Improvement of Surface and Properties of Cast Stone by Coating and Palm leaf Sheath Fiber Wastes

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Abstract

The addition of natural wastes to improve the mechanical properties of construction materials are becoming increasingly important over the past decades for economic and environmental advantages. The present study is an attempt in improving the mechanical and antibacterial surface properties of the cast stone by self compacting concrete method by using different volume fractions of palm leaf sheath fibers (PLSF) (0.1, 0.2 and 0.3) % and coated with nano Zno/Epoxy coating using doctor blade method , at different Zno ratios (0.5 ,1 and 1.5) %. The fresh concrete tests such as : slump flow test, V-funnel test and L-box test, were done . Also , the CS were characterized by tests of compressive strength, flexural strength and splitting tensile strength. The coatings were evaluated by antibacterial activity, Atomic force microscope, roughness and wettability. The results could prove the success of addition of 0.1 % PF in improving the compressive strength at (7, 14 and 28 days), flexural strength and splitting tensile strength at (28 days) of cast stone from 58 MPa, 11.06 MPa and 5.21 MPa to 65.3 MPa, 15.2 MPa and 5.35 MPa, respectively. In addition, increasing the PF content above 0.1 % showed undesirable compressive strength and flexural strength but improved splitting tensile strength for cast stone. Results of coating show that better concentration to killing bacterial E. coli is 1% Zno, where this concentration increase inhibition zone 19.5 mm and contact angles increased with Zno ratio increasing, therefore, resulting in less wettability.

Keywords*: cast stone, Palm leaf sheath fiber, reinforcing material, compressive strength.*

1. Introduction

Cast stone masonry is a form of precast concrete that attempts to replicate the texture and appearance of natural dimension stone. It can be formed to almost any shape and size the designer wishes and can equal, or even surpass, the technical capabilities of quarried natural stone in terms of strength, moisture penetration, colouring and textural consistency [1].

Date tree has various byproducts which are dropped into the river or deposited in the farmlands or in most of the cases they will be burnt by the farmers . All the mentioned issues are definitely harmful for human and environment that their proper application could be beneficial to the environment [2].

Also microorganisms are ubiquitous and dispersible from soil and water as well as from air. Building materials are permanently exposed to such microorganisms and may easily become targets for contamination and growth. The growth of microorganisms can have various detrimental consequences, including the bio deterioration of materials, which may concern structural and aesthetic properties [3].

Recently, more attention has been increased to the use of natural waste such as rice husks, date seed palm and date tree fibers in improving the mechanical specifications of construction materials for various economic and environmental advantages [4]. Coating or pigmented consider suitable solution when the CS products are soiled crazed or discolored [5]. Mahyuddin and Eethar used natural fibers to improve properties of lightweight concrete (LWC) by addition of palm fiber of different volume fractions [6]. Mohd and Nurazuwa discussed the usage of palm oil fiber as discrete reinforcing fiber that can restrain minor cracks that developed in the concrete from spreading [7]. Z. Ahmed et al. studied the effectiveness of oil palm trunk fibers used at relatively low volume fractions, in enhancing the mechanical properties of concrete material [8].

2. Research Significance

The increased demands for cast stone products with modified properties and surfaces will open new prospects for research on this study to attain now days requirements :

1.Technical, where much improvements in the mechanical properties have become increasingly important.

2- Economical and Environmentally , where less cost and pollution are expected to be achieved from the view point of "using natural waste materials " in manufacturing of CS.

3. Experimental Program

3.1 Materials

Palm leaf sheath fiber (PLSF), also called palm silk or palm wool, have been used in many works to improve the mechanical properties of concrete [9] .The chemical structure of natural fiber or plant fiber comprises of cellulose، hemicellulose, lignin, pectin and extraneous materials [10]. Properties of PLSF were tested in university Babylon/ college of materials engineering/ Babylon – Iraq. The properties are listed in Table 1.

Table (1): PF Properties

Properties	Values
Bulk density, g/cm3	1.20
Elongation (%)	2.74
Tensile strength (MPa)	225
Young’s modulus (GPa)	4.5

The PLSF were undergone several cleaning and drying processes to remove the dust. Then they were cut according to specified length ϕ 0.6x 40 mm as shown in figure 1.

