EFFECTS OF VISCOSITY MODIFYING AGENTS ON FRESH AND HARDENED PROPERTIES OF CONCRETE

BY

UPENDRA NEUPANE

A THESIS SUBMITTED IN PARTIAL FULFILLMENT OF THE
REQUIREMENTS FOR THE DEGREE OF MASTER OF SICEINCE
(ENGINEERING AND TECHNOLOGY)
SIRINDHORN INTERNATIONAL INSTITUTE OF TECHNOLOGY
THAMMASAT UNIVERSITY
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A Thesis Presented

By
UPENDRA NEUPANE

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Abstract

EFFECTS OF VISCOSITY MODIFYING AGENTS ON FRESH AND HARDENED PROPERTIES OF CONCRETE

by

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This study emphasizes the effects of viscosity modifying agents (VMAs) on fresh and hardened properties of concrete. The properties of concrete were examined in terms of initial slump, bleeding, air content, setting time, compressive strength of concrete, and dewatering of mortar under high pressures. Additionally, the effect of surfactant type VMA on blending between concrete and bentonite fluid was also examined. Two different types of VMA, which are a surfactant type and a starch ether type with various dosages were used with or without water reducing admixtures in the tested mortar and concrete mixtures.

From the experiments, it was found that the tested surfactant type VMA was not compatible with type D admixtures. The surfactant type VMA with type F admixtures increased the initial slump and air content, significantly reduced the bleeding, slightly reduced the compressive strength and had a negligible effect on setting time of the concrete. However, surfactant type VMA slightly increased the setting time of fly ash concrete. Furthermore, it effectively reduced blending between bentonite fluid and concrete. On the other hand, the use of starch in concrete mixtures slightly increased the air content, moderately reduced the bleeding, and slightly reduced the compressive strength of concrete. The increase of air by starch is less significant when compared to the case of surfactant type VMA. In the case of mortar test, the addition of surfactant type VMA slightly increased the mortar flow and v-funnel flow time due to enhancement of the air content and viscosity, respectively, of the mixtures, whereas starch ether decreased the mortar flow and increased the v-funnel time due to viscosity increase. By using dosages of surfactant type VMA equal to or higher than 3%, the pressurized dewatering of the mortars was significantly reduced. Furthermore, the use of surfactant type VMA in mortar mixtures with polycarboxylate based superplasticizer effectively reduced the pressurized dewatering of mortar whereas use of surfactant type VMA with naphthalene based superplasticizer was ineffective to reduce the dewatering of mortars under high pressure. Similarly, the use of starch in mortar mixtures was ineffective to reduce dewatering of mortars under high pressure.

Keywords: Bleeding, Pressurized dewatering, High pressure, Bored piles, Viscosity modifying agents.

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Chapter1

Introduction

1.1 Background of Study

Concrete is a 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 produce durable concrete structures. One of the important problems of fresh concrete causing the durability problem in long term is bleeding (Powers,1968). Bleeding is a form of segregation where some of the water in a freshly mixed concrete tends to drain out to the surface. It happens due to different specific gravity of ingredients of concrete. The heavier particles of concrete settle down faster while water, having the lowest specific gravity as compared to other components of concrete, moves up to the surface (Nevil, 2011).Various studies (Thumasujarit & Tangtermsirikul, 2004; Thumasujarit & Tangtermsirikul, 2005; Hoshino, 1989; Tangtermsirikul, 1989; Yim et al. 2013) state that the amount of bleeding water depends on water to binder ratio, free water content, present of fine particles, type and dosages 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 (Ouchi, 2015). When the concrete mixtures are placed in a deep bored pile, the mixture is pressurized due to its self-weight, bleeding as well as channeling or dewatering happen (Kog, 2009). Due to the high pore pressure in a deep section, water is squeezed out from the concrete which is known as dewatering. The mechanism of dewatering in a bored pile is that water can flow under pore pressure gradient which is based on Darcy’s law (Tangtermsirikul, 1988). Variation of the pressure gradients and amount of free water present in mixtures affect the bleeding and dewatering properties in terms of the rate and the amount of drained water (Yim et al., 2014). Loh.et al. (1989) studied the dewatering on channeling in cement paste and mortar model pile. In both cases (paste and mortar models) dewatering started at a certain level from bottom and stopped before reaching the top surface.

Prediction of bleeding of concrete is important in order to control the quality of the hardened concrete. Conventional test methods ASTM C232, ASTM C243 are normally used to measure the normal bleeding. Till date, there is lack of specific methods used to measure the dewatering of concrete under high pressure. In many bored pile constructions, 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 piles and later trimming it to the cut off level (Sliwinski & Fleming, 1983). This causes extra expenses to the construction of bored piles. But in the case of dewatering, there is no any appropriate method applied to evaluate the dewatering of concrete in bored piles under pressure. Khayat (1998) explained that a part of 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. Therefore, the evaluation and control of the dewatering of fresh concrete under pressure is very significant to save the labour, cost and to control the quality of the bored piles.

On the other hand, in boreholes, various pressure like hydrodynamic pressure, overburden pressure, pore water pressure and active earth pressure are exerted during boring. Due to such pressures the side of borehole becomes unstable and is possible to collapse. For stabilizing the side of the borehole, supporting fluid such as bentonite is used to counter the above pressure (Fleming, 2008). During the period of concreting in the borehole, there are some possibilities of mixing the bentonite fluid or ground water in the borehole with fresh concrete. This affects the actual properties of designed concrete and leads to reduction of strength and durability of bored piles structures (Tomlinson, 2008).

