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EFFECT OF VISCOSITY MODIFYING AGENTS ON PERFORMANCES OF CONCRETE

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ABSTRACT:

This study emphasizes the effect of viscosity modifying agents (VMAs) on performance of concrete. The performances of concrete were evaluated in terms of the bleeding and compressive strength of concrete. Additionally, the influence of the VMAs on dewatering of mortar under high pressure was also investigated. Two different types of VMA, namely surfactant and starch ether were used with a fixed dosage of polycarboxylate based superplasticizer in the tested mixtures. All mixtures of concrete and mortar were prepared with the same water to binder ratio at 0.39. Experimental results showed that surfactant type VMA significantly reduced the bleeding, dewatering and slightly reduced the compressive strength of concrete. Whereas the use of starch in concrete mixtures moderately reduced bleeding, slightly reduced the compressive strength of concrete and was ineffective to reduce the dewatering of mortar under high pressure.

KEYWORDS: Bleeding, Dewatering, High pressure, Viscosity modifying agent

1. Introduction

Concrete is the combination of binder, fine aggregate, coarse aggregate, water and some admixtures, and is widely used as a construction material for different types of construction worldwide. The quality of concrete plays an important role to make durable concrete structures. One of the important problems of fresh concrete causing the durability problem in long term is bleeding [1]. Bleeding is a form of segregation where some of the water is free from the restriction of solid particles of the concrete and water is raised to the top surface of freshly mixed concrete [2]. Various studies from [3]-[7] describe that the amount of bleeding water depends on water to binder ratio, free water content, presence of fine particles, type and dosage of water reducing admixtures, shape and size of aggregate, leading to their interparticular solid contact forces, permeability of the fresh concrete and pore pressure gradient in the fresh concrete.

Bored pile concrete can be considered as a type of self-compacting concrete which requires excellent properties in fresh stage which are deformability, segregation resistance and passing ability [8]. When the concrete mixtures are placed in a deep bored pile, the mixture is pressurized due to its self-weight, so bleeding as well as channeling or dewatering happen [9]. The bleeding and dewatering are considered to affect the quality of the top part of the pile and this problem is normally solved by overcasting the pile top and later trimming it to the cut off level [10]. This causes the extra works and expenses to the construction of structures. Due to the variation of pressure in a bored pile, water is drained out from the concrete mixture which is known as dewatering. It happens due to variation of pore pressure gradient in the concrete mixture [11]. A part of the drained water from the concrete mixtures is trapped on the underside of reinforcement bar and gravels, thus creating the abnormal voids, weakening the bond strength between the constituents and reducing the strength and durability of the concrete structures [12]. Therefore, the evaluation and control of bleeding and dewatering of fresh concrete under pressure is very significant in order to save the labor, time, cost and to control the quality of the bored piles.

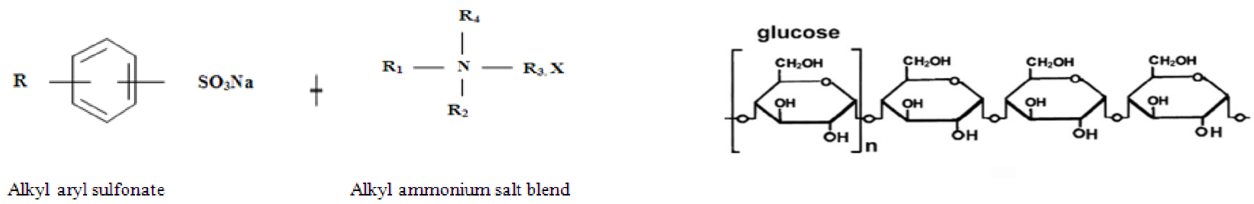
The workability of concrete can be controlled by the use of superplasticizers (SP) and the viscosity modifying agents (VMA). SPs are used to enhance deformability whereas VMAs are used to improve segregation resistance by increasing the viscosity of the concrete [13]. The most important aspect is that VMAs, commonly used with SP, should not worsen any fresh properties of the mixtures except increasing viscosity [14]. Various studies from [15]–[17] describe that VMAs improve the viscosity of pastes as well as reduce the risk of segregation. It improves the resistance to bleeding and segregation of concrete as mentioned in [13] and [18]. However, there is lack of experimental investigation on controlling the dewatering of concrete with VMA under high pressure.

Therefore, this study attempts to evaluate the effect of VMAs on bleeding of concrete and dewatering of mortar under high pressure. Additionally, their effect on compressive strength of concrete was also investigated.