Fig. (1) Photography of PF before and after cutting

A high-quality epoxy resin used as the matrix material (Bisphenol A(epichlorohydrin) oxirane [(c-12-14 alkyloxy) methyl]) and Hardener –amine (3-aminomethyl-3,5,5-tri methyl cyclo hexylamine) from Sika Co. Ltd. The density of cured epoxy resin about 1.14 gm/cm^3. Zinc oxide (Zno) provided from Hongwu International Group Ltd which have purity 99.8 % and nano size 30-50 nm.

The cement used was the white portland cement provided from the Saveh Cement Company of Iran. It is ready-made in local market. The physical properties of cement shown in Table 2 [11].

Table (2): Physical properties of white cement

Physical Property	Symbol	Percentage %	Limits of Iraq specification No.5/1984
Initial Setting Time	I.S.T	95 min	≥45 min
Final Setting Time	F.S.T	2:50 hr :min	≤10 hr
Specific Surface Area	S.S.A	480 m²/Kg	≥230 m²/Kg
Compressive Strength (MPa)	3 day	19.60 MPa	≥15 MPa
Compressive Strength (MPa)	7 day	28 MPa	≥23 MPa

The fine aggregates used were natural sand specified according to the requirements of the (IQSNo.45/1984), zone 2 [12] . Table 3 shows the sieve analysis of the fine aggregate. The coarse aggregates specified according to the requirements of the (IQSNo.45/1984) as shown in table 4 were used in the range 5-20 mm.

The range water reducing admixture used in this study was a third generation super plasticizer for concrete , commercially known as (Hyperplast PC200) ,it is a high Performance super plasticizer concrete admixture which is imported from (DCP) company [13].

Table (3): Grading of fine aggregate according to Iraqi specification

Sieve size (mm)	Passing accumulate %	Percent passing accumulate limit of Zone II of IQS 45/1984
10	100	100
4.75	93	90-100
2.36	76	75-100
1.18	65	55-90
0.6	42	35-59
0.3	16	8-30
0.15	5	0-10

Table (4): Grading of coarse aggregate according to Iraqi specification

Sieve size mm	Passing accumulate %	Specification IQS 45/1984 standard regime 5-20
37.5	100	100
20	97.3	95-100
10	48.2	30-60
5	6.4	0-10

3.2 Mix Design

The mixture design was done according to the European Guidelines for Self Compacting Concrete (EFNARC) [14]; therefore, many trial mixes should be done to achieve the required characteristics for SCC in fresh state such as filling and passing ability and segregation resistance. Table 5 shows the mix proportion for SCC. Table 6 shows the quantity calculation in the mix design.

Table (5): Mix Proportion of Self-Compacting Concrete

Materials	Proportions of mix (kg/m3)	Constituent	EFNARC [14] (Kg/m3)
Cement	454	Powder	380-600
Coarse aggregate	825	Coarse aggregate	750-1000
Fine aggregate	800	Fine aggregate	(48-55) % of total aggregate weight
Water	200	Water	150-210
Super plasticizer	1.5	------	------
W/c ratio	0.38	------	------

Table (6): Proportions of raw materials and percentages addition of PF waste

Mix Symbol	Materials						
	Cement (Kg/cm^3)	Gravel (Kg/cm^3)	Sand Kg/cm^3)	Palm Fiber Waste (Kg/cm^3)	Percentage of PF Waste %	W/C Ratio	Super plasticizer by wt. of cementious %
Re	454	825	800	-	0	0.38	1.5
PF_1	454	825	800	40	0.1	0.38	1.5
PF_2	454	825	800	80	0.2	0.38	1.5
PF_3	454	825	800	120	0.3	0.38	1.5

3.3 Coating Preparation

ZnO / epoxy nanocomposite coatings were prepared via Epoxy resin diluted by adding acetone and stirring at about 500 rpm for 5 minutes. Zno Nano powder was directly added to the resin acetone solution in various percentage (0.5, 1 and 1.5) % and stirred at a speed of 2500 rpm for at least 1 hr, using mechanical stirring. After mechanical stirring the solution was sonicated for 90 minutes at 50 ºC. The hardener was also diluted with acetone before addition to the solution with 1:2 weight ratio, followed by mechanical stirring at a speed of 600 rpm for few minutes. Finally, CS samples (5x5x5 mm^3) coated with a resultant solution using a Doctor Blade technique Figure 2 .

