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Using Polyethylene Glycol to Produce Self Cured Cement Mortar

Abstract-*The capacity of self-curing admixture is to reduce the evaporation of water from mortar, and subsequently they increase the ability of water retention from mortar contrasted with those traditionally cured mortar. Polymeric phase is disperse in cement causing diminish in water absorption and Likewise its connection with hydrating cement create further bond formation which lead to the increment in strength. In this study two group of mortar samples were prepared, first group consist reference and fly ash mortar, second group prepare with admixtures of polymer were PEG 400 used as self-curing agent in this study. Flow test and setting time performed on fresh mortar to reach to the optimum standard specifications. Two mechanical test were carried out include compressive, tensile strength tests, the effect of PEG 400 on bulk density of polymer-modified hardened mortar also studied. The optimum results observed at the age of curing 28 days for PEG wt% 1and 3 were 39.4 and 37.7 MPa for compressive strength tests respectively, and the tensile strength at the age of curing 28 days for PEG wt% 1and 3 were 3.67 and 4.1 MPa respectively, bulk density decrease when increasing the percentage of PEG.*

Keywords*- Self curing; Mortar; Polyethylene Glycol (PEG) 400; Strength.*

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1. Introduction

Now a day's many techniques are introduced and rapid improvement in the mortar technology. Self-curing technique is one of the techniques, used in less water resource areas. Using of self-curing admixtures is very important that the water save every day. Jagannadha et al. [1] concerned to identify effective self-curing agent. Therefore, several researchers are attracted towards identifying the self-curing agent. Self-curing admixtures causes decreasing in the evaporation of water from mortar, also to increment the retention ability of water from the concrete and mortar compared to others. These compounds will rise to concrete surface that finished were effectively seal the surface to allow evaporation. The water-soluble polymers using as self-curing compounds. Using of self-curing compounds are very important from that the water resources are getting valuable every day. The useful of self-curing compounds are more significant in desert areas where water is not adequately available. PEG, which reduces the water surface tension and minimizes the evaporation of water from mortar and hence increases the ability of water retention from the mortar [1].

I. Polymer Modify Mortar

Polymer alteration for cementinous material these days will be utilized within rebuilding also repair industry and in particular situations, where high requests forwards adhesion, durability and climate capacity [2]. In general, the properties of the polymer mortar materials are high strengths, great cohesiveness, superior durability, also water resistance, acid and alkalis resistance. So, these materials might be used to advance the harmed concrete structure, for example highways bridges, railroads, river and sea banks. In addition, this material it is possible to use in destructive environment as resisting of corrosion material. As contrasted to traditional Portland cement concrete, polymer cement composites can have significantly very good strengths and may be much more durable [3]. In up to date mortar building and works of repairing those part of polymers is rising day by day. Organic polymers would possibly consolidated on cement aggregate blend or used as a singular binder. Those materials constructed utilizing polymer along with cement and aggregates are named polymer modifier mortar**.** Ever after polymers consider costly the former type of requisition is preferred over the latter in most of the status. Consolidation of polymers significantly enhances strength, adhesion, resilience, impermeability, chemical resistance what's more durability properties of

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mortars and concrete. The integration of Portland cement concrete or mortar with polymers can result in greatly durable, tough, also solid building material composites those are economic and friendly to the environment. Structures in excessive environments, or alternately for repairs, or object to impact, cyclic, or dynamic loading may all benefit from the utilization of PMM [4].

II. Curing

Curing of mortar is the maintain operation of appropriate moisture conditions to build up optimization hydration of cement instantly after positioning. With insufficient water, hydration will not progress and producing mortar may not possess desired strength, near surface of mortar is specially influenced. Proper curing of mortar structures is important to meet performance and durability. Enough water needs to be present into mortar for hydration of cement take place, even mix contains enough water, any loss of moisture from mortar will reduce the initial W/C ratio and result in incomplete hydration of cement especially with mixes having low W/C ratio [5].

