compressive strength of ETC concrete with standard deviation.

MIX INDEX	COMPRESSIVE STRENGTH (N/mm^2)				INCREASE PERCENTAGE OF COMPRESSIVE STRENGTH AT 28 DAYS	CRUSHING VALUE AT 28 DAYS IN N/mm^2 (X)	AVERAGE STRENGTH (Y)	DEVIATION (X – Y)	STANDARD DEVIATION $\mu = \frac{\sqrt{(\Sigma X - Y)2}}{\sqrt{N-1}}$
	7 DAYS	28 DAYS	56 DAYS	90 DAYS					
Reference	16.1	22.5	25	26.3	–	22.5	25.57	–3.07	0.009
ETC1%	15.1	23.3	25.9	27.3	3.56	23.3	25.57	–2.27	
ETC3%	14.3	25.6	26.1	28.2	13.78	25.6	25.57	0.03	
ETC5%	13	26.5	27.3	29.8	17.78	26.5	25.57	0.93	
ETC7%	12.5	27.1	28.2	31.1	20.44	27.1	25.57	1.53	
ETC9%	12.1	28.4	29.9	32.5	26.22	28.4	25.57	2.83	

Table 4: Average tensile strength of ETC concrete with standard deviation.

MIX INDEX	TENSILE STRENGTH (N/mm^2)				INCREASE PERCENTAGE OF TENSILE STRENGTH AT 28 DAYS	CRUSHING VALUE AT 28 DAYS IN N/mm^2 (X)	AVERAGE STRENGTH (Y)	DEVIATION (X – Y)	STANDARD DEVIATION $\mu = \frac{\sqrt{(\Sigma X - Y)2}}{\sqrt{N-1}}$
	7 DAYS	28 DAYS	56 DAYS	90 DAYS					
Reference	1.9	2.13	2.41	2.55	–	2.13	2.79	–0.66	0.0045
ETC1%	1.95	2.25	2.63	2.76	5.63	2.25	2.79	–0.54	
ETC3%	2.1	2.51	2.97	3.10	17.84	2.51	2.79	–0.28	
ETC5%	2.3	2.79	3.2	3.35	30.99	2.79	2.79	0	
ETC7%	2.6	3.10	3.77	3.92	45.54	3.10	2.79	0.31	
ETC9%	3.1	3.95	4.09	4.51	85.45	3.95	2.79	1.16	

30.9%, 45.5%, and 85% respectively at 28 days curing as compare to reference concrete. At the age of 56 days, 9.1%, 23.2%, 32.8%, 56.4%, and 69.7% strength increased as compared to reference concrete. At the end of 90 days of curing, 8.2%, 21.6%, 31.4%, 53.7%, and 76.8% strength enhanced as compared to reference concrete.

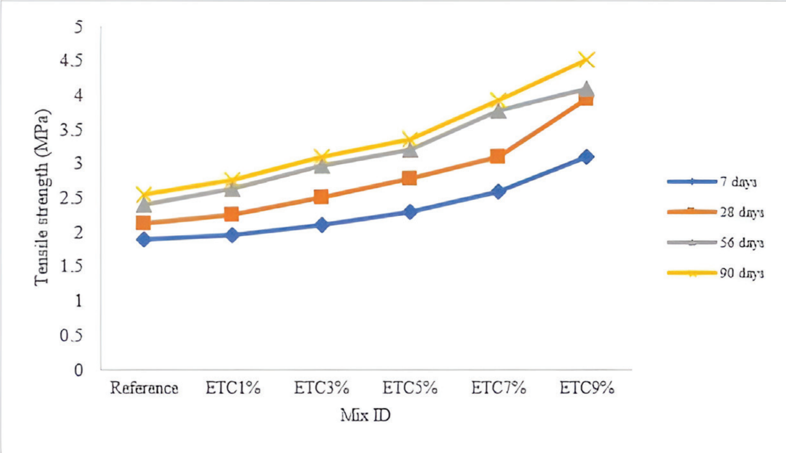

Figure 3: Split tensile strength of concrete with & without ETC.

Table 5: Average flexural strength of ETC concrete with standard deviation.