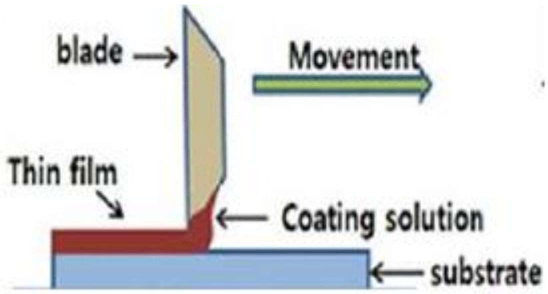

Fig. (2) Doctor Blade method for coating [15]

3.4 Testing Procedures

Tests of workability (slump test), V-Funnel and L-Box were done for the fresh cast stone concrete according to [14]. The compressive strength of 100 mm^3 cubes was carried at the ages of 7 ,14 and 28 days, according to [16].The flexure strength of ($100x100x400mm^3$) samples was tested at age 28 days, according to [17].The splitting tensile strength of cylinders samples (100×200) mm^2 was tested at age 28 days, according to [18].

Fig.(3) Over view of Casting Specimen

4. Results and Discussions

4.1 Fresh Properties of SCC

Fresh properties involved slump flow, and T50cm, V-funnel and L-box. These tests were carried out to ensure that the mixes satisfy the requirements of SCC. Table 7 illustrates the results of the fresh properties for each mix. These results proved that the SCC used was conformed to the requirements of (European Project Group, 2005), i.e. had a good consistency and workability at fresh state [12].

Table (7): Fresh Properties Results of SCC Mixes

Mix Ratios %	Slump Flow		L- Box (mm) BR	V- Funnel (sec)
	D (mm)	T_{50} (sec)		
0	800	2.08	0.85	9.48
0.1	720	3.9	0.83	10.1
0.2	675	4.5	0.81	10.98
0.3	640	6.2	0.80	11.8

Results of slump flow are summarized in Figures 4 and 5, from these figures, it can be observed that the slump flow decreased and T50 increased with PF content increasing. The reason of this behavior is attributed to the relatively high surface area of the fibers, which are typically dry, consume some water to get wet during concrete mixing. This can affect concrete workability and flowability.

