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Evaluation the chemical and mechanical properties of EVA modified concrete

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Abstract

In this study, EVA is added to improve the mechanical and chemical properties of concrete. The concrete mixtures were modified with 5wt%, 10wt%, 15wt%, and 20wt% of EVA. The chemical constituents of the mixture were measured by XRF. The surface morphology of modified mixtures was also scanned by SEM. The chemical reaction between EVA and cement was verified by FTIR analysis. Setting time and water content were conducted at various temperatures (25oC, 30oC, and 40oC). The physical properties of concrete mixtures such as compressive, flexural and tensile strength were evaluated at the curing age of 3, 7 and 28 days. It was found that the setting time was increasing with an increase in the EVA percentage. The results revealed that the compressive and flexural strength of EVA-modified concrete tended to increase at a rapid rate by incorporating EVA up to 15%, but beyond this percentage the rate of strength development become slow at all the ages.

Key words: Chemical, mechanical, Concrete, EVA.

1. Introduction

1. Introduction

The characteristics of concrete are improved by addition of polymers to produce polymer modified concrete (PMC) [1, 2]. The mortar has been improved by using different polymeric materials to be suitable for the most construction purpose. Many studies were conducted on concrete mixtures to be improved by using polymeric materials to produce polymer modified concrete that gave better workability , higher mechanical properties [3] , modulus of elasticity [3-9], improve the adhesion strength and permeability resistant [4,10-12], improve water resistance [13-15], high resistance to moisture [16], low rate of shrinkage [17] well strength [18-21] of the reinforced concrete structures but exhibit a limited value of tensile strength for concrete [22].The benefits of improving polymer concrete mixtures is based on increasing the hydration rate reaction and to fill the voids between molecular particles and cement in a regular manner that leads to raise the improved efficiency. Many researches were performed to improve the concrete properties such as; Son and Yeon [25] concluded that with increasing polymer content, elasticity of concrete increased. Shaker and others [26] demonstrated that the use of polymer as proportion of cement mass 15 % improves many properties of concrete, such as water poverty due to loss, corrosion resistance , sulfate resistance , and protection of reinforcing steel from corrosion. SBR, EVA and acrylates polymers have been used a lot in improving the physical and chemical properties of concrete [10, 11, 27–30], but sometimes it is less flexible [11, 12, 31]. Pei et al. [32] concluded that polymer modified concrete has weak mechanical properties. But in fact, the past results can't be compared with each other directly [33, 34]. When the temperature elevates, a large amount of the water evaporates from the concrete surface, which leads to a decrease in the workability of concrete and cracks appear on the concrete surface after setting. When the concrete temperature raises from 27 to 45, the initial and final setting times is reduced by half because

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heat accelerates the setting time to the half and the concrete became rigid [35]. Wade et al. [36] investigated that the substantial result of high temperature is the acceleration of the hydration reaction of cement which eventually led to the stiffness of the concrete mix because of the early setting rather than normal setting of concrete mix due to such high temperature. Ezziane et al. [37-38] concluded that high temperatures are not beneficial to concrete, but are harmful to concrete, so it is advisable to use lime stone and slag in the mixture to make the concrete unaffected by heat. In order to understand the setting and strength behavior of PM concrete, this research is carried out to evaluate the chemical and physical characteristics of EVA modified concrete. The chemical constituents were measured by x-ray fluorescence, the chemical reaction between cement and EVA was verified by FTIR. The surface morphology of concrete mixture were studied after EVA modification. The setting time of cement was calculated as well as the effect of EVA on the concrete compressive, tensile and flexural strength were conducted. Materials and Method

2.1. Materials

2.1.1 Cement

Ordinary Portland cement of type-I which produced from Suez, the chemical composition of cement is shown in tables (3).

2.1.2. Solid materials

Natural Sand, Size 20mm and Size 12mm. Sieve analysis of Aggregate are given in table (1). The physical properties of aggregates are illustrated in table (2).

Table (1) Grain size distribution of Aggregate materials.

Sieve Size, inch (mm)	**Pass**		**(%wt)**
	Size 2	**Size 1**	**Sand**
"1 (25.4)	100	100	100
"3/4 (19)	92.9	100	100
"3/8 (9.5)	8.1	68.9	100
NO.4 (4.75)	2.0	11.0	98.2
NO.8 (2.36)	-	2.1	97.3
NO.30 (0.6)	-	-	92
NO.50 (0.3)	-	-	57,9
NO.100 (0.15)	-	-	14,6
NO.200 (0.075)	-	-	0.91

Table (2): Mechanical Characteristics of Aggregate materials.