2. Experimental Programs

2.1 Materials

An Ordinary Portland cement (Type I) and a fly ash (FA) from Mae Moh power plant were used as the binders. Chemical composition and physical properties of the cement and fly ash are shown in Table 1. Natural river sand, conforming to ASTM C33 with a specific gravity of 2.59 was used as fine aggregate. Crushed limestone having a maximum nominal size of 19mm and a specific gravity of 2.83 was used as the coarse aggregate. Polycarboxylate based superplasticizer, Mighty 21 WH (labeled as PC-M), was used. Two types of VMA were used in the tested mortar and concrete mixtures. First type of VMA was a surfactant type, Viscotop 200LS (labeled as Surf 20K), which is composed of alkyl aryl sulfonate and alkyl ammonium salt blend. Another type of VMA was starch ether, which is the polysaccharide compound extracted from natural plants. The chemical structures of such VMAs are shown in Fig.1 (a) and Fig.1 (b), respectively.



(a) Chemical structure of Surf 20K

(b) Chemical strucutres of starch ether [19]

Figure 1 Chemical Structures of VMAs

Table 1 Chemical compositions and physical properties of binders.

Binder	**Chemical compositions [% by weight]**								**Blaine's fineness [cm²/g]**	**Specific gravity**
	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	Na_2O_3	SO_3	K_2O		
OPC	18.93	5.51	3.31	65.53	1.24	0.15	2.88	0.31	3100	3.15
FA	35.71	20.44	15.54	16.52	2.0	1.15	4.26	2	2867	2.21

2.2 Mix proportions

In this study, all the mixtures of concrete and mortar were prepared with the same water to binder ratio of 0.39 and sand to mortar ratio by volume of 43%. Fly ash (FA) was used as a cement replacement material at the level of 35% by weight of total binder. From Table 2, the mixtures of concrete (C0-C2) were used to evaluate the bleeding and compressive strength of the concrete. The control mixture (C0), having no VMA, was made by using PC-M 0.35% by weight of binder in order to obtain concrete with a slump 170±10 mm. To investigate the effect of VMAs on concrete performance, 5% dosage of surfactant type VMA (Surf 20K) by weight in unit water content was used in mixture C1, and 0.5% concentration of starch solution in unit water content was used in mixture C2.The dosages of PC-M at 0.35% and 0.6% by weight of binder were used in the concrete mixtures with the surfactant type VMA and starch ether, respectively, in order to obtain 170±10 mm slump which was the same as the slump of control mixture (C0). It should be noted that since the 2 types of VMA are of different nature, it is not possible to apply at the same dosage %. It was found from our preliminary study that 5% and 0.5% are optimum dosages for the surfactant type and starch ether, respectively, by considering deformability and viscosity. The mortar mixtures (M0–M2) were prepared as representative samples of concrete (C0-C2), having the same sand to mortar ratio by volume. The mortar mixtures were tested to quantitatively measure the dewatering under high pressure. Further details about the mix proportion of the tested concrete and mortar samples are shown in Table 2.

Table 2 Mix proportions of the tested concrete and mortar samples with w/b 0.39

Mix Designation	**Type of VMA**	**C (kg/m³)**	**FA (kg/m³)**	**S (kg/m³)**	**G (kg/m³)**	**W (kg/m³)**	**SP/b (%)**	**VMA/W (%)**
C0	-	312	168	715	1015	187	0.35	0
C1	Surf 20K	312	168	715	1015	187	0.35	5
C2	Starch	312	168	715	1015	187	0.6	0.5
M0	-	490	264	1114	-	294	0.35	0
M1	Surf 20K	490	264	1114	-	294	0.35	5
M2	Starch	490	264	1114	-	294	0.6	0.5

C: cement, FA: fly ash, S: sand, G: Gravel, W: water, b: binder, SP: superplasticizer, VMA: viscosity modifying agent

2.3 Bleeding of concrete

A sample consolidated by a tamping method according to ASTM C232 was conducted to measure the bleeding of concrete. A cylindrical container having an inside diameter of 255±5 mm and a height of 280±5mm was used to measure the bleeding of concrete. After placing fresh concrete mixtures into the cylindrical container, the accumulated water at the top surface was drawn off at 10 minutes interval during the first 40 minutes, then 30 minutes interval until cessation of bleeding. The accumulated bleeding b(t), expressed as the percentage of the unit water content in the mixture according to ASTM C232 [20] can be calculated as follows

$$b(t) = \frac{w(t)}{WAH}\ X\ 100 \qquad (1)$$

where w(t) is the weight of bleeding water (kg) at time t (min), W is the unit water content of the tested mixture (kg/m^3), A is the cross-sectional area of the sample (m^2) and H is the height of the sample (m).

