



## **SELF-CURING CEMENT MORTAR COMPOSITE BY USING POLY VINYL ALCOHOL**

**Waleed A. Abbas<sup>1</sup>, Ikbal N. Gorgis<sup>2</sup> and Mahdi J. Hussien<sup>3</sup>**

<sup>1</sup> Asst. Prof. Dr. in Civil Eng. Dept., University of Technology, Baghdad, Iraq. Email: [40017@uotechnology.edu.iq](mailto:40017@uotechnology.edu.iq)

<sup>2</sup> Asst. Prof. Dr. in Civil Eng. Dept., University of Technology, Baghdad, Iraq. Email: [40020@uotechnology.edu.iq](mailto:40020@uotechnology.edu.iq)

<sup>3</sup> Ph. D. Student, Civil Eng. Dept., University of Technology, Baghdad, Iraq. Email: [mahdi\\_201212@yahoo.com](mailto:mahdi_201212@yahoo.com)

<http://dx.doi.org/10.30572/2018/kje/100402>

### **ABSTRACT**

Polyvinyl alcohol (PVA) defines as a self-curing agent when it forms films prevent evaporation water required to hydration. In this study was found the effect of self-curing factor on some mechanical properties is studied by adding of PVA solution to cement ratio (P/C) with varying conditions of curing. The PVA dissolved in water from 1% by weight of cement. It was seen that PVA could service by self- curing through providing increase strength compare with traditional curing. The results showed increased percentages of flexural, tensile and compressive strength of cement mortars with PVA as self-curing agent under dry condition for 28 days were 62%, 101% and 1.5% respectively to compare with self-curing for cement mortars composite modified with PVA as curing agent under wet curing conditions as soon as cement mortars composite modified without PVA were 110%, 5% and 14.5% respectively in dry condition also 48 %, 55% and 41% in wet curing conditions respectively. The use of Fourier Transforms Infrared (FTIR) spectra and techniques like scanning electron microscope (SEM) is very significant to show the impacts of the existence of PVA as water-soluble polymer in the fine structure of modified cement mortar by polymers.

**KEYWORDS:** Cement mortar, Curing system, PVA, Self-curing agent, Water Retention.

## **1. INTRODUCTION**

Building an industry needs a lot of water consumption in the processing period. The alternative curing system for concrete and cement mortar will be applied in days not so far that every construction industry must move to an alternate system of curing not only that water provides in place of sustainable development goals on the other hand to elevate internal and external manufacture actions until with isolated zones somewhere there is lack of recourses of water (Akanksha et al., 2014). Curing is a procedure for governing amount or scope of wetness slack as of concrete in hydration of cement. whichever next it has been located in area or else through production of products of concrete, in that way as long as period for the cement hydration is happen (Pamnani et al., 2013). Then the cement hydration takes period days and equal seven days somewhat but hours times curing necessity is assumed used for a sensible time period, so the requirement for suitable curing of concrete cannot be exaggerated for curing has a best effect on the characteristic of concrete hardened; good curing can be improved strength, dimensions stability, durability, resistance to freezing and thawing influence water absorption, and abrasive resistance (Kholia et al., 2013).

### **1.1. Curing Methods**

Curing can be done by a numeral from methods, and the furthestmost suitable incomes of curing might be read out through the location and the building technique (Kholia et al., 2013). Concrete can conserve wet by subsequent curing ways: (1) Air curing: Concrete specimens gone in exposed air to cure. (2) Normal Water curing: Concrete specimens submerged in the water pool for curing. (3) Self-curing: internal curing admixture or any other water soluble polymeric glycol is blended together with water at the interval of manufacture the concrete and left in exposed air to cure. (4) Non-ordinary water curing: The concrete samples are covered with thin canvas similar to site circumstance and spraying water three times in a day reach to 7 days. (5) Coating curing: Curing combinations are solutions which are usually covered directly onto concrete faces and which at that time, dry to procedure a comparatively waterproof film that delays the reduction of wetness from the concrete (Akanksha et al., 2014). Good curing of cement pastes or concrete microstructure is significant to improve mechanical properties and requirements of durability. In conservative curing this is reached using exterior curing practical next finishing all placing work. Internal curing (IC) is a technique to supply water for all the cement to complete hydrated and achieve what the mixing water cannot do. Drawing water is retained to the comparative moisture, so care self-desiccation from happening. Removes mostly autogenously shrinkage,

cement strengths keep mortar or concrete next to the initial time of life 12 to 72 hours. When the level inside is exceeding the level outside, lead to encourage strain occurs and causes cracks. The main approaches available are two can be used as internal curing of concrete, the main technique procedures represented by porous lightweight aggregate (LWA) soaked so as to provide an inner water source, it can be substituted water loss by shrinkage due hydration of cement. Next, polyethylene glycol (PEG) technique is used. This procedure decreases the vaporization from the external concrete surface and assistances for retaining water (Bhosale, 2016).

