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Using Polymer Materials to Improve Cementitious Products Properties

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Abstract: This study deals with the influence of Poly Ethylene Glycol (PEG) and Poly Acryl Amide (PAA) upon the characteristics of the cementitious brick and board for example setting time, flow-ability, bearing and bending strength, via. including 1, 3 wt.% of PEG400 as well as (PEG/PAA) as additives by cement weight. Also, it was investigated the characteristics of bulk density and water absorbing ability of ensuing produces. By blending the fly ash to cement, the cementitious samples of mortar had been made which were treated via. traditional technique (water based-treatment). Through, appending polyethylene glycol only plus the binary polymer mix (Polyethylene glycol/polyacrylamide) tovarious percentages of weight (1, 3%) of cement weight, the cementitious mortar of self-treated feature had beendone. The findings show that the self-treating strategy being utilized possesses constructive outcome on the work ability and quality of the mortar examples. Cementitious Mortar examples, treated via. treating technique showed better productivity bulk density diminishing. It can be noticed that, the execution of self-treating technique is superior to that of water-based treating. In this study the facts develop that indicates the self-curing utilizing in conditions as treating process by water can behard. Nevertheless, amid both study in gtreating techniques, self-treating mortar registered superior physical and mechanical characteristics than the mortar of water-based treating nature. Cementitious board and bricks were produced from the optimum results of 3 wt.% PEG400 and (PEG/PVA). It was found that the bearing strength of PEG 400 modified cementitious brick ranged from 26.38-27.24 MPa and its water absorption from 4.56-5.06 wt.% while the bending strength values of polymer blend modified cementitious board were within the range of 3.6-4.5 MPa which were higher than that of the reference cementitious board which equal to 1.9 MPa.

Key words: Self-curingbrick, cementitious board, Polyethylene Glycol (PEG) 400, utilizing , ability, findings

INTRODUCTION

Nowaday'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. The self-treating agents can be used to decrease evaporating water out of concrete that increments the capacity of retaining water from concrete when compare to traditional concrete. These compounds will ascend to the completed concrete exterior then efficiently close the exteriorin opposition to evaporating. Because the resources of water have been becoming precious day after day, the utilization of self-treating admixtures can be so significant. Moreover, the needs for these kinds of admixture are so, urgent in desert areas as water resources cannot be sufficiently exist. Polyethylene glycol which decreases the exterior for waters stressand reducesthe evaporating amount of waterin mortar, therefore, increments the water preservation ability for the mortar (Kumar *et al*., 2012).

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 (Beeldens *et al*., 2005).

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. Also, 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.

In up to date mortar building and repairing actions of polymers have risen gradually. Polymers would possibly be consolidated on a cement collection blend or utilized to be a singular binder. Such kind of composite that is

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constructed via. utilizing polymer plus cement as well as aggregates is known as Polymer Modifier Mortar (PMM). Ever after polymers can be expensive. The first kind of requisition is more prefer able than the second for many cases. The consolidation for polymers significantly enhances strengthen capability, adhesive feature, pliability, impermeable ability, resisting feature of chemical nature andmany other characteristics that makes both mortars and concrete durable.

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 (Aggarwal *et al*., 2007).

Curing: This operation doneto mortar is to maintain the appropriate wetness circumstances for building up optimization cement hydration instantly after positioning. When the water is unsatisfactory, the hydration cannot progress, so, the produced mortar won't have desired force. The close exterior area for mortar can specially influenced if there is no protecting blockade to prevent damaging causes. The suitable process of cure for mortar structures can be significant to satisfy the good performing and durable needs. The cement hydration could happen when is a sufficient amount of water exists within a mortar mixture. Be that as it may, even mixture has sufficient amount of water, little lost of dampness from the mortar can diminish the underlying W/C proportion and causes deficient hydration of concrete particularly with the mixtures possessing low W/C proportion, this outcome is in extremely low quality of mortar (Venkateswarlu *et al*., 2015).