MIX INDEX	FLEXURAL STRENGTH (N/mm²)			INCREASE PERCENTAGE OF FLEXURAL STRENGTH AT 28 DAYS	CRUSHING VALUE AT 28 DAYS IN N/mm² (X)	AVERAGE STRENGTH (Y)	DEVIATION (X – Y)	STANDARD DEVIATION $\mu = \frac{\sqrt{(\sum X - Y)2}}{\sqrt{N-1}}$
	28 DAYS	56 DAYS	90 DAYS					
Reference	6.11	7.91	8.04	–	6.11	7.57	–1.46	0.0045
ETC1%	7.03	8.22	8.81	15.06	7.03	7.57	–0.54	
ETC3%	7.51	8.6	9.59	22.91	7.51	7.57	–0.06	
ETC5%	7.96	9.01	9.82	30.28	7.96	7.57	0.39	
ETC7%	8.06	9.43	10.31	31.91	8.06	7.57	0.49	
ETC9%	8.76	9.97	10.72	43.37	8.76	7.57	1.19	

The result shows better tensile strength due to the bond. The optimum strength is reached when the concrete with 9% ETC. The reason for increased tensile strength may be a strong ITZ between the C-S-H gel produced by cement, ETC, and aggregates.

4.3.3. Flexural test on prism

Flexural strength is one of the significant properties it affects the flexural cracking, brittleness ratio [45], ad bond strength. As per IS 516-1959(R2018), the Flexural strength of hardened concrete beams was conducted on prism measuring dimensions of 100mm × 100mm × 500mm after 28 days, 56 days, and 90 days curing. The 28 days flexural strength of concrete with ETC (1% to 9%) in normal water curing in this study, ranges from 7.03 N/mm² to 8.76 N/mm². With the addition of Euphorbia Tortilis cactus from 1% to 9%, The concrete's flexural strength has been enhanced considerably. The observation for the flexural strength test results is listed in Table 5. From the test result, it is observed that 9% ETC concrete in normal water curing attained optimum flexural strength of 9.97 N/mm² and 10.72 N/mm² at the end of 56 days and 90 days. In Figure 4, flexural strength values of ETC concrete were plotted with various ETC dosages. It is eventually shown that the flexural strength advanced in all the ETC concrete when compared to the reference specimen which may be the filler effect of Euphorbia tortilis, ductile nature of fats, and proper curing. The strength of concrete prism in flexural strength is increased 15%, 22.9%, 30.3%, 31.91%, and 43.4%, while adding natural additive (ETC) 1%, 5%, 3%, 5%, 7% and 9% respectively at 28 days curing. The flexural strength of all the ETC concrete gives a higher value than conventional concrete. The enhancement of 56 days, 90 days flexural strength of all mixes are found to be about 3.9%, 8.7%, 13.9%, 19.2%, and 26% for 56 days and 9.6%, 19.3%, 22.1%, 28.2%, and 33.3% for 90 days, respectively, with reference to conventional concrete. ETC reduces the number of pores in concrete, increasing its strength considerably.

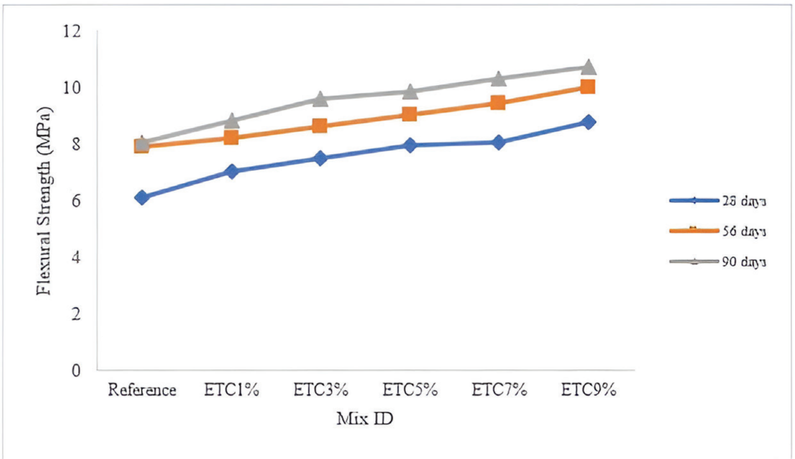

Figure 4: Flexural strength of concrete with & without ETC.