## **1.2. Polyvinyl Alcohol(Pva) Used as Self-Curing**

Polyvinyl Alcohol is the Compound of Poly-ethylene glycol. Hermann and Haehnel, (1924) were prepared to PVA by way of potassium hydroxide with hydrolyzing polyvinyl acetate in ethanol (Thong et al., 2016). Commercially from polyvinyl acetate PVA was manufactured, typically using incessant procedure (Bhosale, 2016). Classification of PVA is two classes specifically: fully hydrolyzed and partly hydrolyzed. Nagesh studied the use of PVA solution as a self-cutting agent and found that agent has greater water retention lead to improve hydration as equivalent to normal concrete, as soon as the percentage 0.48% of PVA as a self-curing agent make available greater flexural, tensile strength also compressive camper to strength of normal mix (Vivek et al., 2015). When the proportion of PVA is increased on the hand concrete weight is decreased. This curing technique of self- cured concrete has efficiency about 92.5% as equivalent to normal standard water curing technique (Akanksha et al., 2014). Knapen and Van Germert presented a study to the influence of curing situations in the trend of splitting tensile strength and the flexural strength of modified mortar by PVA. The researcher showed that the strength of modified mortar by PVA had importantly influenced through the curing circumstances believed (Knapen et al., 2005). Modified mortar by PVA agent prism cured by wet curing was showed to record a decrease of about 21% in flexural strength equal to modified mortar by PVA prism cured in dry condition (Knapen et al., 2005). A just as tendency was too pronounced for modified mortar by PVA under the splitting tensile strength, in which modified mortar by PVA cured with dry state better than that mortar cured in wet situation. Furthermore, all the modified mortar by PVA samples under dry curing state have more value in splitting tensile strength and flexural strength than that of unmodified mortar samples (Knapen et al., 2005). The enhancement of flexural strength and tensile strength of modified mortar by PVA with dry curing circumstance due to the formation film of PVA (Knapen et al., 2005). Finley, self- curing is appropriate for all

overall concreting applications and provides specific advantage for large area concrete planes, such as roads, bridgeworks and airport runways. It is also appropriate for tunnel lining work and for part works where, it is challenging to curing (Gebler, 2001). In current study, influence of PVA on tensile strength, modulus of rupture and compressive strength, and compared with unmodified mortar at varying condition of curing.

## 2. MATERIALS AND TESTS

In this experimental work, the mix design is carried out using various percentage of PVA solution.

### 2.1. Materials Used

#### 2.1.1. Cement

Portland cement type I meeting the requirements to Iraqi Specification (IQ.S. 5:1984) having specific gravity 3.15 was used as shown in (Table 1).

**Table 1. Chemical properties of the cement.**

Composition	Cement Oxide (%)	Compound composition according to Bouge's equations	Compound (%)
CaO	61.53	C <sub>3</sub> S	51.03
SiO <sub>2</sub>	20.16		
Al <sub>2</sub> O <sub>3</sub>	4.95	C <sub>2</sub> S	19.30
Fe <sub>2</sub> O <sub>3</sub>	3.86		
MgO	1.62	C <sub>3</sub> A	6.59
SO <sub>3</sub>	2.62		
K <sub>2</sub> O	0.58	C <sub>4</sub> AF	11.75
L.O.I.	1.63		

#### 2.1.2. Fine aggregate

The type of fine aggregate was natural sand meeting the requirements to Iraqi standard passing from 1.18 mm, having Specific gravity 2.70, Fineness Modulus 1.64 is used for this study. Particle size distribution is given in (Table 2). Which conform with the Iraqi Specification (IQ.S. No 45: 1980).

