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Effects of Polyethylene Glycol in Self-Curing Mortar Containing Fly Ash

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Abstract: Curing is maintaining a sufficient water and temperature in concrete through its early periods to get the aimed properties of concrete. Curing is critical in production of concrete to ensure that concrete will have the durability and strength. In order to make the concrete cured by itself, a chemical called Polyethylene Glycol 400 (PEG) is used where it helps in water retention throughout the concrete during curing process. In this project, PEG and Fly Ash (FA) were added as a self-curing agents in mortar to determine the effects of self-curing agents in term of compressive strength. The mortar ratio was 1:2.75 (cement:sand). PEG was added first with different percentage 1, 2 and 3% by weight of cement. Then, FA was added with different percentage 20, 40, 60, 80 and 100% by weight of cement. The w/c ratio was 0.45 to ensure the workability. All mortars were exposed to the fresh air (in the laboratory environment with 25°C for curing to see the effect of self-curing agents. The result showed that, self-curing agents have improved the strength of mortar. The mortar using PEG has scientifically increased the strength by 31% compared to conventional mortar. And 1% was the optimum percentage. FA enhanced the early age strength by 80% compared to normal mortar. Also, 20% of FA was the optimum percentage.

Key words: Polyethylene glycol, fly ash, self-curing mortar and compressive strength, optimum percentage, Malaysia, sand

INTRODUCTION

Curing is a maintaining process of sufficient water and temperature in concrete through its early periods to get the aimed properties of concrete. Curing process is a critical phase in production of concrete to ensure that concrete will achieve the desired properties. The durability and strength of concrete will be completely developed unless it's cured. No action to this end is required. However, concrete has to remain in satisfactory conditions of moisture, humidity and temperature to fully cure. Otherwise, specified curing method shall start as soon as required (Varga *et al*., 2012).

Conventional curing is achieved by external curing applied after mixing, placing and finishing. While, self-curing techniques are used to provide extra moisture in concrete to improve the hydration of cement and reduce the self-desiccation (Kumar *et al*., 2012). The ACI-308 code states that "internal curing refers to the process by which the hydration of cement occurs because of the availability of additional internal water that is not part of the mixing water". Conventionally, curing concrete means creating conditions such that water is not lost from the surface, i.e., curing is taken to happen 'from the outside to inside'. In contrast, 'internal curing' is allowing for curing 'from the inside to outside' through the internal reservoirs (in the form of saturated lightweight fine aggregates, superabsorbent polymers or saturated wood fibers) created. 'Internal curing' is often also referred as 'self-curing'.

The curing water demand (external or internal) can be much larger than that in a usual ordinary portland cement concrete when the mineral admixtures react entirely in a mixed cement system. When the water lost because of depercolation of the capillary porosity, for example (early-age) cracking may result and significant autogenously deformation (Kumar *et al*., 2012).

This project presents the FA as a waste material that is going to use it in the mixture to accomplish the sustainable results for self-curing mortar. The production of FA has increased over the word according to the statistic reported for years 1987-1989, 415 million tons of FA was produced all over the world. Therefore, this research purposely to eliminate the negative environmental impact that was only dumped the waste industries (Ismail *et al*., 2007). The aim of this research is to determine the effects of different percentage of self-curing agents on the mechanical properties of mortar in term of compressive strength and the optimum percentage of self-curing agents.

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MATERIALS AND METHODS

Polyethylene glycol: PEG is a polyether compound with many applications from industrial manufacturing to medicine. The structure of PEG is: H-1-OH PEG is also known as polyethylene oxide or polyoxyethylene, depending on its molecular weight. The PEG has proved that it helps low the absorption of water in concrete. Pharmaceutical causes the reduction of the surface tension of the mixing water and reduces the water evaporation from concrete (Kumar *et al*., 2012). Thus, it increased the water retention capacity of the concrete. Besides that, it also increased the hydration process and strength development, reduced autogenously shrinkage and cracking, reduced permeability and increased durability. The impact of curing begins immediately with the initial hydration of the cement, so that the benefits were observed at ages as early as 2 or 3 days. From previous researcher (Mousa *et al*., 2014) has used polyethylene-glycol (Ch.) with different percentages; 1%, 2 and 3% of weight of cement. A lower volumetric water absorption of concrete containing different percentages of Ch. relative to conventional concrete during the experiment, where after 28 days concrete with 1, 2 and 3% Ch. decreased by about 8.2, 18.4 and 14.3%, respectively compared with 0.0% (conventional concrete) to confirm that 2% Ch. is the optimum ratio. Results of this study demonstrate that a significant improvement took place in the physical properties studied for self-curing concrete with PEG (Ch.) as self-curing agent.