2.4 Dewatering of Mortar Under Pressure

Since there is a lack of standard instrument for measuring the dewatering of concrete under high pressure, in this study the cylindrical pressure vessel having an internal diameter of 80 mm and a height of 330 mm was developed to measure the dewatering under pressure as shown in Fig. 2. A porous stone having a diameter of 100 mm and a thickness of 6 mm was fixed at the bottom of the device to filtrate the drained water from the mortar sample. A filter paper was placed at the top of the porous stone before filling the cylinder with mortar samples. A freshly mixed mortar sample was placed in the vessel up to the height of 250 mm while the bottom valve was closed. A force of 3.62 KN with a stroke of 6 mm/min was applied directly to the sample through a piston in order to create pressure on the sample corresponding to a self-weight pressure of 30 m deep and 1m in diameter of a bored pile. Open the bottom valve after reaching the target pressure. Continue applying the force on the sample till the sample was finally consolidated. However, a slight fluctuation of load was observed during the dewatering test of mortar under pressure. The deviation of load during the test was ±5.64% of targeted load of 3.62 KN. The drained water from the sample during the pressurization was collected and measured periodically after opening the bottom valve. The accumulated dewatering percentage, d(t), is expressed as the percentage of the unit water content in the mixture [21]-[22] and can be calculated in the similar manner as calculating the accumulated bleeding b(t).

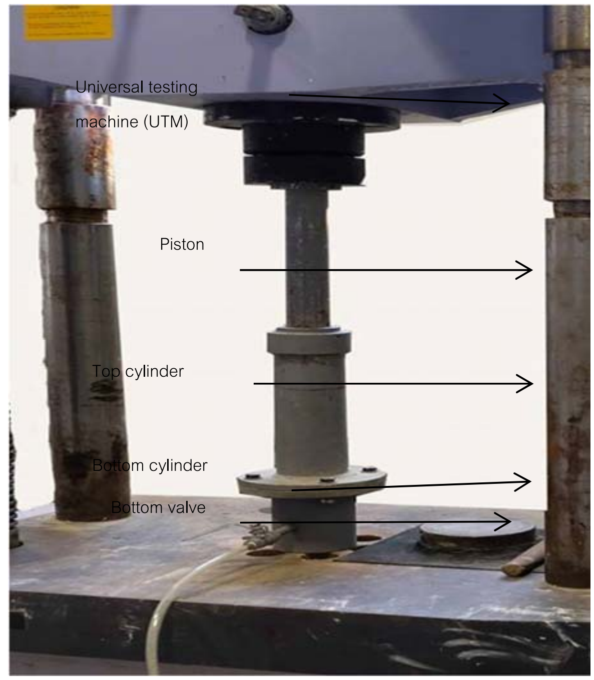


Figure 2 Experimental Setup of Dewatering Device for Dewatering Test

2.5 Compressive Strength

The compressive strength of cylindrical concrete specimens having a diameter of 100 mm and a height of 200 mm at the age of 7 days and 28 days were measured according to ASTM C39. Three specimens were tested for obtaining an average at a concrete age. The effect of VMAs on compressive strength was evaluated from the different mixtures (C0-C2) of concrete.

3. Results and Discussions

3.1 Effect of VMA on Bleeding of Concrete

The influence of VMAs with PC-M superplasticizer on bleeding of concrete is shown in Fig. 3. It can be observed that the addition of Surf 20K effectively reduces the bleeding of concrete as compared to the concrete without Surf 20K. The bleeding ratio of concrete (C0) without VMA is 2.5%, whereas the same concrete containing 5% dosage of Surf 20K shows no bleeding. On the other hand, starch moderately reduces the bleeding of concrete. Concrete containing 0.5% concentration of starch solution in unit water content is used in the mixtures C2 with PC-M at the dosage of 0.6% of binder in order to control the slump 170±10 mm as same as the control mixture (C0). Starch reduces the bleeding of concrete (C2) from 2.5% to 1.7%. It is because Surf 20K makes the micelle net structures in the liquid phase. This micelle structure lowers the amount of free water in the mixture by restricting the free water, as well as increases the stiffness of solid structures and reduces permeability of the fresh concrete, therefore, reduces the bleeding of the concrete. In addition, reduce bleeding in concrete by application of VMAs was also mentioned in [13].