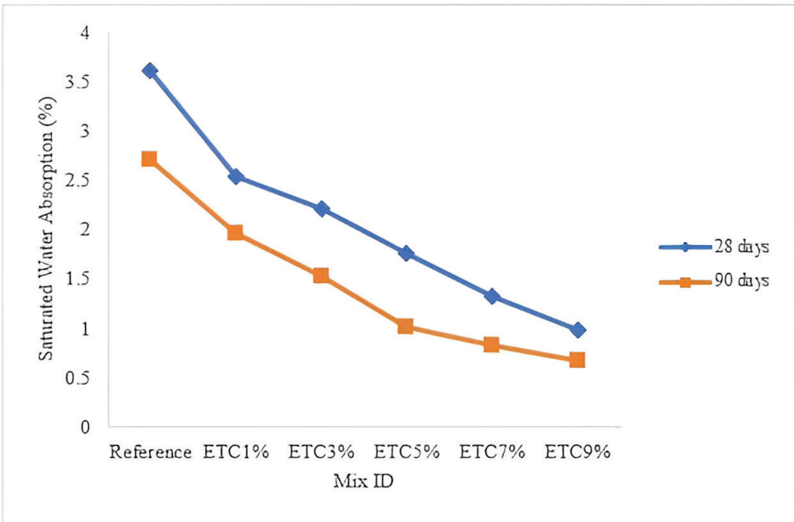

Figure 5: Water absorption percentage of concrete.

4.4. Durability test on hardened concrete

4.4.1. Saturated water absorption test and porosity test

As per ASTM C642 [41], Saturated water absorption tests are conducted on cube specimens measuring 150mm × 150mm × 150mm at 28 days, and 90 days curing period. The initial weight of the specimens was taken before drying. The sample was dried by keeping at 105°C temperature in a hot air oven. The drying procedure was repeated until the mass alteration between two consecutive values taken at 24-hour intervals was nearly identical.

Dried specimens were chilled to room temperature before being immersed in water. At predetermined intervals, the samples were removed. The surface of the concrete specimen was dried with a clean cloth before being weighed in a machine. The water-saturated absorption value is calculated as the percentage of measured water-saturated mass divided by the oven-dried mass. The Saturated water absorption values were calculated by using weight difference, and the results are revealed in Table 6 and Figure 5. Improvement in water absorption was observed with a dosage of ETC percentage. At the end of 28 days and 90 days, the water absorption for the ETC9% mix has the lowest percentage of 72.8% and 75.2% respectively, when compared to reference concrete. It proves that when more ETC are added to the concrete, the depth of water penetration decreases. Therefore 9% ETC gives less depth of water absorption when compared to the reference mix, ETC1%, ETC3%, ETC5%, and ETC7%, due to the fact that they should be able to fill the gaps in the specimens. ETC concrete has a dense microstructure and water absorption is less when compared to control concrete.

The porosity of the concrete specimen was directly measured after the completion of the Water-saturated absorption test. It refers to the amount of water that may be removed from a saturated specimen after drying. Effective porosity is defined as the porosity derived from absorption tests. The effective porosity of concrete was calculated by using Equation 4 and it is shown in Table 6 and Figure 6. The obtained results show that the porosity of the concrete decreased with the increased dosage of ETC percentage. The water absorption and porosity are directly proportional to each other. While adding ETC1%, ETC3%, ETC5%, ETC7%, and ETC9%, the percentage of porosity was 15.1, 23.9, 33.44, 38.1, and 43.5 lesser than reference concrete at the age of 28 days curing period. Due to the effect of Polysaccharides and fats, ETC concrete has a dense microstructure and porosity was less when compared to control concrete. 9% ETC concrete has the lowest value of 7.21% and 7.07% than conventional concrete, at the end of 28 days and 90 days respectively.