Item	Size 20(mm)	Size 12(mm)	Natural sand
Abrasion Test			
After 5 minutes, %wt.	5.0	5.8	-
After 15 minutes, %wt.	21.8	24	-
Specific gravity			
Bulk Specific gravity	2.568	2.521	2.573
Bulk Specific gravity(SSD)	2.607	2.567	2.595
Apparent Specific gravity	2.673	2.644	2.632
Absorption (%wt.)	1.8	2.8	-

2.1.3. Ethylene Vinyl Acetate (EVA)

EVA was requested from CMB Company as Vinnapas 5044 N.

2.2 . Methods and testing procedures

2.2.1. Preparation of polymer modified concrete (PMC)

EVA was added with the percent 5%, 10%, 15%, and 20% by cement weight and addition the water is added to cement according to consistency standard test, where water/cement (w/c) ratio is changed with the change in EVA percent. The mixture employed on IKA RW 20 DZM. n mixer and mix (300 rpm) for 3 minutes.

2.2.2. Chemical evaluation of modified concrete (MC).

2.2.2.1. Chemical constituents by (XRF)

2.2.2.2. FTIR analysis

FTIR analysis was applied to investigate the reaction between EVA and cement. The machine used for FTIR analysis is“Nicolet IS-10 FTIR spectrophotometer-Thermo Fisher Scientific” using the range of wavenumber of “400-4000 cm^{-1}”.

2.2.2.3. Surface morphology by (SEM)

The microstructure of the prepared concrete mixtures was studied using SEM. Samples were imaged by JEOL-5400 scanning microscope Japanmodel, and operated at accelerating voltage 30 KV with SE mode imaging. The samples were gold sputtered for 8 min. using ion sputtering device model is JEOL-JFC-1100 E.

2.2.3. Fineness Tests

The fineness of cement is responsible for the rate of hydration ;(i.e. rate of evaluation of heat and the rate of gain of strength). Finer the grains give more surface area and faster strength improvement. The fineness of cement is determined by sieve tests. Where 100 gm of cement were taken on a standard IS sieve NO 170. Continuously sieve the sample manually or mechanically for 15 minutes, weight the residue left on the sieve. The weight shall not exceed 10 % for ordinary cement and 5 % for rapid hardening or low heat cement.

2.2.4. Consistency Tests

The purpose of the test is to determine the amount of water needed to form a cement paste of standard consistency to be used in determining the setting time for cement. The standard amount of water: it is the amount of water needed to form a cement paste that allows 10mm diameter and 40-50 mm length for Vicat needle to penetrate through the cement paste at a point 5mm away from the mold bottom.

To prepare a quantity of cement weighing 400 gm, add to it an amount of water that is enough to make a cement paste within 4 minutes, then put it in a vicat mold, then leave the needle to penetrate the cement paste for a period of 5 seconds, then measure to the bottom of the mold. Prepare several pastes with different water percent and repeat the previous test until reach a distance of 5mm from the needle tip to the bottom of the mold.

2.2.4.1. Initial and final setting time

In initial setting time; a needle of 1mm square size is used. The needle is allowed to penetrate in to the paste (admixture of water and cement as per the consistency test). The time taken to penetrate 33-35 mm depth is recorded as the initial setting time.

- In final setting time; after the paste has attained hardness, the needle does not penetrate the paste more than 0.5 mm. the time at which the needle does not penetrate more than 0.5 mm is taken as the final setting time.

2.2.6. Compressive test

Sample are prepared for testing by casting, mixing, compacting and curing concrete cubes (15cm*15cm*15cm). Samples are tested at age 3days, 7days and 28 days from casting date, the test is carried out by placing the sample on the crushing machine and the load is vertical to the direction of the concrete. The compressive strength is calculated from the equation.

Compressive Strength = Load/ Cub cross section area.

2.2.7. Tensile test

Casting cylindrical of unmodified concrete and modified concrete with different percent 5% EVA, 10%EVA, 15%EVA,20%EVA and 25%EVA,which curing it in water tank at temperature 25 ◦C foe 28 day after that tested on tensile machine test, which cylindrical crushed and calculate the maximum tensile load. Tensile stress calculates from the relation. Tensile stress (lb/in2) = Max tensile load / area of cylinder cross sectional area [39-41].