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 (Mousa *et al*., 2015). Self-curing technique uses Polyethylene Glycol (PEG) that minifies the evaporating capacity of water out of the exterior of mortar as well assists in water retaining. The constant evaporating for dampness in self-curing technique occurs in an uncovered exterior because of the distinction in the possibilities of chemical nature (free energy) amid the vapours and fluid stages. Polymers adding to mixing principally construct connections of hydrogen with water particles and decrease the possibility of chemical nature for atoms, thus diminish the force of vapours, subsequently lessening the proportion of evaporating out of the exterior, therefore, preventing the self-desiccation of happening also to remove chiefly autogenous contraction. Self-treating compensate for a part of lacks of exterior cure both person connected (significant timeas cure is needed in the initial 12-72 h) as well as hydration.

The purpose of this study is to determine the strength of cementitious brick and board utilizing water-soluble polymer (Polyethylene Glycol) as self-curing agent.

MATERIALS AND METHODS

Materials and their properties

Cement: Iraqi ordinary Portland cement (type 1) had been utilizedinthe current study. This cementhad been put within (air-tight rubber canisters) for lessening the dampnessas well as heat influence. Table 1 and 2 show all cementious chemical composition and material characteristics, respectively. Investigation outcomes demonstrate that the used cement complies with qualifications being adopted in Iraq (IQS No. 5/1984) (Anonymous, 1984a, b).

Fine aggregate: The fine aggregate, nature sands was utilized all through this work of 4.75 mm most extreme of grade limited zone 2. Table 3 reports the sieve analysis were made in the laboratory. Outcomes point out that the excellent aggregate grading complies with demands required by the standards used in Iraq (IQS No. 45/1984) (Anonymous, 1984).

Polyethylene glycol: PEG 400 $H(OCH_2CH_2)_nOH$ is highly hydrophilic. PEG 400 can be dissolved within water, acetone, alcohols it also can be somewhat solvable in hydrocarbons. Depend uponthe molecular weight the wide diversity of the physical features for instances, solubility, hygroscopic, vapour pressure, freezing point and viscosity can be changeable: Solubility-Increment the molecular weight of PEG causes diminishing solubilit in water and solvents (Kumar and Babu, 2015) (Table 4 and 5).

Fly ash: It represents fine and glassy dustwhich can be recuperated as an after effect of coal burning during creation of power in ISKEN ment-Turkey electricity location. This dustcan be seen like coal ignition waste. The formation of fly ash depends upon its source.

Table 1: Cement chemical composition and main compounds*

Composition of oxide	Abbreviation	Percentage by weight	Limits of (IQSNO.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	Mg O	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	$3CaO.SiO_2$	C3S	58.16
Dicalcium silicate	$2CaO.SiO_2$	C2S	19.00
Tricalcium aluminate	$3CaO.Al_2O_3$	C3A	7.95
Tetracalcium aluminoferrite	$4CaO.Al_2O_3.Fe_2O_3$	C4AF	9.43

*Chemical composition and practice size analysis were made by Iraq Geological Survey Central Laborties Department and Nanotechnology and Advanced Materials Research Center, respectively

Table 2: Cement material characteristics*

Physical property	Test results	Limits of Iraqi specification No.5/1984
Specific surface area 376 (Blaine method) (m^2/kg)	≥230	
Setting time (vicat's method)		
Initial :by minutes	2.05	≤1.1 h
Final, by minutes	4.00	≤10.00 h
Soundness (autoclave method) %	0.12	≤0.8%
Compressive strength (70.7mm cube) (MPa)		
3 days	20	≥15
7 days	25	≥23

*The investigations of Physical naturehad been made by the National Center for Construction Laboratories and Research (NCCLR)

Table 3: Grading of fine aggregate used throughout this research

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: Specificationof PEG400 according to the manufacturer

Average molecular	380-420
Weight	g/(moL)
Viscosity at 20°C	85-105 (Cs)
Weight per ml at 20°C	About 1.12 g
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 5% (g)	P/C ratio
M*	500	1000	0.35	3.5	-	-
M	500	1000	0.35	3.5	25	-
M1	475	1000	0.30	3.0	25	1
M3	475	1000	0.30	3.0	25	3

It's particles have mostly the form of sphere and particle size vary between 0.5-100 μm out of two fundamental types of this ash: Class F and C , Class F has been explored and it contains not exactly than 20% CaO (ASTM C 618, 2005) (Kim, 2012).