III. Self-Curing Mortar

In place to obtain the designated self-curing mortar properties, water evaporation toward the surface should be avoided in addition to providing water from the exterior. If enough water is at the transfer of the cement paste for hydration to continue, the mortar will accomplish great properties. The conventional methods for curing regularly fail in practices. Even when carefully performed just water evaporation can be diminished, but the water supply on the surface of vertical structural elements is still a specialized issue [6]. Presently, there are two main methods accessible of self-curing of mortar. First technique utilizes saturated porous lightweight aggregate to provide internal source of water, which can replace water consumed by chemical shrinkage through cement hydration. The second technique uses polyethylene glycol (PEG) that minify evaporation of water from mortar surface that lead to water retention. The self-curing technique continuous evaporation of moisture takes place from an exposed surface due to the distinction in chemical potentials (free energy) between the vapors and fluid stages. Polymers adding in the mixing principally form hydrogen bonds with water particles and decrease the chemical potential of the atoms, which thus diminishes the vapors pressure, subsequently lessening the rate of evaporation from the surface. The self-curing gives water to keep relative moistness (RH) higher, keeping self-desiccation to occur. Also, remove largely autogenous shrinkage. Strengths of mortar/concrete maintains at the early age (12 to 72 hrs.) over the level where internally and externally actuated strains that cause cracking. Self-curing compensate for a part of lacks of external curing, both human related (critical period when curing is required in first 12 to 72 hours) and hydration [9].

The aim of this paper is to concentrate on the strength of mortar utilizing water-soluble polymer (PEG) as self-curing admixture.

2. Experimental Work

I. Materials and their Properties

1. Cement

Iraqi ordinary Portland cement (type I) was used throughout this study. It was put in (air-tight plastic containers) to lessen the effect of humidity and temperature. The chemical composition and physical properties of this cement are given in Tables 1 and 2, respectively. Test results demonstrate that the adopted cement complies to the Iraqi specifications (IQS No.5/ 1984) [7]**.**

2. Fine Aggregate

The fine aggregate, natural sand was utilized all through this work of 4.75mm extreme with grading limited zone II. Table 3 reports the sieve analysis were made in the laboratory. Results indicate that the sand grading within the requirements of the Iraqi specification (IQS No. 45/1984) [8].

3. Polyethylene Glycol

PEG 400 $H(OCH_2CH_2)_nOH$ is highly hydrophilic. PEG 400 is soluble in water, acetone, alcohols and is somewhat soluble in hydrocarbons. According to molecular weight extensive variety of physical property such as solubility, vapour pressure, freezing point and viscosity are variable: Solubility- Increasing the molecular weight of PEG results in diminishing solubility in water and solvents [9].

4. Fly Ash

Fly ash is fine and glassy powder that is recuperated as an aftereffect of coal burning during creation of electricity from ISKENment-Turkey power station. It is viewed as coal ignition waste. Composition of Fly ash relies on upon source. Fly ash particles are mostly spherical in shape and range in size from 0.5 μm to 100 μm. Two fundamental types of fly ashes: one Class F fly ash and Class C fly ash. Class F fly ash has

been explored and it contains not exactly than 20% CaO (ASTM C 618, 2005) [10].

II. Strength Activity Index for Fly Ash

The strength activity index for Fly Ash is conducted according to the ASTM C311–05, cubic specimens casting with and without containing Fly Ash by use standard sand in both mixture. Mixing procedure and compressive test of specimens were according to ASTM C109/C 109M-05 [13], strength activity index for Fly Ash about 78.5.

III. Mix Procedure

Distinctive mixes were utilized to examine the effect of PEG400 on the compressive, tensile strength and bulk density of mortar. Table 6 gives the specifics of the mix proportions. The reference mix M* had weight of 1 cement to 2 sand and mix M had weight of 1cement to 2 sand with 5% fly ash by weight of cement and did not include PEG 400. Mixes M1, M3, M5 and M7, were the PEG 400 mortar of 1, 3, 5, 7, wt.% respectively. Before molding, the molds were oiled carefully to be prepared for casting fresh mortar. The casting of mortar in 3 layers for all specimens; by using a rod the layer was compact, wet-cured of specimens by covering the complete surface and molds by sheet of polyethylene. After one day, the molds were expelled and cured the specimens in water for period of 7, 14, 28 days except PEG mortar which was cured in air for the same duration. High performance Superplasticizer admixture (Glenium 54) (3.5,3 ml) added to reference, fly ash mixes and polymer modified mortar mixes respectively, tap water is utilized as a part of the test work for both mixing and curing purposes of conventional, self-curing mortar.