2.2.8. Flexural test

The flexural properties of the produced composites were tested using a three-point bending system according to ASTM C78 where the beams of standard size of 18´´ × 4´´ × 4´´ were used and then tested in UTM using single point loading. The strengths were calculated in lb/in2 using the formula

Fr=3PL/2bd2 where Fr= modulus of rupture, P= ultimate load (KN), L= length of the beam, b= width of beam and d= depth of beam.

3. Results and discussion

3.1. Verification the chemical interaction between EVA and cement.

EVA hydrolyses in pH alkaline and consumes calcium ions from the solution, forming an organic salt (calcium acetate), reducing the calcium hydroxide content and, its interaction occurred in the first 15 min of hydration. The reduction of Cao is monitored by XRF as illustrated in table (3) Cao content decreased from 49 to 45. Also by comparing the results of FTIR spectra for unmodified and modified mixtures shown in Fig.(1), this reduction in Ca2+ ions, related to acetate groups of EVA undergo alkaline hydrolysis and interact with Ca2+ ions of the pastes to form calcium acetate. it was noticed that the appearance of a band at 1560 cm-1 that is corresponded to calcium acetate group which isn't exist in unmodified sample. a band at 1243 cm-1 that is corresponded to (C-O) bond and a band at 2914 cm-1 that is corresponded to (C-H) bond, which formation of this bond due to the interaction between cement and poly ethylene vinyl acetate.

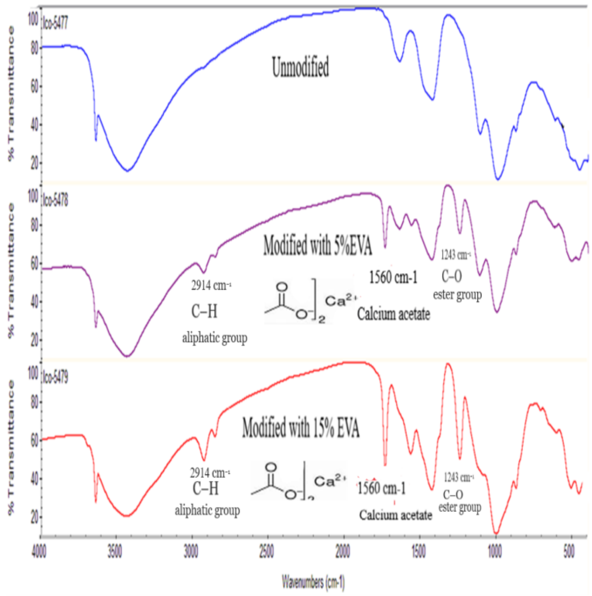


Fig. (1) FTIR of unmodified and modified concrete mixture.

Table (3) The chemical constituents by XRF of unmodified and modified concrete mixture.

Sample name	Blank	5% EVA	10% EVA	15% EVA	20% EVA	25% EVA
SiO2	18.30	17.89	17.0	16.4	15.8	15.60
Al2O3	3.72	3.74	3.75	3.76	3.55	3.55
Fe2O3	5.47	5.50	5.54	5.61	5.57	5.55
CaO	49	48.78	47.57	45	45.0	45.0
MgO	2.23	2.2	2.0	1.97	1.81	1.79
Na2O	0.52	0.53	0.54	0.54	0.49	0.48
K2O	0.33	0.34	0.34	0.34	0.29	0.28
SO3	2.79	2.71	2.61	0.94	2.48	2.39
P2O5	0.1	0.1	0.1	0.09	0.09	0.09
SrO	0.1	0.1	0.11	0.11	0.09	0.08
MnO	0.12	0.12	0.12	0.09	0.13	0.13
Cr2O3	0.05	0.05	0.05	0.04	0.05	0.06
ZnO	0.02	0.025	0.27	0.03	0.06	0.08
LOI	16.30	17.77	19.9	20.30	23.10	23.10
Total	99.9	99.9	99.9	99.89	99.99	99.99