The strength action guide of fly ash was performed in compliance with the ASTM C311-05 that involves casting cubic samples whether including or not including fly ash in addition to utilizetypical sandsforthe two mixtures. ASTM C109/C 109M-05 (ASTM C109, 2005) are standard of mixing procedure and compressive test of specimens, strength activity index of fly ash about 78.5.

Mix procedure: Distinctive mixes were utilized to examine influence of PEG400 upon the compressive, tensile force 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 1 cement to 2 sand with 5% fly ash by weight of cement and did not include PEG 400. Mixes M1, M3 were the PEG 400 mortar of 1, 3 wt. %, respectively.

Before molding, the molds were oiled carefully to be prepared for casting fresh mortar. The mortar had been casted within 3 layers to each sample every layer had been compacted via. a rod, then each sample was wet-treated through enveloping the completed exterior along with casts using polyethylene cover. For 1 day period, the casts had been expelled then curing the samples within water for 28 days time except PEG mortar which was cured in air for the same duration. High performance Super plasticizer 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.

Testing of fresh mortar

Setting time: This test was specified according to the ASTMC191-03 (Anonymous, 2004). This procedure is utilized to determine initial setting and final setting time of cement paste by utilizing Vicat needle.

Flow test: This test gives an allusion of the consistence of mortar and its inclination to isolation via. calculating the stretch of a mortar pile under goes jerking. This test

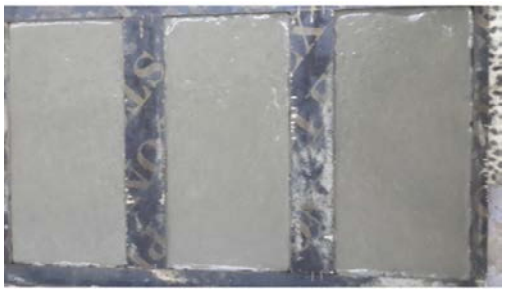

Fig. 1: Cementitious board specimens

concerns isolation that it is of highest significance, yet this additionally provides a better estimation of stiff, wealthy, along with quite unified mixtures. The test was according to ASTM standard C1437-15 (Anonymous, 2015).

Testing of hardened cementitiousboard: The cementitiouspolymer boards were produced at weight of cement 1000 g and sand 2000 g at cement to sand ratio 1:2 for one mix, polymer blend (PEG 50%/PVA50%) ratio, 3% by weight of cement. The mix containing polymer blend, cement, sand, G54 and water was uniformly spread in a wood mould of (30×15×1.5) cm specimen was acquired as shown in Fig. 1. After demolding, all specimens of polymer modified board were self-cured at room temperature of 25±2°C and reference cement board water cured. The mixing procedure can be given as: at the beginning, the cement had been put inside the mixer besidethe water, G54, polymer blend (PEG/PVA) that mixed to 1 min then addedsand were mixed for another 1 min, the new mixes had beencompressed using a rod of steel. The mixing of board was extracted from wood mould and stayed in lab at 28 days of self-curing.

The bending strength was tested by utilizing bending machine LARYEE Model WDW 50(Chain) at capacity of 50 kN. Bending load was applied to specimen face at (30×15) cm in dimension, load applying at rate of 0.5 mm/min then distributed on surface of specimen. The results were checked according to ASTM C 208-95 (Anonymous, 2001) as shown in Fig. 2.

Cementitious brick: Bearing strength, water absorption and bulk density tested physical and mechanical properties were carried out on the cementitious brick products according to I.Q.S (Anonymous, 2001). Weighing appropriate amounts of cement and sand with needed water for preparation by mixing for (2-3 min) utilizing cement mortars mixer for getting homogeneous

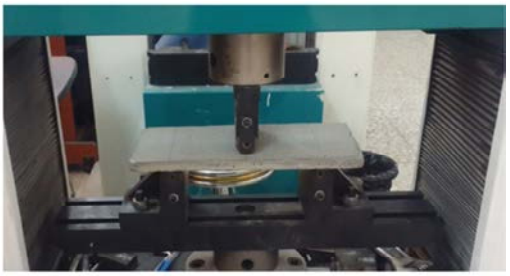

Fig. 2: Bending test machine

consistency. After that, the mixtures were put into a brick mold (20×10×5) cm by utilizing steel rod for manually compaction until mould was full, ethylene nylon placed on top of the mix. Self-curing of specimen in laboratory achieved at room temperature for 28 days then measured their dimensions and weight for testing.