The workability of concrete can be controlled by the use of superplasticizers (SP) and 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 (EFNARC, 2006). The most important aspect is that VMAs, commonly used with SP, should not worsen any fresh properties of the mixtures except increasing viscosity (Umar et al., 2011). Currently, some viscosity modifying agents (VMAs) are used to control the normal bleeding of concrete (Lachemi et al., 2004).Various studies (Khayat, 1998; Lachemi et al., 2004; Rols et al., 1999; Umar et al., 2011) described 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 (EFNARC, 2006; Khayat, 1997). 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 dewatering of freshly mixed mortar under high pressure. A dewatering device was developed to experimentally measure the potential dewatering of fresh mortar under high pressure. The flow properties such as mortar flow, v-funnel speed were also tested in order to investigate the effect of VMAs on workability and viscosity of mixtures. Additionally, effect of surfactant type VMA on the properties of concrete such as initial slump, compressive strength, setting time was investigated quantitatively, and its effect on blending between concrete and bentonite fluid was investigated qualitatively.

1.2 Statement of Problems

Bleeding of concrete creates serious problems which affect various properties of concrete from fresh state to hardened state. The segregation of water from solid particles reduces homogeneity of concrete which will affect the quality of the concrete. In order to minimize such problems, a control of bleeding and dewatering of concrete is important to build durable structures.

Bored piles concrete can face the problems of bleeding and dewatering under pressure. 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. It increases the use of labour, materials and spends more time to complete the piling process, as a result it increases the cost of construction.

On the other hand, there is still no any standard instrument for measuring the dewatering of concrete under high pressure. Furthermore, the suitable admixture is hardly found for controlling the dewatering of concrete in bored piles under high pressure. Therefore, the evaluation and control of the dewatering of fresh concrete under pressure is very significant to save the labour, time, and cost and to control the quality of the bored piles.

Similarly, the strength reduction of pile structures due to mixing bentonite fluid and ground water with concrete is another serious problem in bored piles concrete. Therefore, to understand the performance of VMA on preventing the blending between the concrete and the borehole stabilizing fluid, such as bentonite slurry, selection of the proper type VMA for designing mix proportion of concrete is beneficial to control the blending of fresh concrete and the bentonite slurry.

This study will be useful to control bleeding and dewatering of concrete, and reduce the blending between concrete and bentonite fluid, especially in bored piles concrete.

1.3 Objectives and Scopes of the Study

The key objective of this study is to evaluate the effect of viscosity modifying agents (VMAs) on bleeding and dewatering of fresh concrete under high pressure. The developed dewatering device was designed and the experimental programs were carried out in order to determine the dewatering of freshly mixed mortars under high pressure. The flow properties; mortar flow and v funnel flow time, of mortar were additionally tested in order to examine the effect of VMAs on workability and viscosity. Moreover, the effects of surfactant type VMA with type D and type F water reducing admixtures on fresh and hardened properties of concrete were determined. The fresh properties of concrete were evaluated in terms of initial slump, bleeding, air content, setting time of concrete and hardened property was tested in terms of compressive strength of concrete at 7 days and 28 days. Furthermore, the effect of surfactant type VMA on blending between fresh concrete and bentonite fluid used in bored pile concrete was investigated.

This study deals with the effect of VMAs on performance of concrete. Two different types of VMA, namely a surfactant type and starch ether type were used in the mortar and concrete mixtures. The mix proportions of concrete and mortar mixtures were prepared with water to binder ratios of 0.39, 0.45 and 0.55. Additionally, two types of admixture, which are a type D (lignosulphonate based) and a type F (polycarboxylate based or naphthalene based) with different dosages were used in the tested mixtures in order to control the concrete with the slump of 175±25mm. Furthermore, a load of 3.62 kN ±5.6% was applied on the mortar samples to measure the dewatering under pressure.

1.4 Significance of Study

This study aims to find the proper methodology to measure the dewatering of mortars under high pressure and investigate the effects of different types and dosages of VMAs on dewatering under high pressure.

This study investigates the performance of different VMAs on fresh and hardened properties of concrete. Additionally, it will be applied to minimize the existing problems of bored piles such as dewatering of concrete under high pressure and blending between bentonite and ground water with the bored pile fresh concrete.

Chapter 2

Literature Review

2.1 Bleeding of Concrete

Neville (2011) explained that bleeding is a form of segregation in which some of the water in the freshly placed mixture of concrete or mortar tends to drain out to the surface. It is caused by the inability of solid ingredients of the mix to hold all of the mixing water and to support the total gravitational weight of the mixture. The heavier particles of concrete settle down faster while water, having the lowest specific gravity as compared to other components of concrete, travels upward. Powers (1968) defined bleeding as the accumulated water to the surface of freshly placed and compacted concrete. It is a kind of settlement where the water is forced to the surface as the heavier solids in the concrete settle.

2.1.1 Bleeding mechanism

Bleeding water is the water which is free from the restriction of the solid particles in the concrete and is raised and accumulated on the top surface of the freshly mixed concrete. Principally, it happens due to gravitational settlement of the solid particles and inability of solid particles to hold all of mixing water in concrete (Neville, 2011).

Thumasujarit (2005) described the phenomena of bleeding of concrete by considering the different forces in concrete as shown in Fig 2.1. Normally the weight of concrete is supported by the contacts of solid particles, pore water inside the concrete and friction between the concrete and formwork which develop the effective stress, the pore pressure and friction stress, respectively. Due to the difference of pore pressure along the vertical direction, water will rise to the top surface of concrete.