4.4.2. Sorptivity test

The water penetrates through the voids of concrete by capillary action. Additionally, water absorption affects concrete quality because, according to Hall in 1977 and 1989, entry of water through pores might result in issues with concrete's durability. The rate of penetration of water can be calculated by sorptivity analysis. This test was done with different ratios of ETC concrete from 1% to 9% as per ASTM C 1585-2013 [46]. After the curing period of 28 days, cubes of concrete measuring 150mm × 150mm × 150mm were made in contact with atmospheric temperature. The test specimens of different ratios of cactus (1%, 3%, 5%, 7%, and 9%) are made cut into diameter of 10cm (4inch) with a length of 150mm. The cut specimen is further smoothed at both edges for about 1cm each. Then the specimen is cut into further 4 pieces with a thickness of 3cm each. And these small specimens are smoothed on either side. The initial weight of the specimen was noted. After being immersed in water, the average weight of the specimens was noted at 30 minutes, 60 minutes, 120 minutes, 180 minutes, 240 minutes, and 300 minutes. Figure 7 explained the slope of absorption and square root time

Table 6: Results of durability test of hardened concrete.

MIX INDEX	SATURATED WATER ABSORPTION (IN %)		% OF POROSITY		p^H	HALF-CELL POTENTIAL VALUE (mV)
	28 DAYS	90 DAYS	28 DAYS	90 DAYS		
Reference	3.61	2.71	12.77	12.15	8.45	–271
ETC1%	2.53	1.96	10.84	10.75	9.1	–206
ETC3%	2.21	1.52	9.72	9.51	9.2	–178
ETC5%	1.76	1.02	8.50	8.37	10.5	–142
ETC7%	1.33	0.83	7.91	7.65	12.5	–121
ETC9%	0.98	0.67	7.21	7.07	13.3	–97

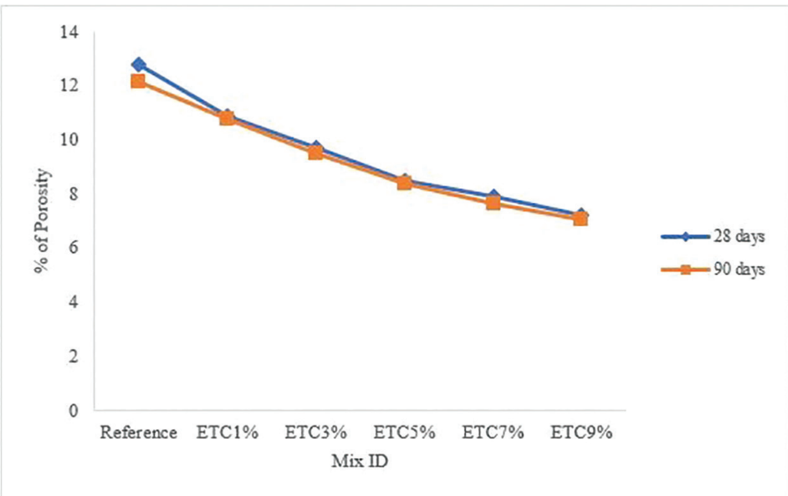

Figure 6: Porosity of concrete.

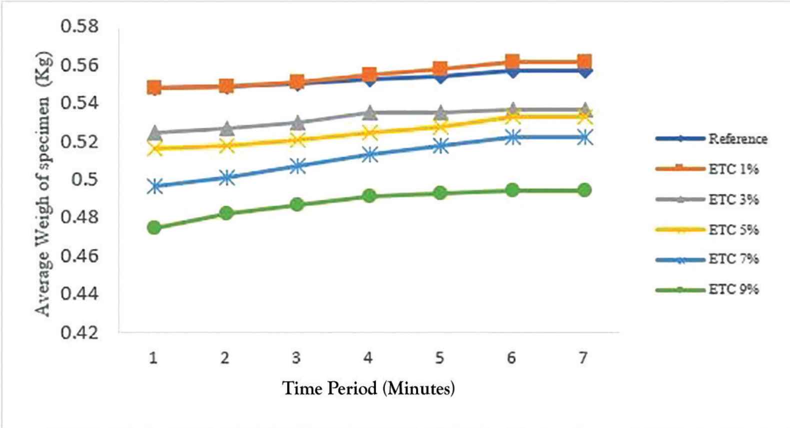

Figure 7: Results of sorptivity test.

Figure 8: Sample for sorptivity test.

of ETC and reference concrete. It can be noted that the correlation coefficient was acceptable between the absorption and square root of time. Figure 7 depicts the achieved results, whereas Figure 8 depicts the test set-up From the result, it is clear that at the early stage, water absorption was high in the steeper curve. Later in a gentle curve, the water absorption was very less with respect to time. At the end of 300 minutes, the weight was 2.5%, 2.6%, 2.3%, 3.3%, 5%, and 4.9% enhanced for the reference mix, ETC1, ETC3, ETC5, ETC7 and ETC9 mix respectively when compared to the initial stage. As a result, it is evident that ETC concrete has very less water absorption when compared to conventional concrete, also has less permeable, homogeneous and dense microstructure.