All tests were performed according to Iraqi's Standards (No. 1077/1985). Each test result represented average of 8 brick specimens for mixes. Specimens drying were accomplished by placed them in drying oven at (100-110°C) for not <24 h until getting a fixed weight. After cooling at RT, specimens were weighed and kept in water at RT to a period of 24 h these samples had beentaken out of water then cleaned by damppart of clothing, after that weighed within1 min. of expanding. Bearing strength test was performed according to I.Q.S.

During producing, all dimensions of brick specimens displayed elevated steadiness accompanied by sharp ends before and after curing and straight exterior without concavity or convexity, this represents good method of forming and using press in molding (Fig. 3).

After casting of brick, they were extracted from wood mould and stayed in lab for 28 days for self-curingto determine bearing strength, bulk density as well as water absorbing. The investigated specimens undergo water absorbing in addition to bulk density had been put into furan at 110°C, then dehydrated till a steady mass within 24 h, immersing the specimens in water for 24 h, after that the specimens had been weighed again to obtain the saturated heaviness for them. When the dissimilarity amid saturated and dried weight got divided by total size of samples, the absorbing capability forwater per, unit volume had been measured. Bulk density of bricks had been measured via. dividing dried weight of every sample to the total volume of that sample. Bearing strengths were specified through employing compressing experiment appliance along with a highest capability of 1500 kN.

Fig. 3: Bearing strength testing of cementitious brick

RESULTS AND DISCUSSION

Physical and mechanical properties of produced bricks: Average values of testing results are summarized and appeared in Table 7. Effect of polymer content on physical and mechanical properties was studied. Effect of polymer content on the water absorption, bulk density and bearing strength were showed inside Table 7. Depending uponthe outcomes an increase of bearing strength of PEG400 modified cement brick ranged from 26.38-27.24 MPa and water absorption from (4.56-5.06) wt.%. This distinguishes that addition of PEG400 decreased bulk density of brick from 2.124-2.016 g/cm^3. Bearing strength of brick is an important material property for structural applications increasing bearing strength of unit will increase masonry assemblage bearing strength absorption are properties which affect bond strength of masonry assemblage and durabilitywhich influence useful product life (Fig. 4).

The existence along with motion of water tomaterial causes deterioration and freeze-thaw harmfor the produce because water is able to convey chlorides as well as sulfates along with different damaging ions (94). Thus, absorbing ability of the produce possess significant influence upon durable capacity of that produce. Table 7 indicates water absorption values in wt.% for brick at 28 days of self-curing, water absorption of brick decreased with the addition of PEG 400.

Optimum bulk density result of cementitious brick is about 2.016 g/cm^3. It is expected to decrease bulk density of cementitious brick if PEG 400 added to cementitious brick of about than 3% in weight.

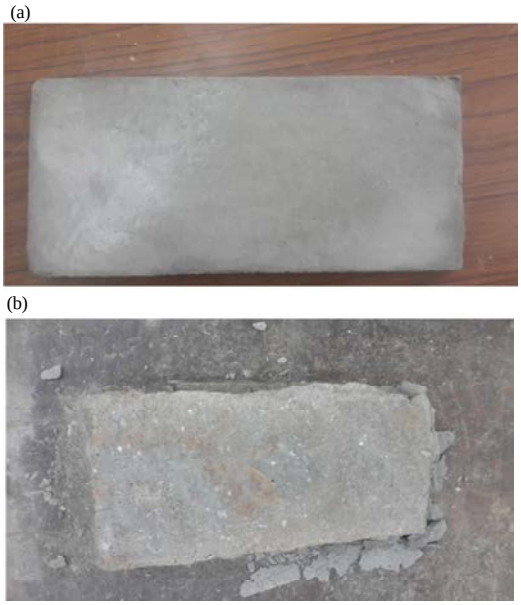

Fig. 4: Cementitious brick specimen: a) Before failure and b) After failure

Table 7: Physical and mechanical properties of the produced brick

Properties of cementitious brick	Experimental results at 28 days			Limits of I.Q.S
	Mix. 1	Mix. 2	Mix. 3	Avg. 3 bricks
Bearing strength (MPa)	26.38	26.63	27.24	Min. 13
Water absorption (wt.%)	4.560	4. 910	5.060	Max. 10
Bulk density (g/cm^3)	2.016	2.018	2.124	-