IV. Testing of Fresh Mortar

1. Setting time

This test was specified according to the ASTM C191-03[11]. This procedure is utilized to determine initial setting and final setting time of cement paste by utilizing Vicat needle.

2. Flow Test

This test gives an allusion of the consistence of mortar and its inclination to isolation by measure the spread of a pile of mortar undergo to jolting. It is concerning isolation the flow test is of greatest value yet it additionally gives good estimation of stiff ,rich ,and rather cohesive mixes .The test was covered by ASTM standard C1437 – 15 [12].

V. Testing of Hardened Mortar

1. Compressive Strength

Compressive strength test was specified according to B.S.1881, (Figure 1)[13]. This test was made on (50*50*50) mm cubes utilizing compression testing machine (ELE) 2000 kN capacity, test was proceeded ages of 7,14,28 day. Calculating the compressive strength of the specimen by dividing the maximum load carried by the specimen by the average cross-sectional area of the specimen.

2. Tensile Strength

A mortar briquette samples of dimensions (76.2*44.4 mm) put with its horizontal axis between platens of tensile testing machine (ELE) with a capacity of 10 kN . The tensile strength test was done according to BS 6319-7: 1985 specification [14]. Form of dumb-bell shaped briquette test specimens. were utilized and load was connected constantly up to failure, the test was led at ages of 7,14,28 days.

3. Bulk Density

The bulk density test was specified by B.S 1015, Part 10[15]. Three test specimens of cube standard shape are set up from the mortar to be tested and cured. The hardened test specimens are dried to constant mass at temperature 70 ^{0}C, dry mass is recorded and volume of the test specimens is determined. Bulk density of each test specimen is computed by divided the mass on volume of specimen.

3. Results and Discussion

I. Setting Time

The setting time results are represented in following Table 7. As the wt% of PEG400 are increased the setting time is found to increase.

II. Flow Test

The flow rate of self-curing mortar is higher than that of reference mortar, therefor lessening the water–cement proportion from 0.35 to 0.3. The effect of different polymer percentages on superplasticizer dosage and on workability were superplasticizer dosage decrease from 3.5 to 3 ml when using polymer.

Table 1: chemical composition and main compounds of cement *

Composition of Oxide	Abbreviation	Percentage by Weight	Limits of (IQS NO.5 /1984)
Lime	CaO	66.11	-
Silica	SiO_2	21.93	-
Alumina	Al_2O_3	4.98	-
Iron oxide	Fe_2O_3	3.10	-
Sulphate	SO_3	2.25	≤ 2.8 %
Magnesia	MgO	2.0	≤ 5 %
Loss on Ignition	L.O.I	2.39	≤ 4 %
Insoluble Residue	I.R.	1.29	≤ 1.5 %
Lime Saturation Factor	L.S.F.	0.93	0.66 – 1.02
Main Compounds (Bogue's equations)			
Name of Compound	Formula	Abbreviation	Percentages
Tricalcium silicate	$3\ CaO.SiO_2$	C3S	58.16
Dicalcium silicate	$2\ CaO.SiO_2$	C2S	19
Tricalcium aluminate	$3\ CaO.\ Al_2O_3$	C3A	7.95
Tetracalcium aluminoferrite	$4\ CaO.Al_2O_3.Fe_2O_3$	C4AF	9.43

* Chemical tests were made by the National Center for Construction Laboratories and Research (NCCLR).

Table 2: Physical properties of cement *

Physical property	**Test Results**	**Limits of Iraqi Specification No.5/1984**
Specific surface area (Blaine method), m^2/kg	376	≥ 230
Setting time (vicat's method)		
Initial :by minutes	2.05	≥ 1 hr.
Final, by minutes	4.00	≤10.00 hrs.
Soundness (autoclave method) %	0.12	≤0.8%
Compressive strength (70.7mm cube) (MPa)		
3days	20	≥15
7days	25	≥23

* Physical tests were made by the National Center for Construction Laboratories and Research (NCCLR).