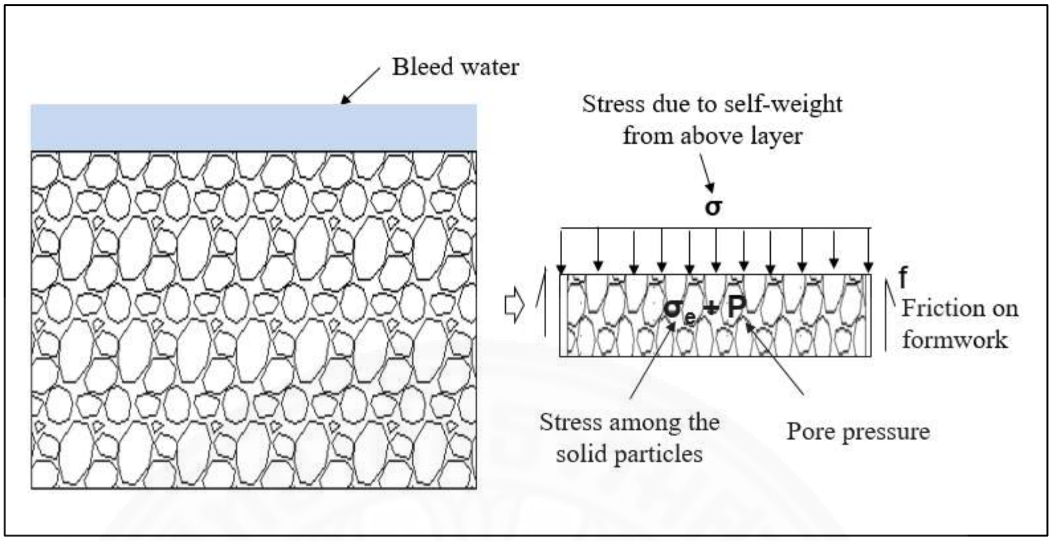

Fig. 2.1 Mechanism of bleeding of concrete

2.1.2 Causes and effects of bleeding

The major causes of bleeding of fresh concrete are lack of fine particles and high water content in the mix. When water to cement ratio is increased in the concrete, the rate of bleeding will increase due to increase of free water in the mixture. The presence of more fine particles in concrete will decrease the bleeding because fine particles have better water retaining capacity than the coarse particles (Powers, 1968).

Bleeding in concrete can have multiple negative effects on its fresh stage as well as hardened stage of concrete structures. Bleeding can result in high water to cement ratio near the top surface, which causes increase of the permeability and reduce the strength of the structures. The bleed water which accumulates below the reinforcing bars and cranked bars, reduces the bond strength between the reinforcement and concrete (Khayat, 1998). Heavy laitance gathering at horizontal construction joints near the surface can cause a plane of weakness at the joint (Hoshino, 1998). Bleeding may cause a poor pump ability due to blocking the gravel in pipelines (Kwon, 2013). It can delay finishing of the construction as well as cause the loss of homogentiy.

2.1.3 Bleeding measurement

A sample consolidated by a tamping method according to ASTM C232 can be used to measure the bleeding of concrete. A cylindrical container having an inside diameter of 255±5mm and height of 280±5mm is used to measure the bleeding of concrete. The geometry and dimension of the container is shown in Fig. 2.2. After placing fresh concrete mixtures into the cylindrical container, the accumulated water at the top surface is drawn off at 10 minutes interval during the first 40 minutes, then 30 minutes interval until cessation of bleeding.

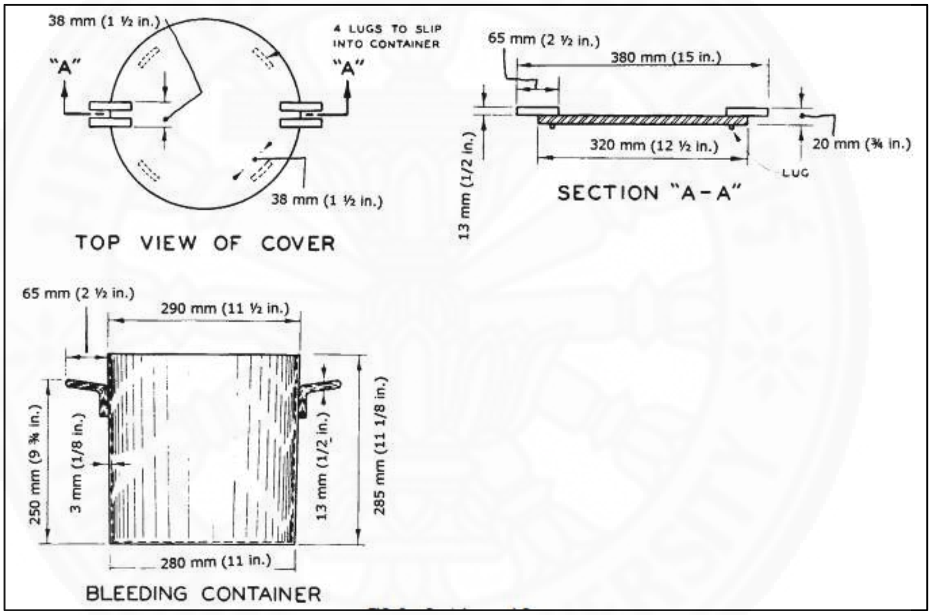

Fig. 2.2 A cylindrical container for bleeding test (ASTM C232, 1999)

2.2 Bleeding in a Bored Pile

When the concrete mixtures are placed in a deep bored plie, there is bleeding as well as channeling or dewatering (Kog, 2009). Some of bleeding water gathered at the top surface of a bored pile whereas dewatering starts at a certain level from the bottom and stop before reaching the top surface (Loh.et al.1998). This phenomenon happens immediately after pouring the concrete in a borehole which is influenced by self-weight of concrete as well as external factors such as ingress of water in the hole, hydrodynamic pressure, overburden pressure, pore water pressure and active earth pressure in bored pile as shown in Fig. 2.3 (Fleming, 2008). Variation of the depth of a bored pile indicates the variation of pressure. The variation of the pressure gradients and free water present in concrete mixtures affect the bleeding and dewatering properties of concrete such as the rate and the amount of drained water (Yim, 2014).