Table 8: Bendingproperties of the produced board

Properties	Experimental results at 28 days		
	Mix 1	Mix. 2	Mix. 3
	F	----------(PEG/PVA)----------	
	1.90	3.70	4.8
	1.76	3.50	4.2
	1.80	3.07	4.6

In spite of the fact that fly ash helped increase density by filling up the voids into the matrix, it was insufficient to compensate decreasing caused by polymer (Bustamante *et al*., 2015).

Bending strength of cementitious board: The specimens were tested for products at 28 days-period of self-cure in bending strength test, the test result is appeared in Table 8, Fig. 5 and 6. Bending stress of polymer blend modified cementitious board within range from 3.07-4.8 MPa which is higher than that of reference cementitious board of 1.9 MPa. This is for polymer blend can strengthen bending strength by increasing bonding between constituents matrix and decreasing volume of

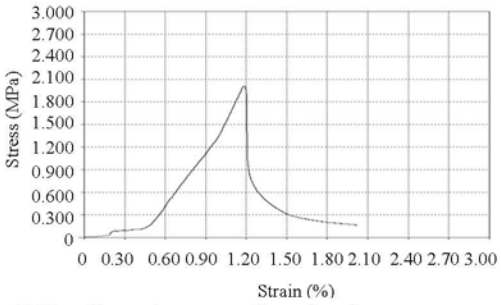

Fig. 5: Bending stress results of reference cementitious board

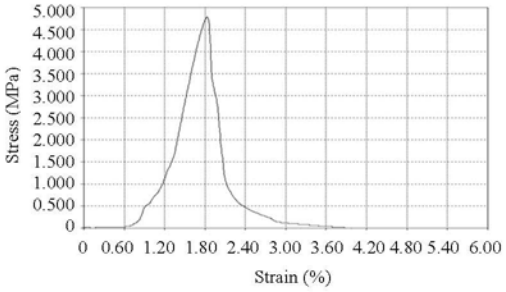

Fig. 6: Bending stress results of polymer blend (PEG/PVA) modified cementitious board

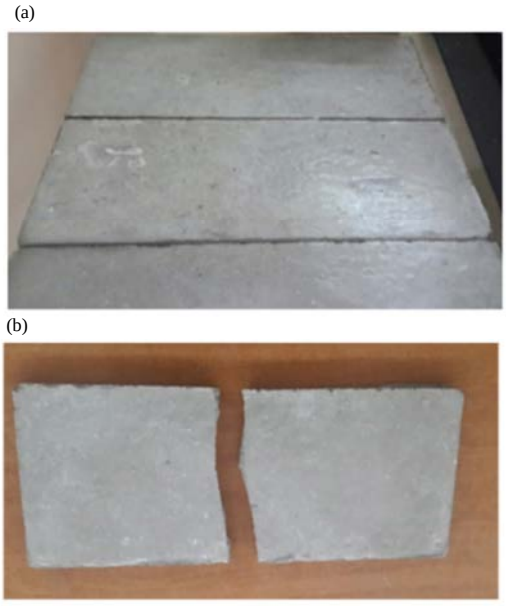

Fig. 7: Cementitious board: a) Self-curing specimens before test and b) After bending test

voids within mix which leads to increase bending value (Shawia *et al*., 2014). Figure 7 shows the self-curing board before and after bending test.

CONCLUSION

It is possible to produce cementitious brick based on cement and sand where the optimum mix was having the parameters (cement to sand ratio 1:2 and 3 wt.% of PEG 400). This products satisfy the required characteristic which produced bricks with 26.6 MPa in bearing strength and water absorption of 4.9%.

Bending strength of cementitiousboard was lower for the specimens stored under water as compared to the results obtained for specimens tested in self-curing condition.

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