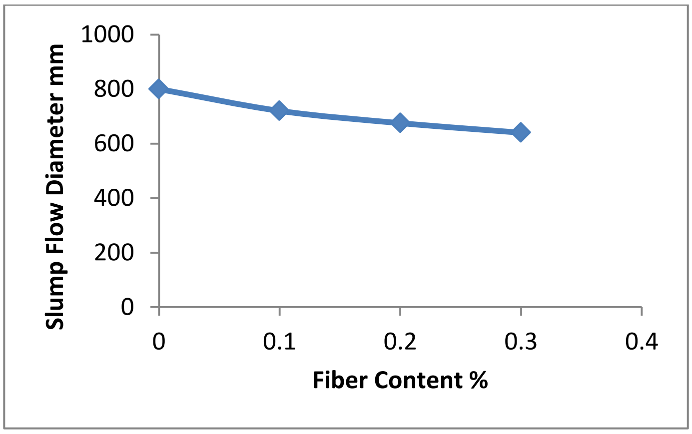

Fig. (4) Variation of Slump Flow Diameter (mm) with PF Content %

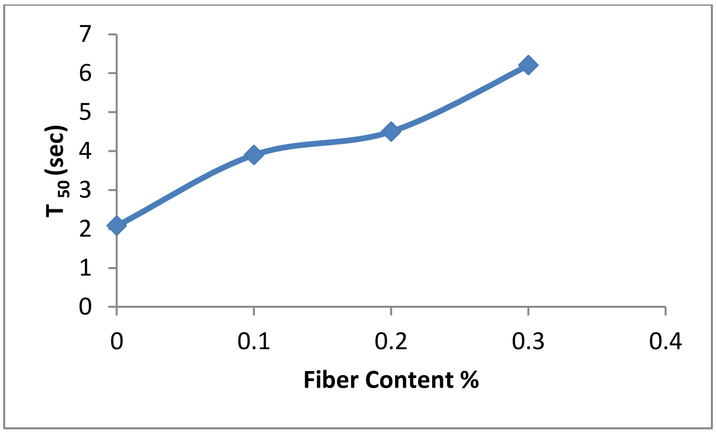

Fig. (5) Variation of Slump Flow Time T50 (sec) with PF Content %

L- Box test was used to assess the passing ability of SCC mixes, the values of (H2/H1) represent the blocking ratio (BR) . V-Funnel test was conducted to determine the filling ability and stability of SCC. The results obtained are reported in Table 6 and figure 6. It can be observed that BR decreased with an addition of PF. This due to introducing fibers which resist passing ability and therefore increase the internal resistance of flow of concrete, thus resulting in decreasing the BR with increasing fibers content .From figure 7 V-Funnel increased with PF addition increasing due to increase the friction between the fibers and aggregates and the friction of the fibers with each other which could extend the required time to empty the V-funnel.

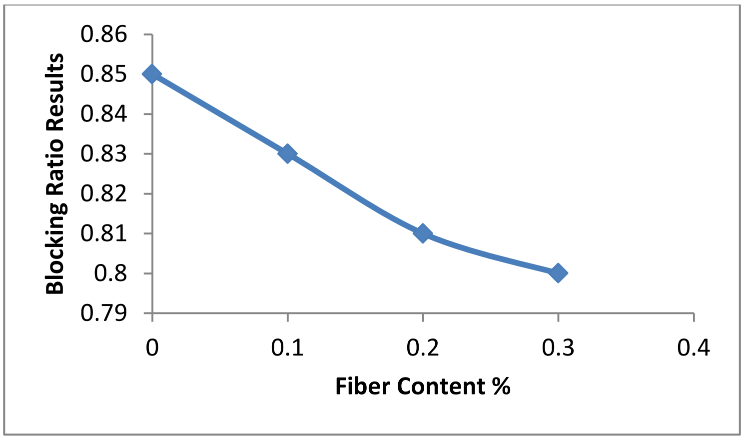

Fig. (6) Variation of Blocking Ratio Results with PF Content %

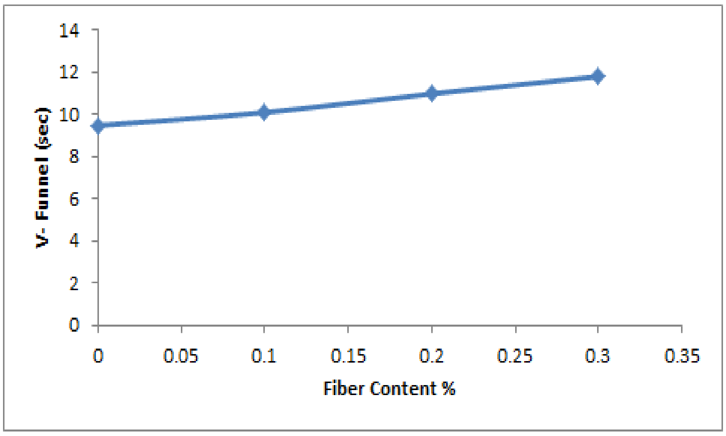

Fig. (7) Variation of V- funnel Result with PF Content %

4.2 Hardened Properties of SCC

4.2.1 Compressive Strength

Table 8 and figure 8 show the compressive strength results.