Table 3: Grading of sand used throughout this work

Sieve size (mm)	**Cumulative passing %**	**Limits of Iraqi Specification No.45/1988 ,zone (2)**
10	100	100
4.75	96.6	90 -100
2.36	92.4	60 -90
1.18	85.8	30 – 70
0.6	74.4	15 -34
0.3	40.3	5 -20
0.15	6.9	0 -10

Table 4: Specification of PEG400 according to the manufacturer

Average Molecular Weight	**380-420 g/mol**
Viscosity at 20^0c	85-105 Cs
Weight per ml at 20^0c	About 1.12g

Shape and appearance	Viscous Liquid
Color	Colourless

Table 5: Chemical Composition of Fly ash

Materials	**SiO_2%**	**Al_2O_3%**	**CaO%**	**SO_3%**	**Particle size µm**
Fly ash	57.36	19.17	1	0.07	**82-145**

* Chemical Composition and Particle size analysis were made by Iraq Geological Survey central laborites department and Nanotechnology and Advanced Materials Research Center respectively.

Table 6: Mix proportions

Mix type	**Cement g**	**Sand g**	**W/C ratio**	**G %**	**Fly ash g 5%**	**P/C ratio**
M*	500	1000	0.35	3.5	-	-
M	500	1000	0.35	3.5	25	-
M1	475	1000	0.3	3	25	1
M3	475	1000	0.3	3	25	3
M5	475	1000	0.3	3	25	5
M7	475	1000	0.3	3	25	7

Figure 1: Tool for tension strength test

Table 7: Setting Time of all specimens

Mix type	Setting Time	
	Initial Time	Final Time
M	58 min	125 min
M*	95 min	137 min
M1	70 min	123 min
M3	75 min	125 min
M5	80 min	150 min
M7	80 min	150 min

Table 8: Compressive strength results for polymer modified mortar specimens

Mix type	Compressive strength MPa		
	7 day	14 day	28 day
M*	24.5	23	27
M	22	25.4	28
M1	26.3	31.5	39.4
M3	29.7	35.6	37.7
M5	25.8	28.3	29.5
M7	20	24	25.3

III. Compressive Strength

Outcomes of the compressive strength are show in Table 8 and the graphical representation is appeared in Figure 2, found that compressive strength increment up to 1,3 wt% of PEG which may be attributed to the continuation of the hydration process, which leads to, lower voids and pores, and greater bond force between the cement paste and aggregates[6] and then decreased for 5,7wt%. In the mixes of PEG

mortar 3wt% additive content at 7 days has given maximum compressive strength 29.7MPa, at 14 days, 35.6 MPa and at 28 days, 37.7MPa. Strength depends on nature and amount of additive and W/C ratio. Strength of mortar at late curing periods increase by using organic set retarders [35].

The compressive strength of mortar mix increased as compared to the reference mortar show increase in compressive strength with addition of self-curing agent up to 3 wt% due to required moisture content that is provided via hydrophilic compounds. PEG is giving optimum results compared to other curing conditions. There is a slight decrease in compressive strength with self-curing agent at 5,7% of PEG [5].

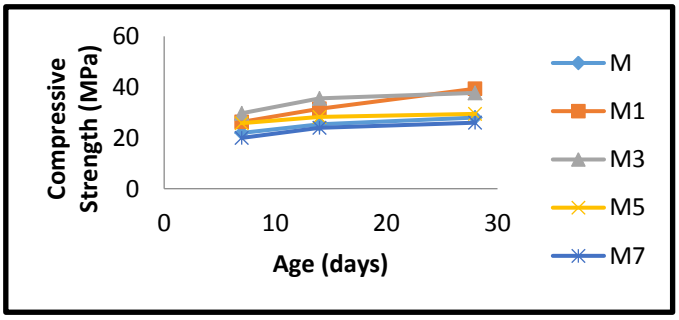

Figure 2: Compressive strength results for PEG polymer modified mortar specimens at 7,14,28 days.