#### 2.1.3. Polyvinyl Alcohol (PVA)

The polymer used in this test was polyvinyl alcohol (PVA), as 87-89% hydrolyzed polyvinyl acetate in granular form as shown in (Fig. 1 and 2) to prepare PVA solution, about

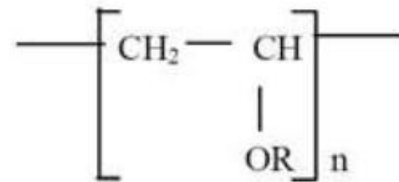
1% of weight cement.

**Table 2. Sieve analysis of fine aggregate.**

Sieve Size, mm	Passing%	(IQS 45/1980), Zone 4
4.75	100	100-95
2.34	100	100-95
1.18	100	100-90
0.6	98.4	100-80
0.3	30.2	50-15
0.15	7	15-0



**Fig. 1. PVA powder.**



where R = H or COCH<sub>3</sub>

**Fig. 2. Chemical formula for PVA (Assessment, 2004).**

#### 2.1.4. Super-plasticizer

Modified poly carboxylates was useful as super plasticizer (SP) to control the excellent flowability properties of fresh mortar which conform with specification of ASTM C494 (ASTM C494M/2014).

#### 2.2. Mix design

Table 3 demonstrate the mixing proportions of all mortar mixes that were used in this study. Firstly, cement and sand are mixed in dry state with small amount of water for prewetting. Then SP, PVA solution and all water were added to mixture as soon as it is mixing for meeting the requirements to ASTM C305 (ASTM C305/2014) by using a spiral hand mixer (Kim et al., 1999).

#### 2.3. Specimens and Testing Details

For the mechanical strength tests mortar prism for flexural (40 \* 40 \* 160 mm) (ASTM

C348, 1998), (50\*50\*50) cubes for compressive (Cabinets et al., 2012) and direct tensile dog bone brachiate test (British Standard, 1985) specimens were prepared, shown in (Fig. 3).

**Table. 3. Ingredients of plain mortar and PVA modified mortar.**

Mix No.	Cement, kg/m <sup>3</sup>	Sand, kg/m <sup>3</sup>	Water, l/m <sup>3</sup>	SP, l/m <sup>3</sup>	P/C, l/m <sup>3</sup>
Mix <sub>1cc</sub> *	1000	500	450	0	0
Mix <sub>1sc</sub> **	1000	500	450	0	0
Mix <sub>2cc</sub>	1000	500	300	5	0
Mix <sub>2sc</sub>	1000	500	300	5	0
Mix <sub>3cc</sub>	1000	500	300	5	16
Mix <sub>3sc</sub>	1000	500	300	5	16

\*CC=conventional curing, \*\*SC=self -curing



**Fig. 3. Specimens test.**

#### 2.4. Curing condition

All the samples were demolded after 24 hours after their casting. The specimens of cement mortar are enveloped for 1days before molds are removed. Procedure of curing applied after molds remove. First part of specimens was immersed in water in moist room for 2 days (20 °C, 100% R. H.), then dry curing for day of testing, while the second part of mortar specimens cured were immerse in water a moist room for 28 days.

### 3. TEST RESULTS

The compressive, tensile and flexural strengths were determined at the age of 28 days of cement mortar as shown in Table 4. Compressive, flexural strength and tensile strengths of control mix was found to be 38.8 MPa, 5.6MPa and 5.2 respectively. Assignment effected by replacing cement by Polyvinyl Alcohol in the proportion of 1% of cement weight and all

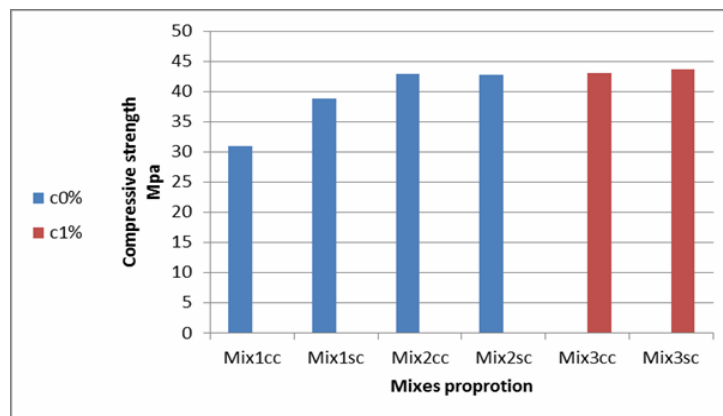
specimens tested at 28 days. The compressive, flexural and tensile strength of results was found 43.65, 11.78 and 5.43 respectively. The average compressive, and tensile flexural strength was found out shown in Figs. 4, 6 and 7 respectively demonstrations graphical representation of strengths.