Table (8): Results of compressive strength after different immersion times

Mix Ratios (%)	Compressive strength MPa		
	Age/time (days)		
	7	14	28
0	51.7	54	58
0.1	53.27	58.79	65.3
0.2	48.5	52	55.09
0.3	42	48	51.11

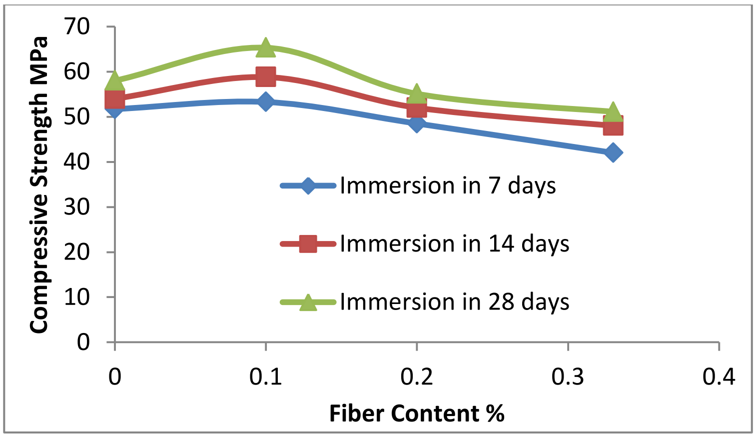

Fig. (8) Variation of compressive strength with PF Content %

It can be seen that fibers mixed with the concrete could increase the compressive strength compared to normal concrete due to their interacting with the advancing cracks and help cast stone to make it more tough and durable, thereby, avoid the cracks from happening. Fiber-reinforced cast stone can sustain load even after initial cracking, which means that the time for micro-crack to occur are withhold when the fibers upholds and prolong the failure time. With increase of fibers content, compressive strength reduces clearly and this can be attributed to the voids introduction in the mix due to excessive fiber content that may lead to reduce bonding and disintegration

4.2.2 Flexure Strength

Table 9 and figure 9 show the results of flexural strength at 28 days.

Table (9): Results of flexure strength after 28 days

Mix Ratios (%)	Flexural Strength MPa at Age/time (days) 28
0	11.06
0.1	15.2
0.2	9.8
0.3	9.08

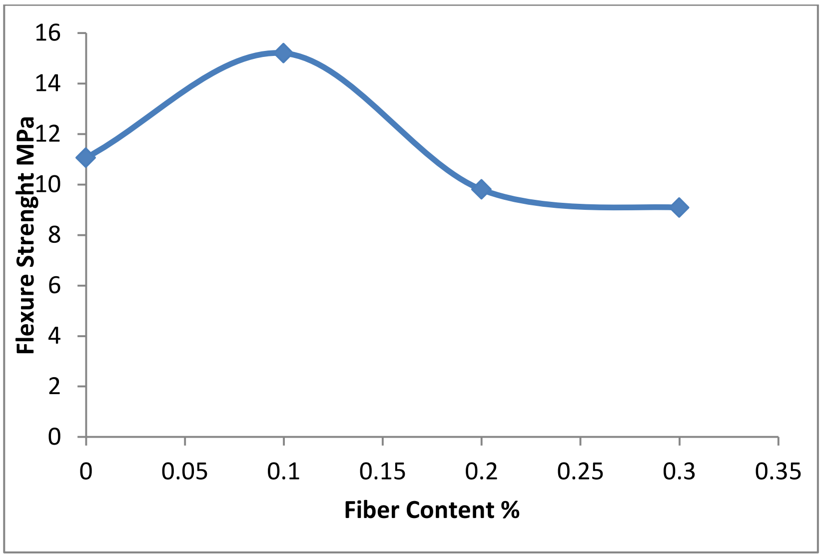

Fig. (9) Variation of flexural strength with PF Content %

The results proved that the addition of 0.1 % PF to the concrete mix could increase the flexural strength from (11.06 MPa) to (15.2 MPa) and record the max. value among the other samples. The increase of strength may be due to uniformly distribution of fibers throughout the concrete body, which can absorb the stress when loading is applied on the body. With uniform distribution of fiber the stress is said to be transferred in a complex way that it fails after higher loading is applied. Increasing of PF content above o.1 % gave low value of flexural strength due to too much of fiber that contributed to weaker bonding between particles.