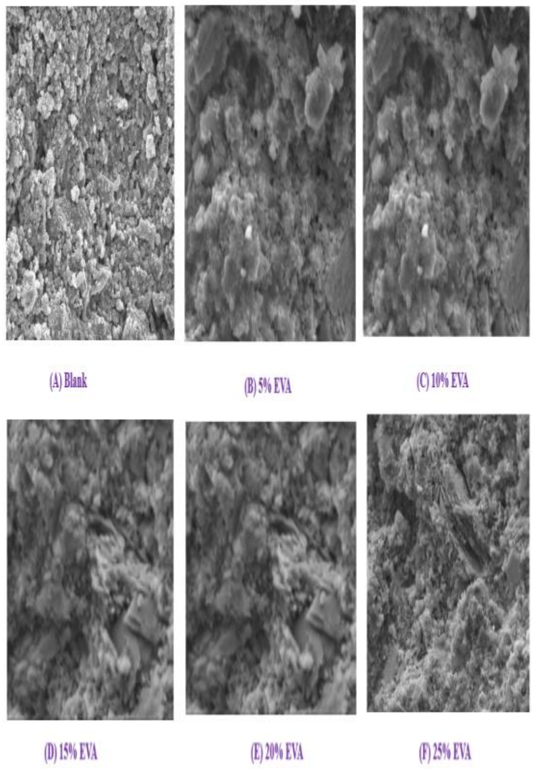


Fig.2. SEM of (A) Blank, (B) 5% EVA, and (C) 10% EVA (D) 15% EVA (E) 20% EVA (F) 20% EVA to concrete mixture.

As illustrated in Fig.2. the concrete mixtures modified with EVA percentages are better than unmodified concrete as a result of the diffusion of EVA between the concrete particles, so EVA fill the graps and the voids between the concrete particles, which may lead to an increase in the permeability resistance of water for modified concrete mixtures and decreasing the water cement content (w/c) and consequently reducing the distance between the concrete particles, which increase the compressive strength, tensile and Flexural for concrete mixtures. Also, EVA particles are intertwined with the concrete particles forming bonds which may increase the cohesion forces between the particles of EVA and concrete. The investigation results in Fig.2 reveal that the 20% EVA is the best percentage of polymer added to the concrete mixtures.

3.2. Setting time

A setting time is improved with adding polymer at different percentages 5%, 10%, 15%, and 20%. at temperatures 22◦C, 35 ◦C and 50 ◦C and with increase temperatures, the initial stetting times and final setting times is reduced by half because the temperature increase the speed of the cements hydration reaction with water, so the initial stetting times and final setting times for concrete decreases as shown in the figure [3], [4].

In figure (5) show that with increasing the polymer addition to cement, the water content reduced because the polymer works on the extension of the spaces in concrete and hold the water inside the concrete so, there no water loss during the hydration reaction between cement and water which lead to the concrete need less water content. With the rise in temperatures from 22 to 50 ◦C the water content (W/C) increased due to hydration reaction is isothermal reaction and water quantity is lost and the concrete need to more water content to complete the setting.

Table [4] Effect of EVA content on the consistency of Portland cement at 22 ◦C.

EVA content in cement.	The Standard of water Content	Setting time(minutes)	
		Initial setting times	Final setting times
0%EVA	32	174	250
5%EVA	27	150	225
10%EVA	25	136	200
15%EVA	23	130	180
20%EVA	22	110	160
25%EVA	21	100	150

Table [5] Effect of EVA content on the consistency of Portland cement at 35 ◦C.

EVA content in cement.	The Standard of water Content	setting time(minutes)	
		Initial setting times	Final setting times
0%EVA	37	135	200
5%EVA	33	130	175
10%EVA	30	120	160
15%EVA	27	108	141
20%EVA	25	94	130
25%EVA	26	85	120

Table [6] Effect of EVA content on the consistency of Portland cement at 50 ◦C.

EVA content in cement.	The Standard of water Content	setting time(minutes)	
		Initial setting times	Final setting times
0%EVA	40	120	160
5%EVA	36	100	140
10%EVA	33	93	130
15%EVA	32	85	100
20%EVA	30	74	80
25%EVA	31	66	75

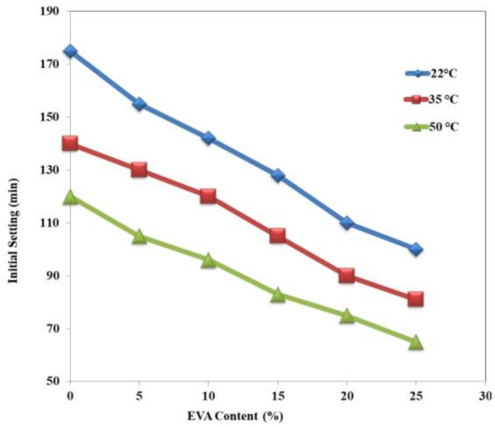


Fig. (3) Effect of EVA content on the initial setting of portland cement at different temperatures.