### 3.1. Compressive strength

Fig.4 represent the results of compressive strength for cement mortar contain PVA solution and without it. Results demonstrated a marked variation in strength at age 28 days for self-curing (SC) mortar specimens, compared to conventional curing (CC) cement mortar specimens at the same ingredients. When the cement mortar modified by PVA are submerged in water.

**Table. 4. Average of test result.**

Mix No.	Compressive Strength, MPa	Tensile Strength, MPa	Flexural Strength, MPa
Mix1cc	30.95	3.5	7.95
Mix1sc	38.8	5.2	5.6
Mix2cc	42.9	4.6	7.153
Mix2sc	42.7	1.41	5.32
Mix3cc	43	2.7	7.3
Mix3sc	43.65	5.43	11.78



**Fig. 4. Compressive strength for mixes proportion with 1% of PVA and without PVA by dry and wet curing.**

Certain compounds of cement hydration and the PVA film-coated are leached out, leading to the increase porosity of the cements mortar and decrease strength in CC concrete compared to SC concrete. As shown in Fig. 5.

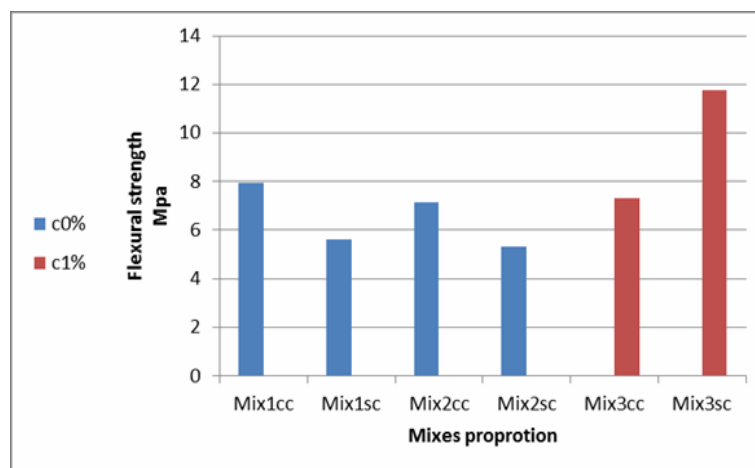
### 3.2. Flexural Strength



Usually, polymer film development increases the strength of flexural, but the strength of compressive is affected by the amount air entrainment and cement hydration. When PVA film leached out, surface become roughness, and high porosity so decrease of flexural strength samples of conventional curing (CC) concrete for comparing to self-curing (SC) mortar samples. To research the effect of the curing environments on the flexural strength, prism exposed to the standard curing, the flexural strength of modified mortars with PVA was increased by about half in wet curing and twice in dry curing respectively as shown in Fig. 6. The increase of flexural strength to modified mortar by dry curing is marked result from it forms PVA film and confirms by research the impact of water on the splitting tensile strength.



**Fig. 5. Photograph of leached in Specimens test.**



**Fig. 6. Flexural strength for mixes proportion with 1% of PVA by the weight of cement and without PVA by dry and wet curing.**

### 3.3. Direct Tensile Strength

Modified mortars with PVA have tensile strength dramatically declined when it is immersed into water as shown in Fig. 7. FTIR spectrum indicate to shift bands or disappear and appearance of novel band when the samples are immersed in to water compare to dry state samples as shown in Figs. 8 and 9. The modified cement mortar with PVA has improvement



in structural and adjustments so that is depended on process of hydration, FTIR of spectra analysis have proved through form new band due to PVA affects under dry curing condition, and form film prevents loss moisture from cement mortar (Aguilar et al., 2013). Through that used XRD systems to determine active reactions energy and observer chemical change of PVA in modified cement mortar demonstrated that after PVA can be added mixture of sample, the polymer delays the hydration because the gel formed and prevents loss water, as shown in Figs. 10 and 11.