The FA is used in the mixture as cement replacement materials were collect from Stesen Janakuasa Elektrik Sultan Abdul Aziz Shah, Kapar, Selangor. FA in Malaysia was classifies in Class F due to the chemical compositions. FA contained a very low percentage of carbon as indicated by the low Loss on Ignition (LOI) values (Kulaots *et al*., 2004). Reffer Table 1 and 2 for chemical composition and physical properties of FA (Kulaots *et al*., 2004). Physically, FA is a powdery material, very fine and composed of silica. Fly ash produced by electric power plant is growing every year in Malaysia. However, 16% of these FA were utilitiesed in construction division. The burning of coal at high temperatures and pressures in power stations creates dissimilar kinds of ashes (Table 3).

Mortar mix design: This research was carried out to determine the optimum percentage of self-curing agent (PEG) effect to the FA mortar. The mix proportions to with percentage of 0-3% of self-curing agent are tabulate in Table 4 and mix design were referring to British Design of Experiment (DOE) method. Concrete samples were design by include OPC, FA and self-curing agent (PEG). The optimum percentage of self-curing agent (PEG) in mix design as tabulated in Table 5.

Table 1: Technical Information of PEG as provided by the manufacture

State	Values
Average molecule weight	380-480
HydroxylNum MgKOh/g	264-300
Liquid density g/cc	
20°C	1.1255
60°C	1.0931
80°C	1.0769

Fly ash; melting or freezing range (°C): 4-8; solidity in water at 20°C (%) by wt.: complete; viscositya 100°C: 7.3

Table 2: Chemical composition of FA

Compounds	Content wt. (%)
SiO_2	59.00
Al_2O_3	21.00
Fe_2O_3	3.70
CaO	0.00
MgO	0.00
SO_3	1.00
K_2O	0.90
LOI	4.62

Table 3: Physical properties of the FA

Colors	Whitish grey
Bulk density (g/cm^3)	0.994
Specific gravity	2.288
Moisture (%)	3.140
Average particle size (%)	6.920

Table 4: Determination of optimum percentage of PEG (PEG)

Mix	OPC (kg/m^3)	Sand (kg/m^3)	W/C (%)	PEG (%)
M1	533.34	1466.69	0.45	0
M2	533.34	1466.69	0.45	1
M3	533.34	1466.69	0.45	2
M4	533.34	1466.69	0.45	3

Table 5: Design mix with optimum PEG and FA replacement

	OPC (%)		FA (%)				
CM	Replaced	kg/m^3	Replaced	kg/m^3	Sand kg/m^3	W/C (%)	PEG (%)
M1	100	533.34	0	0.00	1466.69	0.45	0
M2	80	0.6400	20	0.16	1466.69	0.45	1
M3	60	0.4800	40	0.32	1466.69	0.45	1
M4	40	0.3200	60	0.48	1466.69	0.45	1
M5	20	0.1600	80	0.64	1466.69	0.45	1
M6	0	0.0000	100	533.34	1466.69	0.45	1

RESULTS AND DISCUSSION

Extensive data were collect from testing to ensure the sample achieve the objective to produce a self-curing cubes by using PEG and FA and to investigate the compressive strength of self-curing cubes by comparing with the compressive strength of control mix. Compressive strength was conducted to get the strength