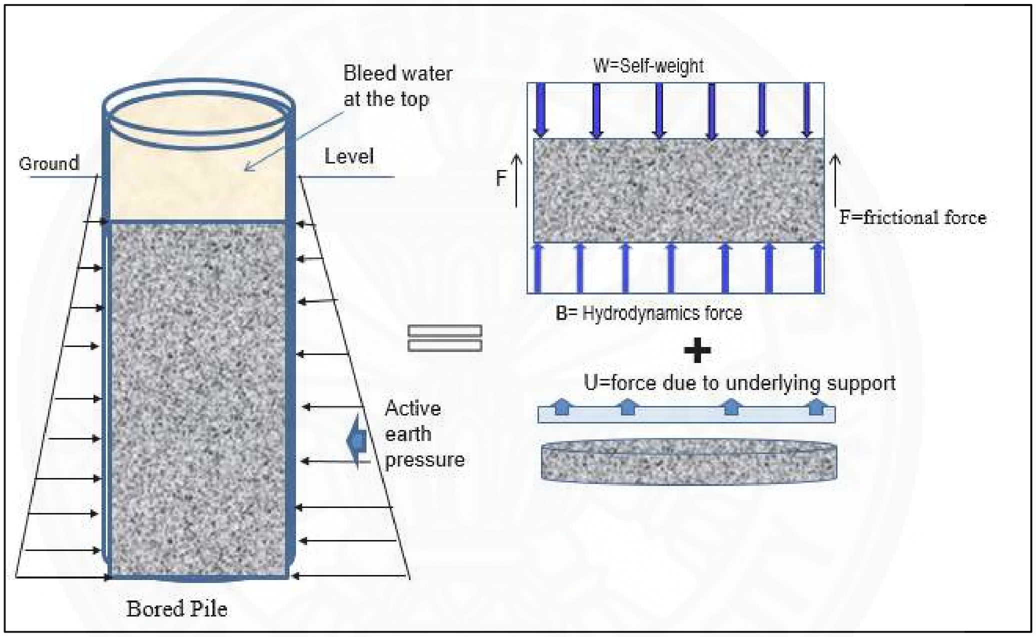

Fig. 2.3 Different forces acting on a bored pile

2.2.1 Dewatering mechanism in a bored pile

The concrete mixture is pressurized due to its self-weight when it is placed in a deep bored pile. There is normal bleeding as well as internal bleeding or channeling (Kog, 2009). Due to the variation of pressure in a deep section, water is squeezed out from the concrete mixtures which is known as dewatering. The mechanism of dewatering under high pressure is described as flow of water under pore pressure gradient which is based on Darcy’s law (Tangtermsirikul, 1988).

Power (1939) demonstrated that during bleeding, water rises up and the particles network in the top portion would be weakened by dilution. The hydraulic gradient in the concrete apparently does not decrease as fast as the weakening process by bleeding. This process causes some ruptures at certain points in the particle networks and thus causes channeling.

Loh.et al. (1998) stated that when an upward hydrodynamic force in a fresh concrete plug is more than the downward forces, water tends to move in upward direction and thereby allow the formation of a channel. It starts at some distance from the base and stop before reaching the top surface.

2.2.2 Problems in a bored pile

Tomlinson (2008) presented that bored piles have very high depths. During excavation as well as before filling the concrete in boreholes, bore holes are subjected to various types of additional pressures such as active earth pressure, overburden pressure due to surcharge load, pore pressure due to underground water, hydrostatic pressure etc. Due to these pressures, the side of borehole is unstable which lead to collapse because the soil strata are not able to resist such pressures. In order to prevent from such problems, a supporting fluid like bentonite is used to counter the corresponding pressures (Fleming, 2008). Bentonite slurry penetrates the walls of the bore and to form like as a filter cake which acts as a sufficiently impervious diaphragm to allow the transmission of hydrostatic slurry pressure. To ensure bore stability, the hydrostatic pressure of the bentonite slurry must be greater than the sum of the water pressure and the net pressure of the soil (Fleming W.K, 1986). However, during the concreting, there is a possibility of bentonite to flow into the concrete. This is a serious defect and it is difficult to detect during the construction (Tomlinson, 2008).

The major problems in bored piles concrete are bleeding and channeling of concrete in fresh state and reduction in its strength in hardened state. Bleeding happens after placing the concrete in the borehole, then this bleed water of concrete with ingress of small quantities of ground water move into pile continuously in upward direction

(See Fig 2.4). Such bleed water and laitance bleeding of concrete may cause a weakness in the pile shaft (Fleming, 2008). Most of the real practices seem to believe that the bleeding problem is considered only at the top part of the piles and this problem is solved by overcasting the bored pile at a certain length and latter trimming it to the cut off level (Sant G, 1979). This causes extra expenses to the construction. On the other hand, due to the variation of pressure in bored pile concrete, water is squeezed out from the concrete and trapped at the underside of reinforcing bars and aggregates, thus creating the abnormal voids inside the concrete, weakening the bond strength between the constituents and reducing the strength and durability of concrete structures (Hoshino, 1989; Khayat, 1998).

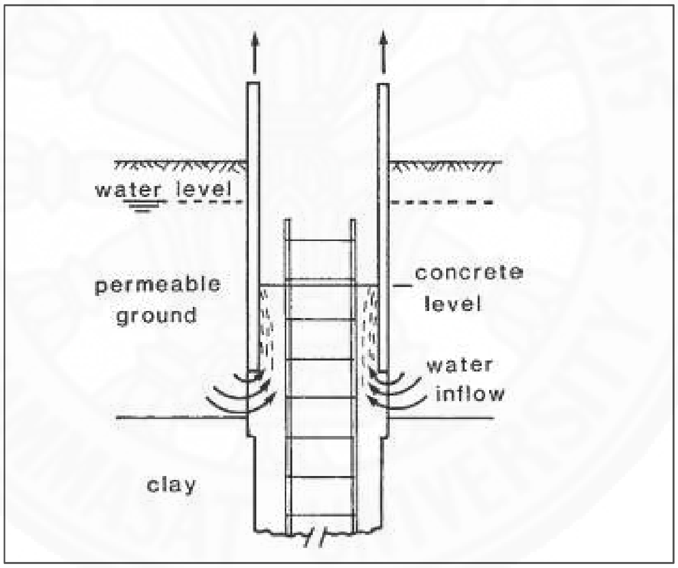

Fig. 2.4 Water inflow at head of pile (Fleming, 2008)

2.2.3 Measurement of bleeding under pressure

Yim (2014) developed a pressure vessel to measure bleeding of fresh cement paste, mortar and concrete mixtures under high pressure. A pressure vessel having 150 mm inner diameter and 300 mm height was fabricated by stainless steel. The detail of the developed pressure vessel is shown in Fig 2.5. A porous stone was used to filtrate the water from the sample. The validity of porous stone was tested before used in the vessel in order to confirm the hydraulic conductivity by measuring the drainage water through the porous stone. The flow rate increased linearly with time (see Fig. 2.6) indicates that the proposed porous stone was valid to be used for all tests.