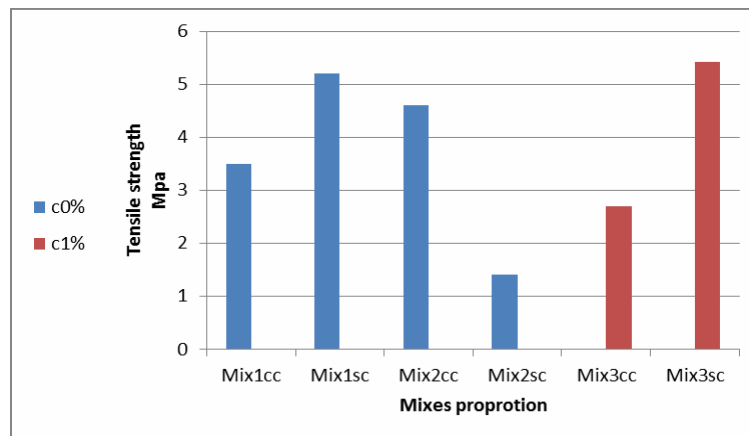


Fig. 7. Direct tensile strength for mixes proportion with 1% of PVA of cement weight and without PVA by dry and wet curing.

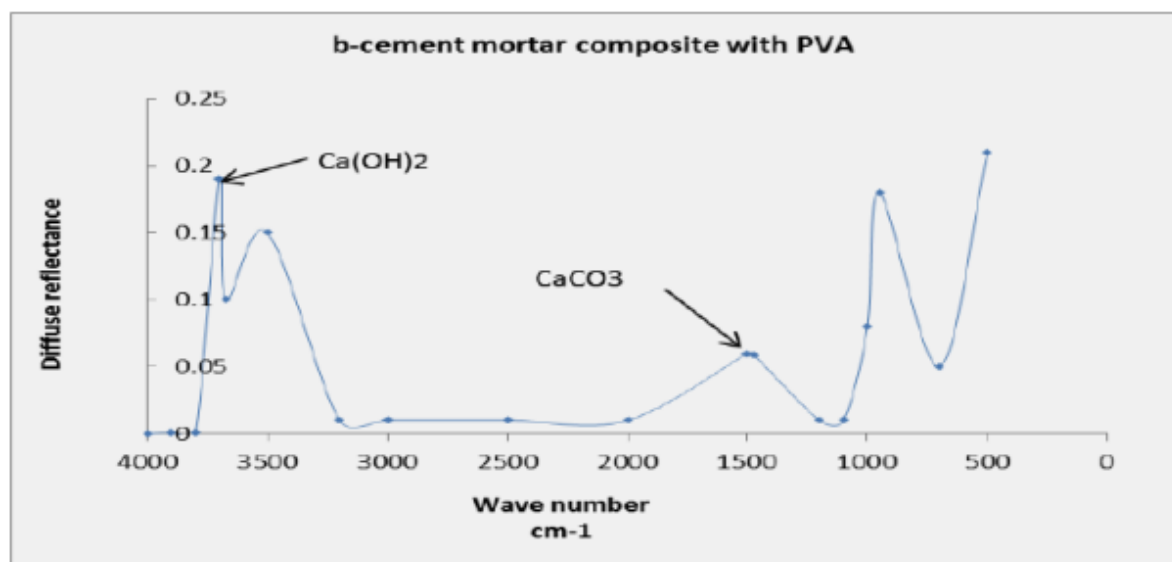


Fig. 8. FTIR spectra for pastes modified with 1% PVAA, after 28 of hydration (w/c=0.3).