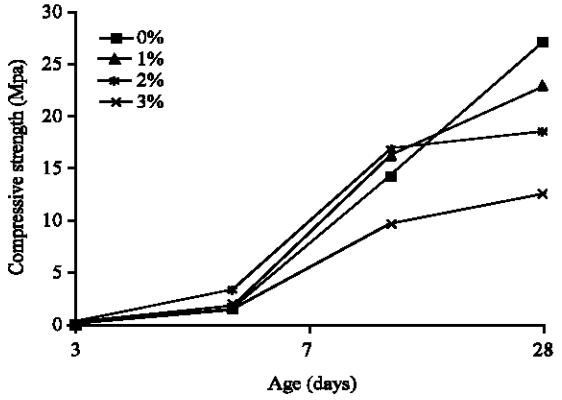

Fig. 1: Optimum PEG on compressive strength in self-curing mortar

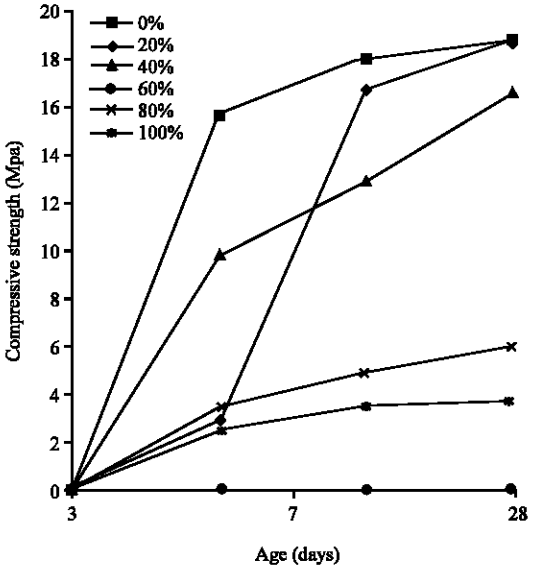

Fig. 2: Effect of FA on compressive strength of self-curing mortar

of using PEG and it was performed according to ASTM C109. Samples have been tested with different PEG content 0, 1, 2 and 3%. Mortars were tested after 3, 7 and 28 days and the reading were taken to study the compressive strength as shown in Fig. 1.

Compressive strength was conducted to get the strength by using 1% of PEG mixed with FA as a replacement material of cement and it was performed according to ASTM C109. Samples were tested with different FA content of 0, 20, 40, 60, 80 and 100%. Mortars were tested after 3, 7 and 28 days and compressive strength was plot as in Fig. 2.

The compressive strength of 54 mortar cubes studied either self-curing or normal curing mortar increase gradually with the time in different rates under air curing. It is known that the purpose of using FA is

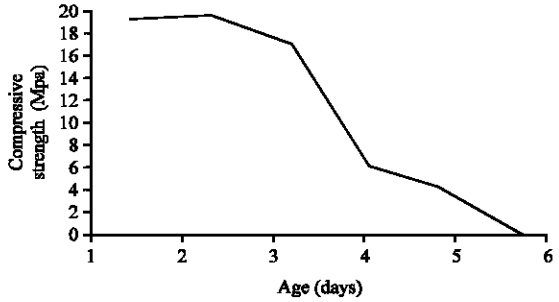

Fig. 3: Effect of fly ash in self-curing mortar at 28 days

to reduce the waste on environment and study the effect of it in self-curing mortar. The result in Fig. 2 and 3 shows a significant increase in the compressive strength of mortar containing FA with time compared to normal mortar during the experiment. After 3 days, mortar with 20% of FA containing 1% of PEG had increased the early age strength by 81% compared to the normal mortar. Also, at the same period 40% of FA containing 1% of PEG had increase the early age strength by 70% compared to the control mortar which means FA with 20 and 40% is can be use to shorting the time of construction projects due its ability to develop the strength in the early ages. However, 60, 80 and 100 of fly ash replaced by cement showed less strength by 1, 15 and 90, respectively compared to the control mortar. Also, after 7 days of air curing the self-curing mortar with 20% of fly ash shows an enhancement in strength by 8% more compared to the normal mortar. However, 40, 60, 80 and 100% of FA showed lower strength by 31, 72, 79 and 99%, respectively compared to the control mortar. The result at 28 days shows, self-curing mortar with 20% increase the strength by 3% compared to conventional mortar. However, mortar with 60, 80 and 100% FA in self-curing mortar shows less compressive strength due to the high amount of FA compared to the control mortar. Which concluded that 20% is the optimum strength.

CONCLUSION

As conclusion, the consequences of self-curing mortar using waste materials as FA in the mixture as fine aggregate during this research with proportion of mix mortar was 1:2.75, cement, sand, respectively. The results were obviously showed that the objective of this project has been achieved. It can eventually be concluded as the following: the first objective of the project is to determine the effect of self-curing mortar using PEG as self-curing agent. The tests that have done in this project were

compressive strength. The result indicated that the PEG achieved the maximum compressive strength after 28 days and improved the strength by 33% compared to the normal mortar. Also, 1% of PEG the optimum percentage.

The second objective of this project is to determine the effect of self-curing mortar using FA as self-curing agent. The compressive strength was conducted and the result indicated that self-curing mortar with 20% of FA improved the early age strength by 81% and the late age by 3% compared to the normal mortar. Total 20% is the optimum percentage.

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