Bleeding properties of samples were measured by filling the vessel with a sample up to 170 mm with the bottom valve closed, then equipped an internal piston for applying the pressure on the sample. The applied force via the piston was measured with a load cell attached to the loading axis. Then the bottom nozzle was opened to collect the drained water through the sample during pressurization and measurements were done periodically till the sample was finally consolidated and there is no more drained water from the sample.

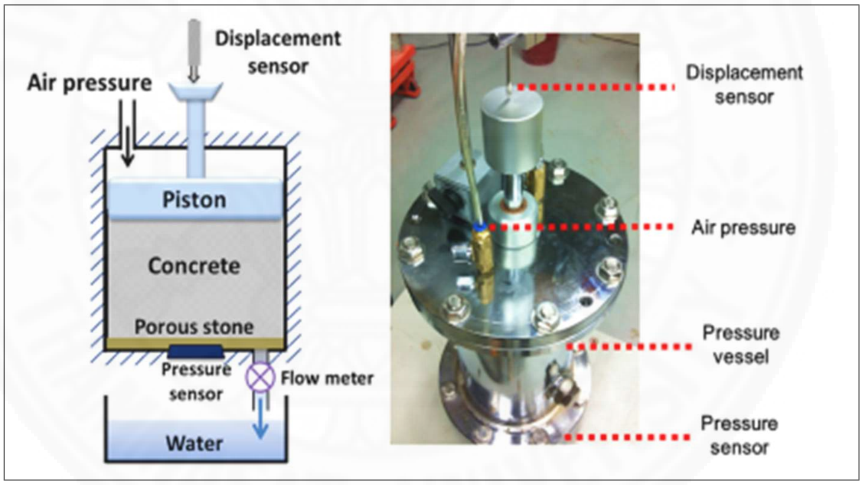

Fig. 2.5 Pressure vessel bleeding test equipment (Yim, 2014)

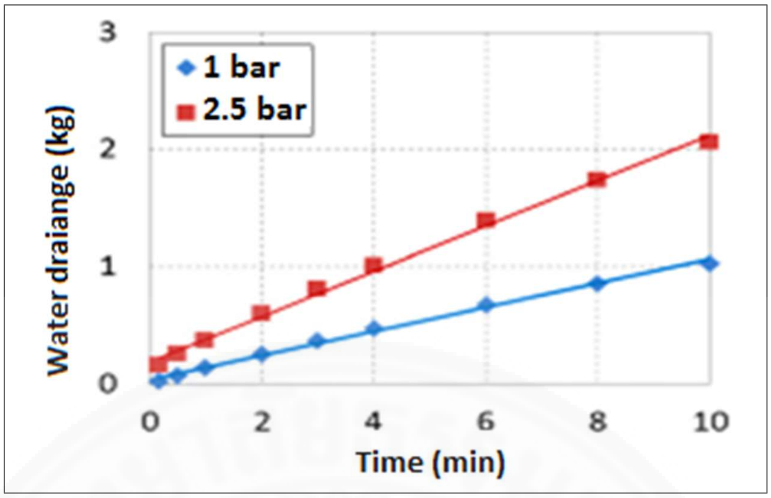

Fig. 2.6 Drainage of water through porous stone when only water is present in the vessel under atmospheric pressure (1 bar) and an additional pressure of 2.5 bar (Yim 2014)

2.2.4 Bleeding of cement paste, mortar and concrete under pressure

Yim (2014) observed the variation of bleeding ratios of cement paste, mortar and concrete under pressure of 2.5 bar. Fig 2.7 illustrates that the final bleeding ratio of cement paste is relatively higher and rate of bleeding is slower than mortar and concrete. It is because aggregates are responsible to develop the internal resistance. In the case of concrete sample, it provides higher resistance as compared to mortar and paste due to presence of large aggregates which is responsible to build a solid aggregate interlocked network than mortar and paste. On the other hand, the rate of bleeding from cement paste is slower than the mortar and concrete samples; however the final bleeding percentage of the cement paste and mortar were higher when compared to concrete. This was due to the lower permeability of cement paste.

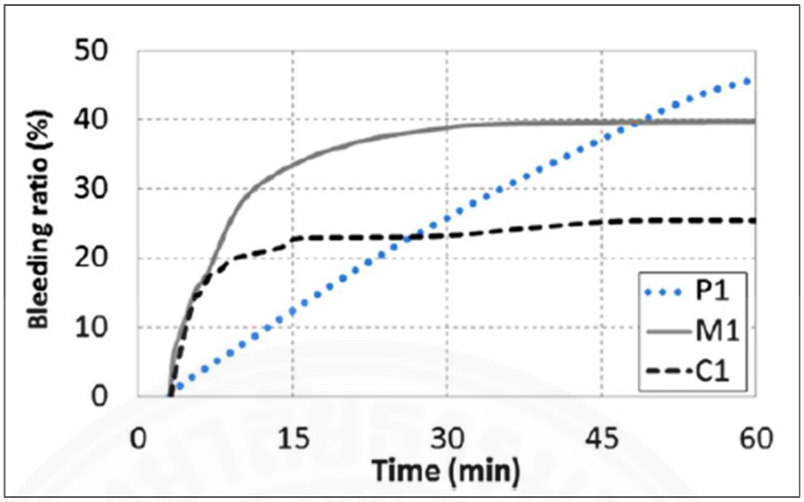

Fig. 2.7 Bleeding ratio under high pressure (Yim, 2014)

2.3 Viscosity Modifying Admixtures

Viscosity modifying admixtures are relatively new admixtures widely used in concrete construction work. It increases viscosity and cohesion of cement based system of fresh concrete by reducing the rate of separation of material constituents (EFNARC, 2006). Most of viscosity modifying agents (VMAs) are made from organic materials (biopolymers) such as polysaccharide based, cellulose ethers, starch ether and natural gum etc. These VMAs are water soluble which increase the viscosity and/or yield point of the paste (Khayat & Yahia,1997). Some VMAs are based on inorganic materials such as colloidal silica which are amorphous with small insoluble, non-diffusible particles but small enough to remain suspended in water without settling (EFNARC, 2006).