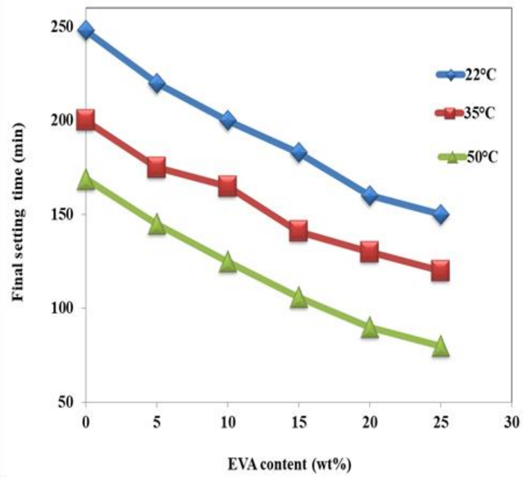


Fig. (4) Effect of EVA content on the final setting of portland cement at different temperatures.

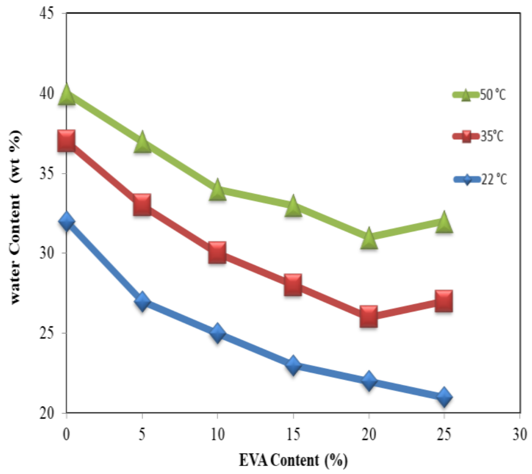


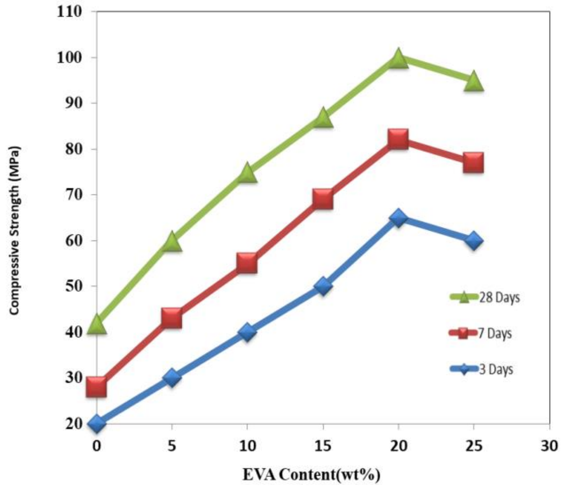
Fig. (5) Effect of EVA content on the consistency of portland cement at different temperatures.

5.4 Mechanical properties

The mechanical tests were carried out on EVA modified concrete and unmodified concrete at ages 3 day, 7day and 28 days. With the increase in the percentage of polymer, the values for all ages increase in compressive strength, tensile and Flexural up to the maximum 20% EVA. This is because the polymer works to form hydrogen bonds with the concrete particles, which increases cohesion force between the particles and this increased the compressive strength, tensile and Flexural of the concrete to three times its value without a polymer as in Figures [6] [7]. EVA polymer fill the voids inside the concrete and thus increases the resistance to water permeability in to the concrete and also works to prevent the exit of water from the concrete and thus provides the water necessary to complete the hydration interaction between water and cement, so that all the cement particles interact, which increases the compressive strength, Flexural and tensile strength. EVA polymer ables to redistribute and organize the cement particles within the mixture, which leads to an increase in the reaction rate of the hydration, and thus works to ensure the interaction of all cement particles which increases reaction rate and leads to a reduction in the stamping time. It also does not require a large amount of water, and thus the distances between the particles are short, which it makes concrete more durable and solid. EVA that forms random and complex hydrogen bonds, which makes the reinforced concrete difficult to penetrate and water permeates increased curvature of the reinforced concrete. EVA is added to concrete with different percent 5%EVA, 10%EVA, 15%EVA, and 20%EVA and 25%EVA, which the best percent of polymer which yield the best mechanical properties is 20%EVA.