4.2.3 Splitting Tensile Strength

Table 10 and figure 10 show the results of splitting tensile strength at 28 days.

Table (10): Results of cast stone splitting tensile strength for palm fibers samples

Mix Ratios (%)	Splitting Tensile Strength MPa at Age/time (days) 28
0	5.21
0.1	5.35
0.2	5.66
0.3	5.9

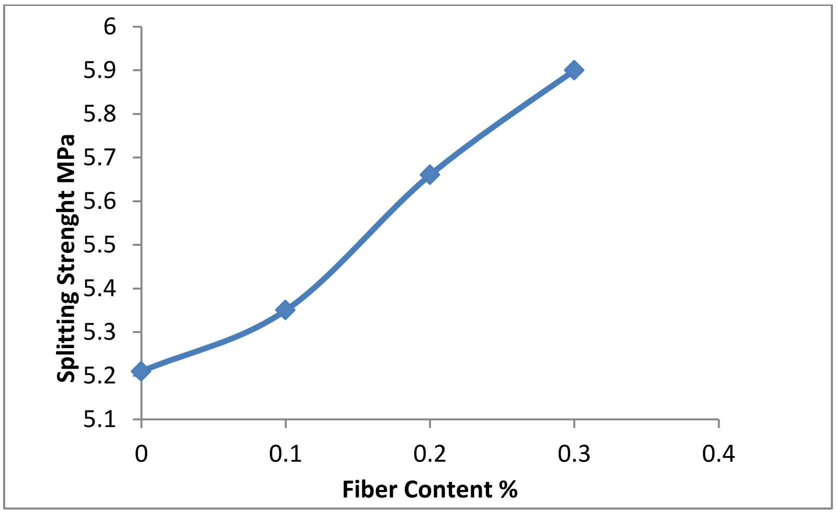

Fig. (10) Variation of splitting tensile strength with PF Content %

It can be concluded that splitting tensile strength increased with increase of PF ratios. The increasing of Splitting Tensile Strength is due to the increase in toughness of concrete provided by the incoperation of PF .Furthermore PF worked as discrete reinforcing fibers that can restrain minor cracks that developed in the concrete from spreading.

4.3 Coating Tests

4.3.1 Agar Well Diffusion Method for Composites

Figure 11 shows results of agar well diffusion method for composites. Antimicrobial activity of composites solution was determined from inhibition zone (mm). In comparison with control epoxy, it can be observed that inhibition zones for (0.5, 1 and 1.5) % ZnO were (8 , 19.5,and 10.5) mm respectively, and the best inhibition zone was (19.5 mm) at 1 % ZnO . High concentrations of ZnO decreased the antibacterial effect due to high concentration which caused recipitation and the resulting material was heterogeneous, while intermediate proportion of ZnO provided a suitable consolidant and antibacterial performance

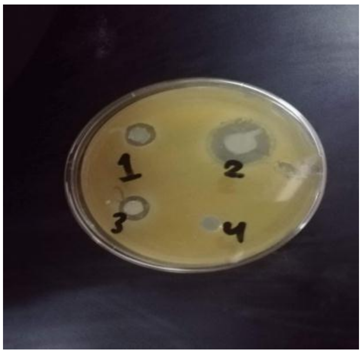

Fig.(11) Epoxy/ZnO solution by agar well diffusion

(1)= 0.5% ZnO, (2)= 1%ZnO, (3)= 1.5% ZnO and, (4) = Pure

4.3.2 Wettability

Figure12 shows the wettability results of nano Zno/ Epoxy composite coatings. The results showed that the addition of antibacterial agent (ZnO) increased the contact angle compared to the pure sample, thereby ,indicates an increased hydrophobicity of the coatings. Consequently, the CS surfaces coated with these coatings will don't affected strongly with waters of humidity and rains ,and provided the required antibacterial surfaces. It can be observed that the contact angle (ϴ) increased with ZnO contact increasing and thus will decrease the wettability .