The workability of concrete can be controlled by the use of a superplasticizer (SP) and a viscosity modifying agent (VMA). SPs are used to enhance the flow ability whereas VMAs are used to stabilize the rheological properties and consistency of concrete (EFNARC, 2006). The most important aspect is that VMAs, commonly used with SP, should not worsen properties of the mixtures except increasing viscosity (Umar et al., 2011).

2.3.1 Functions and applications of VMA

The function of the VMA is to change the rheological properties of concrete mixtures. Rheology of fresh concrete can be explained in terms of yield value and plastic viscosity. The yield stress is related to the force needed to start moving concrete and the plastic viscosity describes the resistance of a concrete to flow under external stress (EFNARC, 2006). VMA is highly effective to control bleeding due to its long-chain molecules which adhere to the periphery of water molecules, thus it adsorbs and fix a part of the mix water, as a result it increases the yield value and plastic viscosity of concrete (Khayat, 1998).

VMA can be used to minimize bleeding of concrete, reduce segregation of self-compacting concrete and to prevent washout in under water concrete as well as reduce the friction and pressure in pumped concrete (EFNARC, 2006). It can compensate for poor gap grading aggregate especially sand having lack of fines.

2.3.2 Types of viscosity modifying agents

Mailvaganam, (1995) classified viscosity modifying agents (VMAs) in two categories according to the production source, one is organic materials (such as polysaccharides, cellulose ether derivatives, polyethylene oxide and polyvinyl alcohol), another is inorganic materials such as silica based materials (nanosilica and colloidal silica) which contains high surface area that increases the content of fine particles in paste. These materials include fly ash, hydrated lime, kaolin, various rock dusts etc.

Furthermore, VMAs are classified into five different classes according to their physical characteristics in concrete. These are: Class A) Water-soluble synthetic and natural organic polymers, Class B) Organic water-soluble flocculants, Class C) Emulsions of various organic materials, Class D) Water-swellable inorganic materials and Class E) Inorganic materials of high surface area (Mailvaganam, 1995).

Ruoting (2015) classified the VMA according to polymer based, chemical composition and its structure. The structure is composed of the long chain polysaccharide backbones and the short side groups which are starch, welan gum or diutan gum, cellulose ethers, and chitosan. The performance of VMA in concrete depends on the type and concentration of the polymer used in VMA.

Surfactant is another type of VMA used in concrete mixtures. This is a large group of surface-active substances used in various applications because of their relatively complex behaviors. Surfactant molecule has a hydrophilic head and hydrophobic ends. These are categorized as ionics, cationic and anionic, according to natures of hydrophilic head (Ohama, 1995). Surfactants are usually added to mortars and concrete in order to enhance some properties such as workability, water retention and permeability (Afridi et al., 2003).

2.4 Factors Affecting the Bleeding of Concrete

2.4.1 Water to binder ratio

Powers (1968) found that lowering the amount of water content of the mixtures decreases the amount of free water in the mixtures. Additionally, lowering the water content of paste results in smaller average inter-particle distance and greater number of points of near -contact of solid particles thus enabling to make strong cohesive force. It leads to a decrease of bleeding whereas increasing the w/b ratio leads to an increase of bleeding.

Yim (2014) evaluated the SCC bleeding with different water to binder ratios of 0.66 and 0.44 and found that higher w/b ratio showed higher amount of bleed water in the samples. Lower the water to cement ratio means higher cement content in the mixture which leads to higher water retainability.

2.4.2 Percentage of fly ash

Helmuth (1987) reported that fly ash affected the bleeding characteristic of the fresh concrete. According to his study, the replacement of cement by fly ash can either increase or decrease the bleeding which depend on the fineness of fly ash. Thumasujarit

& Tangtermsirikul (2005) found that by increasing the percentage of fly ash in mixture tends to increase bleeding when water to binder ratio was kept constant. It is because fly ash has lower water retainability than cement, resulting in large amount of free water in the mixtures. By having a spherical shape of fly ash, the drag force between water and fly ash is smaller which leads to increase of the bleeding of concrete.

2.4.3 Pressure gradient

Tangtermsirikul (1989) studied dewatering of concrete under high pressure and found that amount of bleeding water depends on pressure gradient. Higher pressure on sample gives rise to larger bleeding capacity than that of low pressure. Thumasujarit (2005) observed the bleeding of fresh concrete specimens having different height and found that increasing the height of specimen resulted in increasing of bleeding. This is partly due to increase of pore pressure inside the sample due to increase self-weight of concrete.

Yim et. al. (2014) explained that the variation of pressure influenced the bleeding properties such as the amount and rate of drained water from the fresh cement paste, mortar and concrete mixtures. Variation of mixture height of sample indicates the variation of pressure. In a high concrete column or a deep bored pile, bleeding is expected to increase with increasing the height or depth of structures due to high pressure. For example, a concrete column or a bored pile, concrete having unit weight of 25 kN/m^2 and height of 4m create a pressure at the bottom which is 100 kN/m^2 (1bar) whereas 10m height of column generates 250kN/m^2 (2.5bar) due to its self-weight. Yim (2015) conducted a test related to bleeding of cement paste under high pressure of 2.5 bar, 7.9 bar and 25 bar and found that the highest pressure of 25 bar produces more bleeding when compared to the bleeding due to the other pressures of 7.5 bar and 2.5 bar, respectively.