Table [7] Effect of EVA content on the compressive strength of Portland cement at different stages of age.

EVA content in cement.	**Compressive Strength (MPa)**		
	3 Days	**7 Days**	**28 Days**
0%EVA	31	40	50
5%EVA	34	45	56
10%EVA	45	50	60
15%EVA	51	66	78
20%EVA	60	78	84
25%EVA	58	75	81



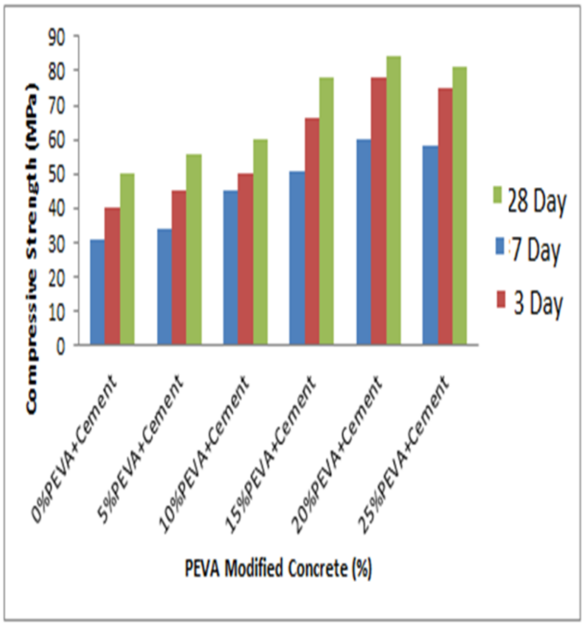


Fig. (6) Effect of EVA content on the compressive strength of Portland cement at different stages of age.

Table [8] Effect of EVA content on the flexural and tensile strengths of Portland cement.

EVA content in cement.	The flexural @ 28 Days	The tensile @ 28 Days
0%EVA	1.1	1.25
5%EVA	1.5	2
10%EVA	1.8	2.8
15%EVA	2.5	3.6
20%EVA	3.3	4.5
25%EVA	3.0	4.5

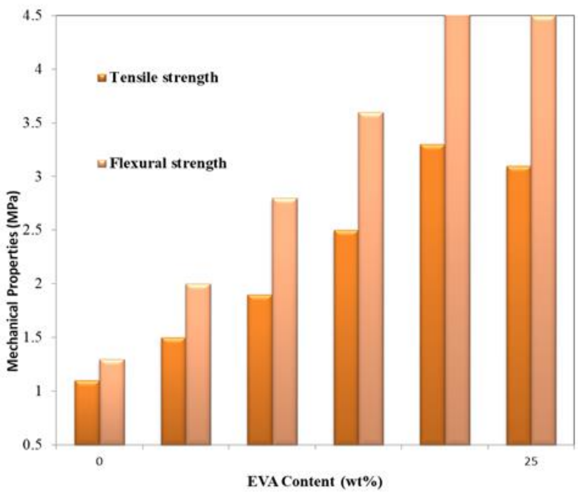


Fig. (7) Effect of EVA content on the flexural and tensile strengths of Portland cement.

4. Conclusion

1. In this study, adding Ethylene vinyl Acetate (EVA) to concrete improves the mechanical properties for concrete such as Compressive strength, Tensile strength and Flexural.
2. Addition EVA to concrete improves the workability of the concrete because of hydrogen bonding is formed between the particles, which increased the cohesion force between the components of the concrete.
3. Using Ethylene vinyl Acetate (EVA) in concrete at temperatures 22◦C, 35◦C and 50◦C, increase the rate of hydration reaction for cement, and then the setting time reduces to the half.
4. Using EVA in concrete fill the voids between the particles so hold the water inside concrete for used it in hydration reaction for cement which lead to improve the physical properties of the concrete.
5. Using EVA in concrete lead to redistribute the cement particles in the concrete, so the reaction rate of the cement particles is faster and better, which gives better results.
6. From overall study, it can be concluded that 20% of EVA is the best polymer content that can be added to the concrete.

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