4.4.3. Alkalinity measurements

The broken pieces of test specimens in the compressive testing machine were collected and cut into small pieces and pulverized in a ball mill once more. The powdered samples were diluted with 100ml distilled water in a beaker. With a help of a p^H meter, the alkalinity value was measured in an aqueous solution. Table 6 and Figure 9 shows the alkalinity value of different ETC mixed concrete. ETC9% contains high alkaline than conventional concrete. The reason for increased alkalinity in the ETC concrete may be the effect of fats and Polysaccharides present in the Euphorbia tortilis cactus.

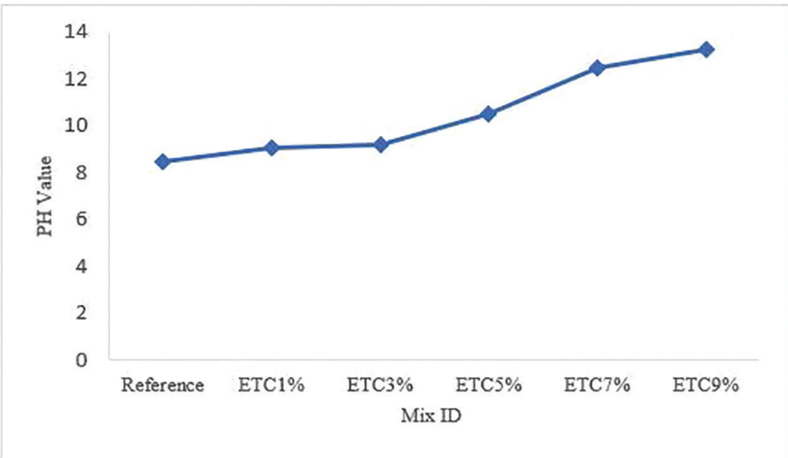

Figure 9: Alkalinity of concrete.

Table 7: Acid test results.

MIX INDEX	VISUAL SCALE VALUE		WEIGHT LOSS (%)		INITIAL COMPRESSIVE STRENGTH AT 90 DAYS (N/mm^2)	STRENGTH OF CONCRETE AFTER THE ACID ATTACK (N/mm^2)		STRENGTH DETERIORATION FACTOR (IN %)	
	H_2SO_4	HCL	H_2SO_4	HCL		H_2SO_4	HCl	H_2SO_4	HCl
Reference Concrete	3	3	6.110	6.603	24.3	20.1	20.0	17.28	17.70
ETC1%	2	2	4.319	4.518	25.3	23.5	24.1	7.11	4.74
ETC3%	2	2	4.175	3.724	26.2	24.4	24.9	6.87	4.96
ETC5%	1	1	3.626	3.548	27.8	25.6	26.7	7.91	3.96
ETC7%	1	1	3.049	3.069	29.1	28.0	27.9	3.78	4.12
ETC9%	1	1	2.438	2.896	30.5	29.1	29.3	4.59	3.93

4.4.4. Acid attack

Based on Table 7, it can be shown that concrete exposed to H_2SO_4 attack had an average visual assessment scale of 2, which denotes a minimal deterioration under appropriate curing conditions. Similar to this, the depiction of the visual scale factor for concrete treated to HCl attack is determined to be an average of 2. At the end of 90 days, the concrete specimens lost their weight in the range of 2 to 5% after the acid attack. Also, while concrete reacts with the acid, the strength of the concrete is also reduced considerably. The strength deterioration values for ETC concrete (1% to 9%) fall between the ranges of 3 and 5%. H_2SO_4 and HCl attacks caused weight changes of 2.438% and 2.895%, respectively, although reference concrete lost 6.11% and 6.60% of weight in the same solution. It is evident from the observation that the typical curing type of concrete has only been very mildly attacked.