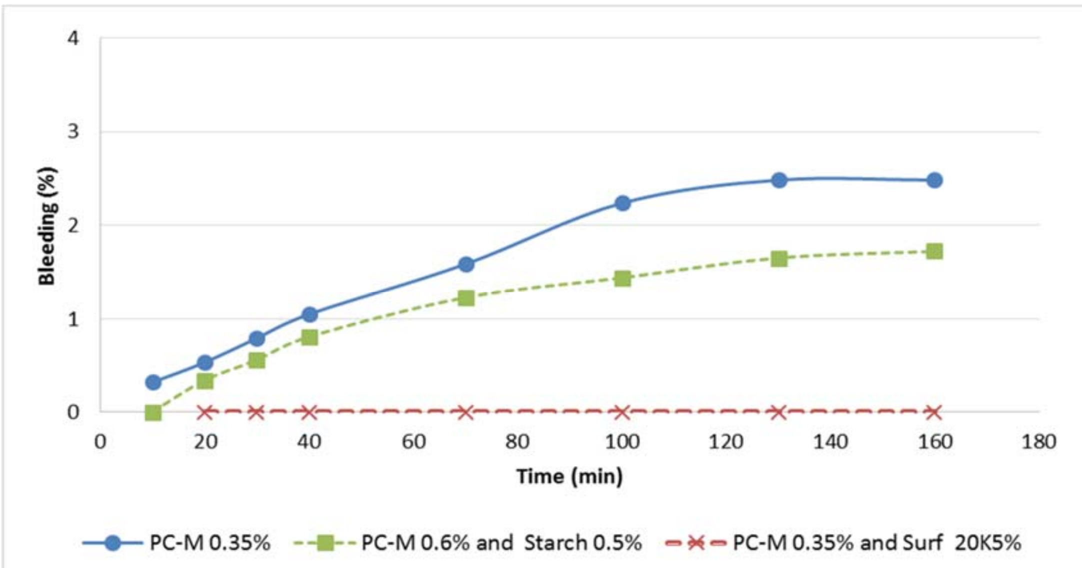


Figure 3 Effect of VMAs on Bleeding of Concrete

3.2 Effect of VMAs on Dewatering of Mortar Under High Pressure

The effect of VMAs on dewatering of mortar under high-pressure (0.72 MPa) is presented in Fig.4. It can be seen that the absolute dewatering of the control mortar (M0) without VMA is 24.3% and by adding 5% dosage of Surf 20K, the dewatering reduces significantly to 2.9%. The test was conducted 3 times and it was found that a slight fluctuation of dewatering was observed during the test and the standard deviation of the dewatering result was 0.075. The reduction of dewatering is because Surf 20K makes the threadlike micelle net structures in the mixtures as can be confirmed by SEM image in Fig.5. This micelle net structure lower the amount of free water in the mixtures by holding the water with its structures, reducing the permeability of the fresh mixtures and increasing the stiffness of the fresh mixtures. On the other hand, the use of starch only slightly reduces the dewatering under high pressure as comparing to the control mixtures. By adding the 0.5% concentration of starch solution in unit water content in the same mixture condition, the dewatering of mortar only reduces from 24.3% to 23.2%. The reduction of dewatering in the case of starch type VMA is less significant when compared to the case of surfactant type VMA (Surf 20K). It is because starch only increases viscosity of the mixing water without ablilities to restain water, to reduce permeablility and to increase stiffness of the mixtures when compared to the surfactant type VMA.