Table 9: Tensile strength values of PEG polymer modified mortar specimens

Mix type	Tensile strength MPa		
	7 day	14 day	28 day
M*	2.1	2.2	2.7
M	2.7	2.8	2.9
M1	2.9	3.1	3.67
M3	2.26	2.93	4.1
M5	1.58	2	2.5
M7	1.3	1.69	1.75

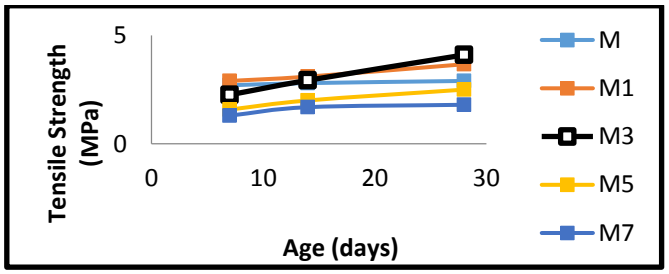

Figure 3: Tensile strength results for PEG polymer modified mortar specimens at7,14,28 days.

IV. Tensile Strength

Test results of mortar containing polyethylene-glycol 400 with different ratios are shown in Fig.3 Results showed higher strength of mortar with PEG400 relative to reference mortar. After 7,14, 28 days, the strength of mortar with 1,3% increased compared to reference mortar, the incorporation of self-curing agents into mortar mixtures provides internal curing for the mortar and thus allowing a continuous hydration, which results in an improvement in the tensile strength of the mortar [6] the polymer modified mortar has tensile strength higher than that of reference mortar and this percent increase with the increase in the P/C ratio at all ages except 5,7 wt% PEG is lower than that of mortar reference.

This behavior may be due to the two reasons: First, the addition of polymers leads to form a continuous three dimensional polymer network, which interpenetrates the cement paste. Second the partial filling of the pores with the polymer particles reduces the porosity of the polymer modified mortar. These factors increase the ductility of mortar and decrease its brittle nature [15], these results are tabulated below.

V. Bulk Density

The influence of PEG 400 on bulk density of polymer-modified hardened mortar was studied. Table 10 illustrates that the bulk density of all mortar mixes (self-curing and conventional mortars) diminishes gradually with time under air curing due to water dissipation from mortar. The varieties of bulk density due to changes in P/C proportion are appeared in Fig.4 at different self-curing periods. According to this figure, it can be concluded that any increments in P/C proportion in the given range result in a significant decrease in bulk density. Such a positive effect of PEG 400 on hardened mortar can be purely attributed to the lubricating effect of which simplify both dispersion and close packing of cement molecules which are then held closely with each other by binding properties of both cement phases and polymer matrix produced [16-17].

Table 10: Bulk density values of PEG polymer modified mortar specimens

Mix type	Bulk Density g/cm^3		
	7 day	14 day	28 day
M*	2.25	2.23	2.1
M	2.24	2.22	2.19
M1	2.2	2.19	2.17
M3	2.19	2.16	2.13
M5	2.18	2.14	2.11
M7	2.13	2.08	2.03

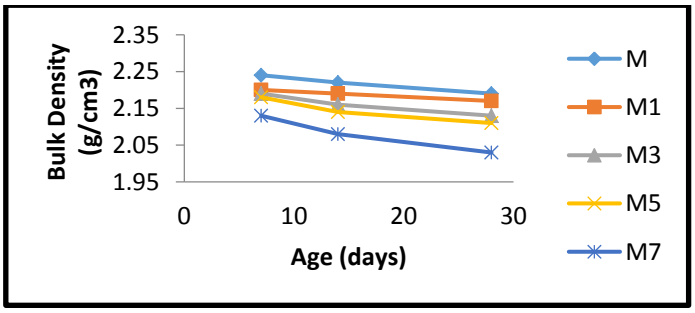

Figure 4: Bulk Density results for PEG polymer modified mortar specimen's at7, 14, 28 days.