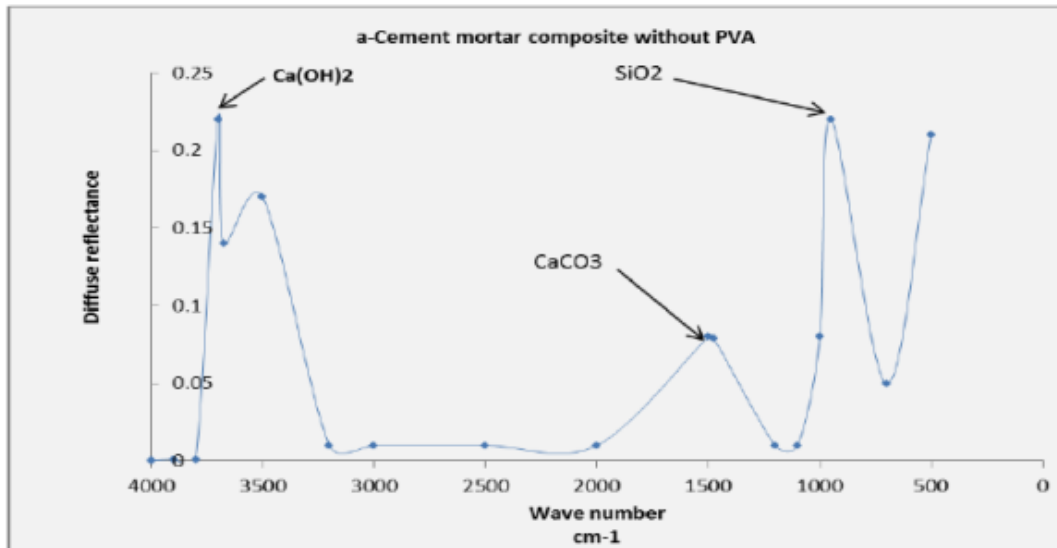


Fig. 9. FTIR spectra for unmodified pastes, after 28 of hydration ( $w/c=0.45$ ).

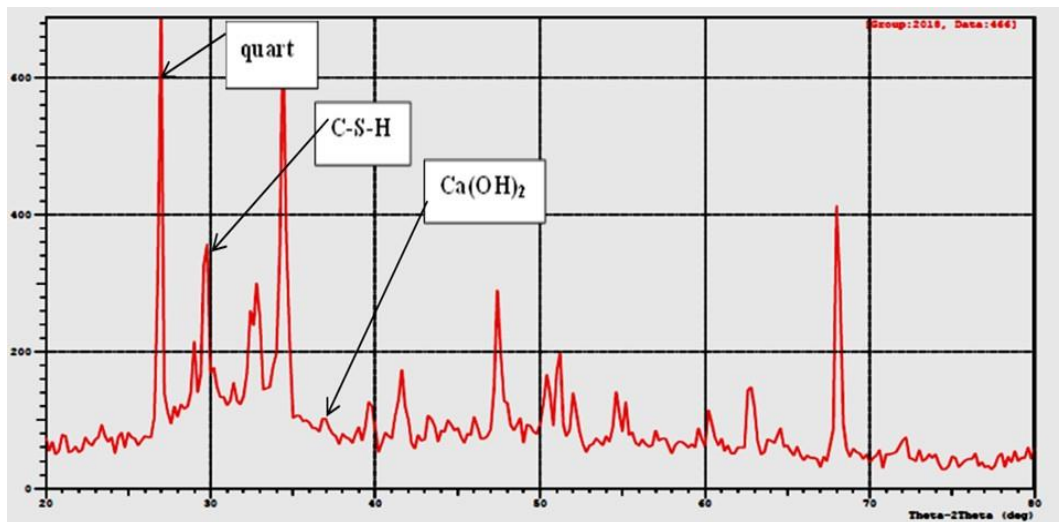


Fig. 10. XRD of reference cement mortar.