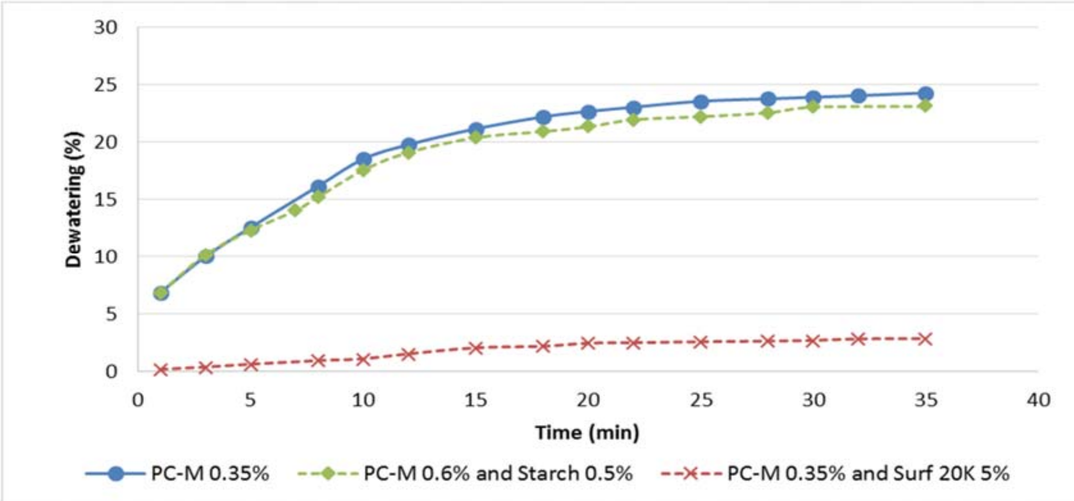


Figure 4 Effect of VMAs on Dewatering of Mortar Under Pressure

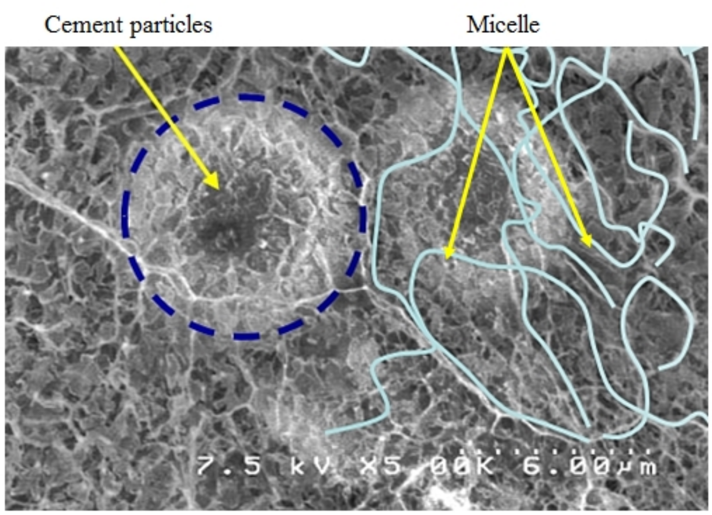


Figure 5 Network of Threadlike Micelle in Water Phase Covers Cement Particles at Magnification of 5000x

3.2 Effect VMA on Compressive Strength of Concrete

The effect of VMAs on compressive strength of concrete at the age of 7days and 28 days is shown in Fig.6. It can be observed that the compressive strength of concrete without VMA at 7 days and 28 days are 35.2MPa and 45.8MPa, respectively. By adding 5% dosage of Surf 20K in same concrete mixtures, compressive strength at 7 days and 28 days reduces slightly to 33.1 MPa and 44.18MPa, respectively. Since surfactant type VMA can be considered as an air entraining agent, the strength loss of sample is occurred due to air entrainment [23]. On the other hand, for concrete containing 0.5% concentration of starch solution in unit water content in the concrete mixture (C2), the compressive strength of concrete at 7days and 28 days reduces to 31.3MPa and 39.63 MPa, respectively. It is indicated that VMAs slightly reduces compressive strength of concrete. The surfactant type VMA has smaller effect on compressive strength than the starch ether type.

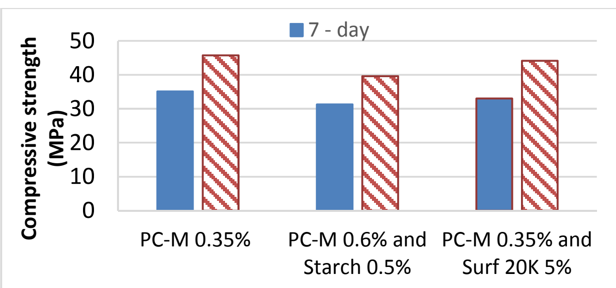


Figure 4 Effect of VMAs on Compressive Strength of Concrete at 7 and 28 Days

4. Conclusions

The effect of VMAs on bleeding of concrete, dewatering of mortar under high pressure and compressive strength of concrete is demonstrated in this work and the following conclusions can be drawn based on the results obtained from this experimental study.

- Bleeding of concrete is completely inhibited by using the surfactant type VMA at the dosage of 5% whereas starch moderately reduces the bleeding of concrete.
- Dewatering resistance of fresh mortar drastically increases with the addition of surfactant type VMA. On the other hand, starch ether is not able to improve the dewatering resistance under high pressure.
- Both of VMAs (Surf 20K and starch) slightly reduces the 7-day and 28-day compressive strength of concrete.
- The results of this study indicate that use of surfactant type VMA is beneficial to control the bleeding and dewatering of concrete under high pressure such as bored pile concrete.

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