VI. Microstructure of Mortar

As shown above, polymer-modified mortar has obvious improvement in mechanical properties. Figure 5 (a), (b), (c), (d) shows the microscopic images of the fractured surfaces of PEG modified mortar specimens at self–curing age of 28 days.

4. Conclusions

1. It is found that the self-curing agents investigated in this work have more enhancing in improving the level of hydration and water maintenance capacity.
2. Self-curing agents PEG400 can be used effectively to produce self-curing mixes with superior properties to those of conventional.
3. Optimum dosage of PEG400 for higher compressive and tensile strength was found to be 1, 3 wt% of PEG.
4. Any increments in C/P proportion in the given range result in a significant decrease in bulk density
5. Higher dosage of PEG400 up to 5% lead to decrease the compressive and tensile strength.

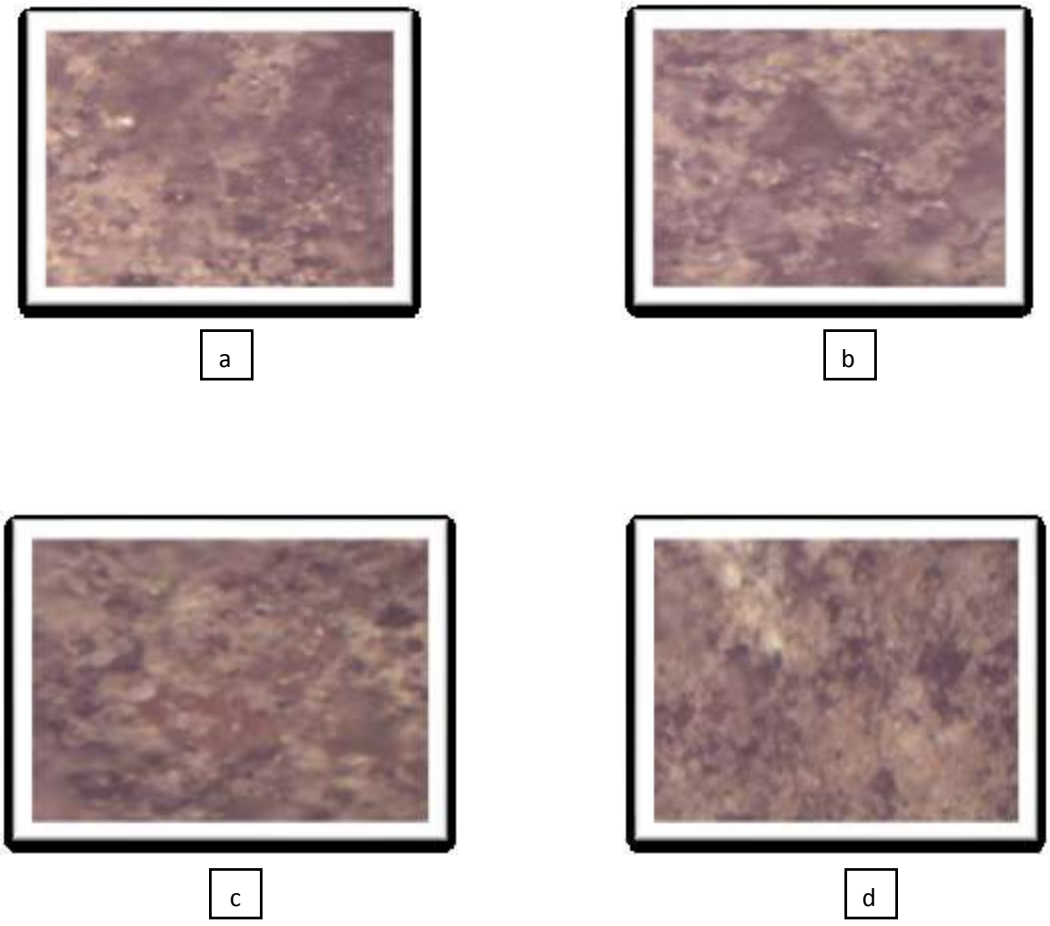

Figure 5: (a),(b),(c),(d), microstructure of PEG modified mortar at 28 days of 1,3,5,7

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