2.4.4 Particle size and viscosity

Tangtermsirikul (1989) reported that the influencing elements of bleeding are surface area of solid particle, water to cement ratio and air content. Larger total surface area of solid particles, in fresh concrete resulted in smaller bleeding rate due to lower permeability of fresh concrete. Similarly, the influence of coarse aggregate on bleeding is less than that of fine aggregate. Furthermore, the mixture which had larger amount of free water expelled greater volume of discharge due to the higher permeability value than the mixture with lower amount of free water.

Yim et al. (2014) investigated the effects of total surface area of solid particles on bleeding of concrete and found that the larger total surface area of solid particles in fresh concrete mixture, the lower the permeability and dewatering of concrete.

2.4.5 Dosage of water reducing admixture

Bleeding depends on the type, chemical composition and dosage of water reducing admixtures used in concrete according to their ability of particle dispersion. Thumasujarit (2015) observed the effect of different dosages of water reducing admixtures on concrete samples having same w/b ratio of 0.5 and found that increasing the dosage of water reducing admixtures caused increasing of bleeding in concrete.

Chapter 3

Experimental Investigation

The experiments were conducted in order to evaluate the effect of VMAs on dewatering of mortars under high pressure. Their effects on flow properties; mortar flow and v-funnel time, of mortar were additionally examined. Moreover, the effect of surfactant type VMA on properties of concrete such as initial slump, bleeding, air content, compressive strength, setting time was investigated and its effect on blending between concrete and bentonite fluid was also examined.

3.1 Materials

3.1.1 Ordinary Portland cement

An ordinary Portland cement type I according to TIS 15, manufactured by Siam Cement Group Co. Ltd., Thailand was used throughout the study. The chemical compositions and physical properties of the cement are shown in Table 3.1.

3.1.2 Fly ash

Fly ash (FA) from Mae Moh electric power plant according to TIS 2135; was used as a cement replacing material. The chemical compositions and physical properties of the fly ash are shown in Table 3.1

Table 3.1 Chemical composition and physical properties of binders

Binder	Chemical compositions [% by weight]								Blaine's fineness [cm^2/g]	Specific gravity [g/cm^3]
	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

3.1.3 Aggregates

Natural river sand, conforming to ASTM C33 with a specific gravity of 2.59 in saturated surface dry condition was used as the fine aggregate. Crushed limestone having a maximum nominal size of 19 mm and a specific gravity of 2.83 was used as the coarse aggregate. Sieve analysis of aggregates was conducted according to ASTM C136. The gradation curves of fine and coarse aggregates are shown in Fig 3.1 and Fig.3.2, respectively.