4.5. Corrosion test on ETC Concrete

4.5.1. Half-cell potential method

The fundamental disadvantage of RC concrete structures is that their performance deteriorates when they are exposed to the action of corrosion. To evaluate the probability of corrosion in concrete, the half-cell potential approach was used. A voltmeter was used to measure the potential difference between the steel reinforcement and the external electrode in this procedure. A metal rod is immersed in $Cu/CuSO_4$ solution in the half-cell.

A voltmeter connects the metal rod to the reinforcement steel. To generate an exact value, steel reinforcement and outside electrodes were connected through wet concrete protection. The availability of oxygen, concrete resistivity, and cover thickness all stimulus the outcome of a half-cell potential test. For determining the possibility of corrosion, the potentials were measured an average of many measurements obtained from different sites on the same surface or at any place on the surface was used as shown in Figure 10. According to ASTM C876 [47], the half-cell potential test was carried out, and the obtained results are listed in Table 6; the graphical variations are shown in Figure 11. After obtaining the results, the contour was plotted on a graph to identify the high corrosion activity. Hence with the reference to the test result, it shows that the corrosion on the ETC Concrete does not affect by any corrosion agent even after placing it in atmospheric conditions and the probability of corrosion was 10% in the concrete.

5. CONCLUSIONS

In this research, experiments were performed to analyze the performance of cement composite with natural additive, namely Euphorbia tortilis extracted from cactus (ETC) on the fresh and hardened cement composite. The most significant findings of this research have been summarized as follows:

1. The Euphorbia tortilis cactus decreases the fluidity of the concrete due to polysaccharides present in cactus which is acting as viscosity modifying admixture. Furthermore, improvement in consistency. In addition to that, it reduces the water requirement of concrete and modifies the setting time of concrete.

Figure 10: Set up for half-cell potential test.

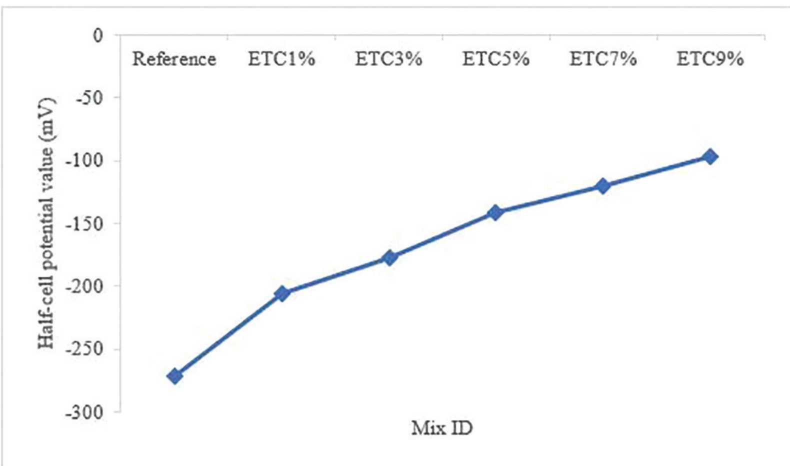

Figure 11: Rate of corrosion in concrete.

2. During an earlier age period, the mechanical properties of the Euphorbia tortilis concrete are slower, enhanced after 28 days curing period due to consumption of Ca^{2+} and portlandite. Furthermore, when compared with reference concrete, the 28 days result indicated that the modified concrete with natural additive showed increased properties of strength (Compressive, Tensile, and Flexural strength) from 10% to 40%.
3. The influence of durability on the behavior of modified concrete with natural additives was evaluated by saturated water absorption, porosity test, sorptivity test, and Alkalinity test. In these analyses, enormous results were observed in durability. Percentage of Water absorption is minimum, less volume of porosity, lesser sorptivity value and contains high alkaline when compared to reference concrete due to the presence of protein and fats in ETC.
4. The possibility of corrosion occurrence was evaluated by the half-cell potential method. Results showed a better inhibiting effect of corrosion rate on steel rods and reduced weight loss. The minimum possibility (36%) was observed at an optimum level of dosage when compared to reference concrete.
5. In general, increasing ETC% impacts the strength and durability of concrete. Specifically, the mechanical strengths are enhanced due to pectin and polysaccharides while fats and proteins influence the durability properties.
6. Natural additives are cheap, easy to handle, and eco-friendly in place of chemical additives. Nowadays, society depends on eco-friendly systems; Thus, the usage of natural additives would be the better solution for sustainability.

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