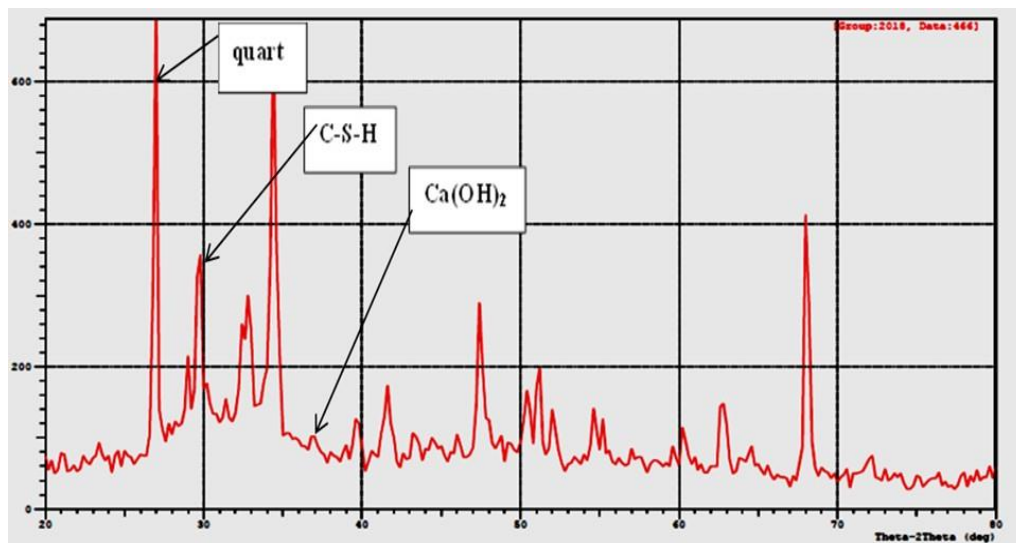
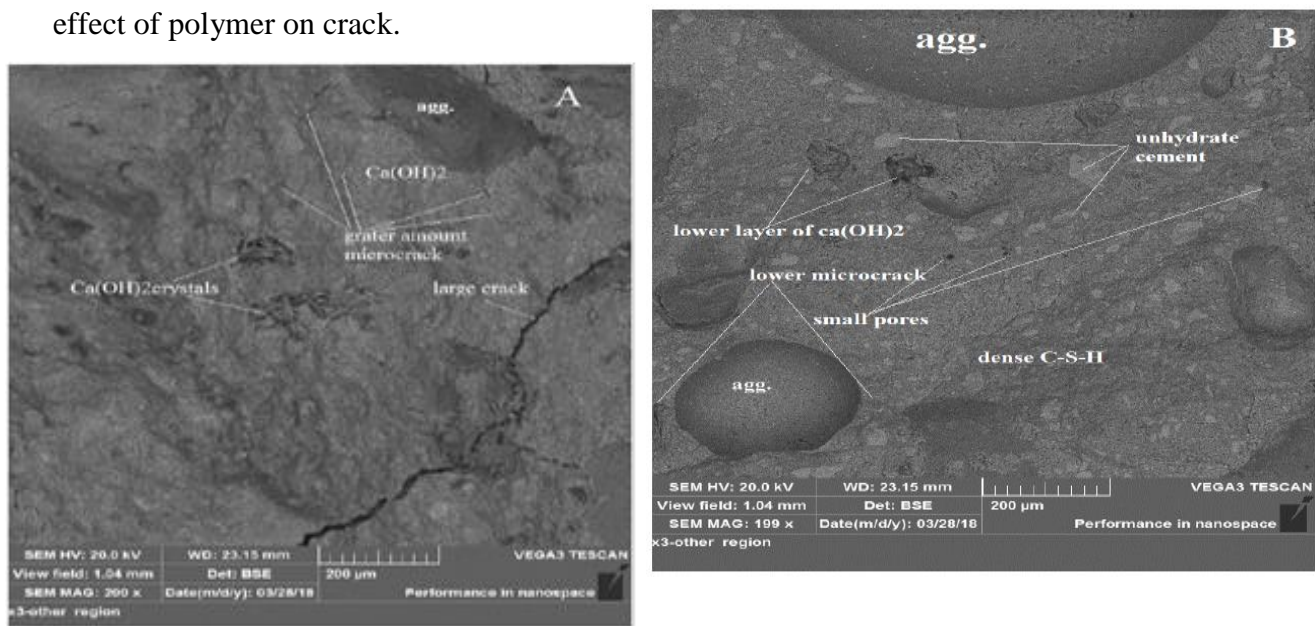


Fig. 11. XRD of cement mortar with 1 % PVA.

SEM is investigated showed uniform distribution of products cement hydration no small cracks due dry shrinkage. When PVA solution can be added as very small percentage, the film of polymer is formed. Typical micrographs are shown in Fig. 12a. The cement grains are understood as the shining of spots in the SEM; Fine sand particles are the bigger bodies. As well as mortar without PVA in SEM appears as a grade of blackness is appreciated trendy the areas neighboring the particles of sand is 0.6 mm of the particles. Fig. 12b, because the SEM shine is related to material density, the dark proposes greater void in these areas. In SEM of cement mortar free of PVA, grains of cement are observable incline to disperse non-uniformly in the matrix. Moreover, grains of cement inclined to uniform dispersed through modified mortar with PVA and bring to be nearby to grains of sand in place of repeatedly as part from the particles. Macroscopically-modified mortar observed sunnier in hue and had extra voids of air and free of cracks due to restrain shrinkage because of the bridging effect of polymer on crack.



**Fig. 12. SEM image demonstrates of cement mortar composite phases and crack in (a) cement mortar without PVA (b) cement mortar with 1% PVA.**

#### 4. CONCLUSION

- Films of PVA formed in mortars due to dry curing play role to the strength inspected by mechanical properties tests, SEM and FTIR. The results of this study shown increased percentages of mechanical properties that flexural, tensile and compressive strength of cement mortars composite modified with PVA as self-curing agent under dry condition for 28 days were 48% ,55%and 41% respectively compared with unmodified cement mortars composite in wet curing conditions.