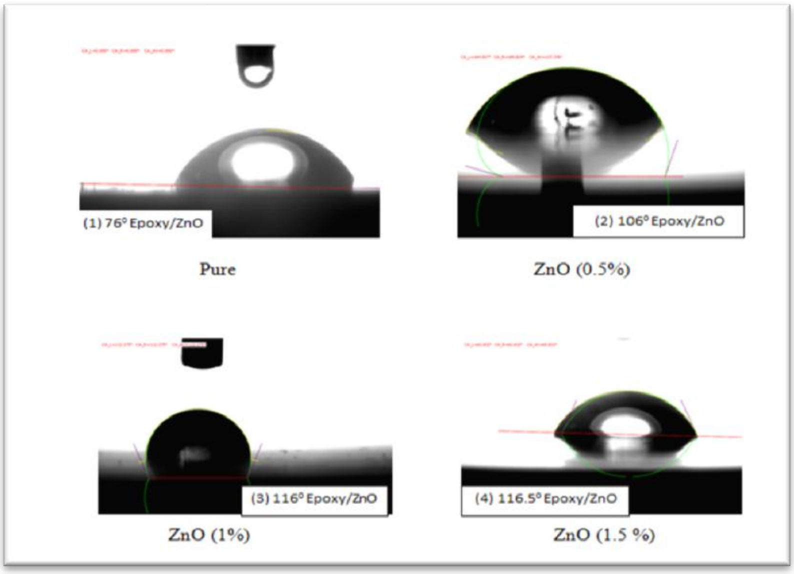

Fig.(12) Wettability angle of ZnO/ Epoxy composite coating at different ZnO ratios

4.3.3 Atomic Force Microscopy

AFM test was used to know coatings surface roughness due to its significant effects on the bacterial growth, and the results as shown in figure 13. It can be observed that the coating with 1.5 % ZnO showed high superficiality roughness due to the agglomeration of ZnO nanoparticles. Also, the coating with 1% ZnO could provide low roughness and homogenous topography. Such low roughness proved its effects in giving the layer inhabitation diameter in the antibacterial test results. Most likely, the high surfaces roughness helps in proving more area for bacterial growth.

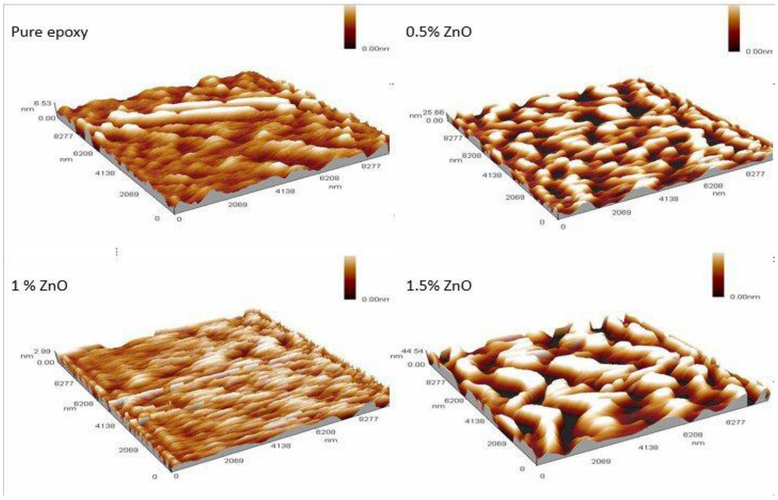

Fig.(13) AFM image of Zno/ Epoxy composite coating at different ZnO ratio

5. Conclusion

The following points can be concluded from the present work:

1. The addition of 0.1 % PF by volume of concrete materials was found to be effectual in enhancing compressive strength and flexural strength.
2. Use of PF above 0.1%, reduced the compressive strength and flexural strength while splitting tensile strength increased.
3. Decreased the slump flow and L- Box and increased the T50 and V-funnel with increasing of PF.
4. Contact angle of coatings increased with ZnO ratio increasing , thereby , resulting in less wettability . Also, the composite coating with 0.1 % ZnO could record the best roughness among the other coating .
5. Zno nanoparticles at concentration 1% give best inhabitation zone (19.5 mm) compared with other concentrations.

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