- Self-curing period is a very essential factor to develop and form a film of polymer, a greatly increase in flexural, tensile and compressive strength PVA modified cement mortar, compared with cement mortars with conventional cured. Flexural, tensile and compressive strength when PVA used as self-curing agent under dry condition for 28 days were 62%, 101% and 1.5% respectively compared with self-curing for cement mortars composite modified with PVA as curing agent under wet curing conditions
- Good suggestion was established of polymer film or connection development in the PVA modified mortars. Results shown that a reduction of w/c to 30% without addition PVA solution (P/C=0) lead to decrease mechanical properties flexural, tensile and compressive strength about 125%, 285% and 2.5% respectively in case of dry curing condition, and 65%, 18% and 1.8% respectively in case of wet curing.
- PVA films are found on top of the cement hydrates have a lower tensile strength are highly sensitive to moisture.

## 5. REFERENCES

- Aguiar J. B., Ozkul M. H., and Cunha S., "Report from 13th ICPIC and 7th ASPIC: New trends on concrete-polymer composites," *Adv. Mater. Res.*, vol. 687, pp. 45–56, 2013.
- Aggregates C., "Standard Specification for Chemical Admixtures for Concrete 1," vol. 04, pp. 1–9.
- Akanksha M., Patil A., and Vyawahare P. M. R., "Comparative study on Durability of Self cured SCC and Normally cured SCC," vol. 3, no. 8, pp. 1201–1208, 2014.
- Assessment T., "Polyvinyl Alcohol ( Pva )," *Int. J. Toxicol.*, vol. 1, no. 3, pp. 3–5, 2004.
- ASTM, "ASTM C305/2014 - Standard Practice for," *Astm*, pp. 1–3, 2015.
- ASTM, "ASTM C494M/2014 - Standard Specification for Chemical Admixtures for Concrete," *Annu. B. ASTM Stand.*, vol. 04.02, 2014.
- Bhosale S., "EXPERIMENTAL CHARACTERIZATION OF STRENGTH OF SELF CURING CONCRETE," no. 4, pp. 151–160, 2016.
- British Standard, "Testing of resin compositions for use in construction —," 1985.
- Gebler S. H., "Guide to Curing Concrete Reported by ACI Committee 308," pp. 1–31, 2001.
- Iraqi specification IQ.S. No 5, "Portland cement", Central Organization for Standardization and Quality Control, 1984.
- Iraqi specification IQ.S. No 45, "Natural aggregate used in concrete", Central Organization for Standardization and Quality Control, 1980.

Kholia, N. R., Vyas, B. A., and Tank T. G., “Effect on Concrete by Different Curing Method and Efficiency of Curing Compounds – a Review,” *Int. J. of Advanced Eng. Technology*, Vol. 4/ Issue 2/April-June, pp.57-60, 2013.

Knapen E., Beeldens A., and Van Gemert D., “Water-soluble polymeric modifiers for cement mortar and concrete,” *Proc. Con. Mat.*, vol. 32, no. 0, 2005.

Medium Strength Self Compacted Concrete by Different Curing Techniques,” vol. 4, no. May, pp. 1451–1457, 2013.

Pamnani P. N. J., Verma A. K., and Bhatt D. R., “Comparison of Compressive Strength Of Thong C. C., Teo D. C. L., and Ng C. K., “Application of polyvinyl alcohol (PVA) in cement-based composite materials: A review of its engineering properties and microstructure behavior,” *Constr. Build. Mater*, vol. 107, pp. 172–180, 2016.

Vivek K., Bhavana B., P. K. W. P, and P. K. M. T, “Experimental Investigation on Properties of Self-Compacting and Self-Curing Concrete with Silica Fume and Light Weight Aggregates,” vol. 4, no. 06, pp. 203–211, 2015.

Kim J., Robertson R. E., and Naaman A. E., “Structure and properties of poly (vinyl alcohol) - modified mortar and concrete,” vol. 29, pp. 407–415, 1999.

ASTM, “ASTM C348. Standard Test Method for Flexural Strength of Hydraulic-Cement Mortars1,” *Annu. B. ASTM Stand.*, vol. 04, pp. 2–7, 1998.

Cabinets M., Rooms M., Statements B., and Mass D., “Standard Test Method for Compressive Strength of Hydraulic Cement Mortars (Using 2-in. or [50-mm] Cube Specimens) 1,” *Chem. Anal.*, vol. 04, no. C, pp. 1–10, 2012.