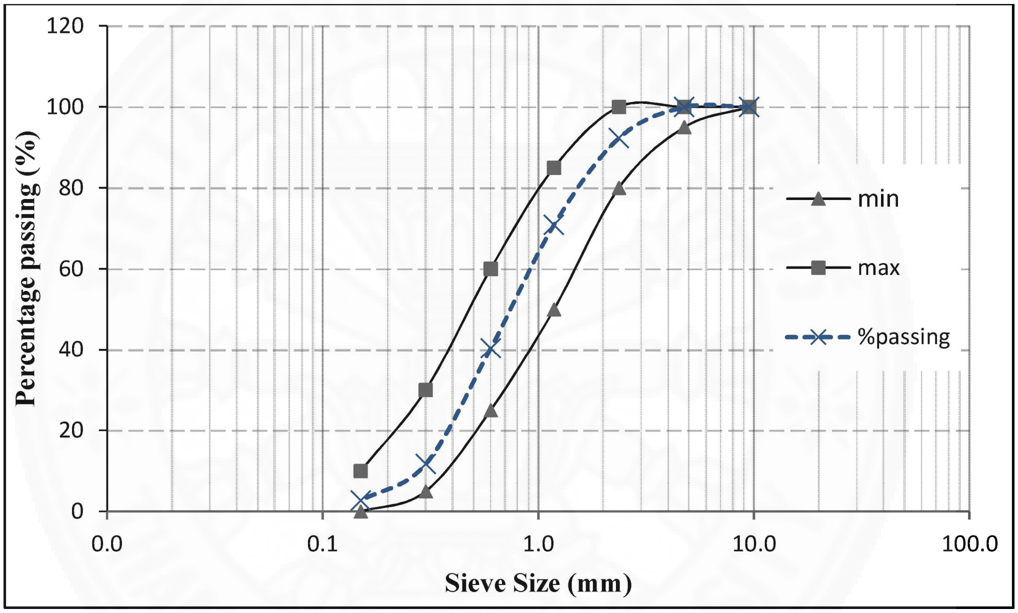

Fig. 3.1 Gradation curve of fine aggregates

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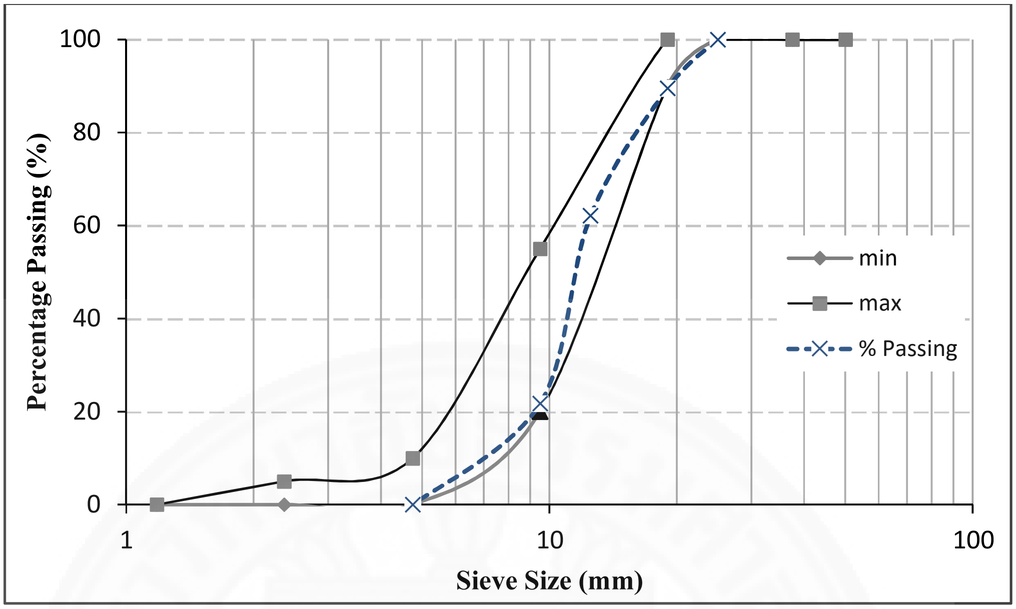


Fig. 3.2 Gradation curves of coarse aggregates

3.1.4 Chemical admixtures

Two different types of water reducing admixtures according to ASTM C494 (Type D and Type F), from different sources were used. Lignosulphonate based admixtures were used as type D admixtures whereas polycarboxylate based and naphthalene based superplasticizers were used as type F admixtures in the tested concrete and mortar mixtures. The details of admixture types, sources and labels are shown in Table 3.2.

Table 3.2 Details of chemical admixtures

ASTM Type	Base	Trade Name	Source	Label
D	Lignosulfonate	Daratard 12	Sika (Thailand) Ltd.	Lig-D
D	Lignosulfonate	Plastiment R	Sika (Thailand) Ltd.	Lig-P
D	Lignosulfonate	Mighty 90RA	Kao Industrial(Thailand) Co., Ltd.	Lig-M
F	Polycarboxylate	Viscocrete	Sika (Thailand) Ltd.	PC-V
F	Polycarboxylate	Mighty 21WH	Kao Industrial(Thailand) Co., Ltd.	PC-M
F	Polycarboxylate	Mighty 3000R	Kao Industrial(Thailand) Co., Ltd.	PC-M3
F	Naphthalene	Mighty MX-T	Kao Industrial(Thailand) Co., Ltd.	NL-M

3.1.5 Viscosity modifying agents

Two types of VMA, which are a surfactant type, Viscotop 200LS (labeled as Surf 20K), and a starch ether type were used in the tested mortar and concrete mixtures.

3.2 Experimental Program

Five different experimental programs were conducted in order to examine the effects of VMAs on mortar and concrete performances. The details of each experimental program are shown in Table 3.3.

Table 3.3 Experimental programs

Program No	Descriptions	Type of Specimen	Studied properties	Test Standard
1	Effect of both VMAs on mortar and concrete performances	Mortar	Flow properties	EN 1015-3
			Dewatering	No standard
			Air content	ASTM C231
2	Effect of Surf 20k with type D admixtures on cement-only concrete	Concrete	Initial slump	ASTM C143
			Compressive strength	ASTM C39
			Setting time	ASTM C403
		Mortar	Dewatering	No standard
3	Effect of Surf 20K with type F admixtures on cement-only concrete	Concrete	Initial slump	ASTM C143
			Compressive strength	ASTM C39
			Setting time	ASTM C403
		Mortar	Dewatering	No standard
4	Effect of both VMAs with type F admixture on concrete containing fly ash	Concrete	Initial slump	ASTM C143
			Compressive strength	ASTM C39
			Bleeding	ASTM C232
			Setting time	ASTM C403
		Mortar	Dewatering	No standard
5	Effect of Surf 20K on blending between bentonite and concrete	Concrete	Blending observation	No standard

3.2.1 Mix proportions

Different mix proportions of mortar and concrete mixtures were designed for the five different experimental programs as shown in the Table 3.3. The mixtures of concrete and mortar were prepared with various water to binder ratios, fly ash replacement percentages, and sand to binder ratios by volume. The details of water to binder ratios, fly ash replacement percentages, types of water reducing admixtures and types of viscosity modifying agents used in concrete and mortar mixtures in each experimental program are shown in Table 3.4.

Table 3.4 Mix proportions of all experimental programs

Experimental Program No.	w/b	Fly ash	S/M	Admixtures	VMA
1	0.55	-	0.46	-	Surf 20K Starch
2	0.45	-	0.49	ASTM -Type D	Surf 20K
3	0.45	-	0.49	ASTM –Type F	Surf 20K
4	0.39	35%	0.43	ASTM –Type F	Surf 20K Starch
5	0.39	35%	0.43	ASTM-Type F	Surf 20K

w: water, b: binder, S:sand, M: Mortar, VMA: viscosity modifying agent

The detail descriptions about mix proportions and mixing procedures for mortar and concrete of each experimental program in Table 3.4 are described as follows;

Experimental program no.1

In this experimental program, all the concrete and mortar mixtures were prepared by using a water to binder ratio of 0.55 and a sand to mortar ratio by volume of 0.46. The control mixture of concrete (C0), having no VMA, was made with Ordinary Portland Cement (OPC) as the only binder. Two groups of freshly mixed concrete samples with different VMAs (Surf 20K and starch) were used to compare their effect on air content in concrete. First group consisted of four different mixtures with surfactant type VMA with dosages from 1 to 7 % by weight in unit water content. Second group consisted of three mixes having starch concentrations from 0.25 to 0.75% solution in unit water content in the mixture. The mortar mixtures (M0 –M7) were prepared as representative samples of concrete (C0-C7), having the same sand to mortar ratio by volume of 0.46. The mortar mixtures were tested to quantitatively measure the dewatering under high pressure and flow properties. Further details about the mix proportions of the tested concrete and mortar samples are shown in Table 3.5.

Table 3.5 Mix proportions of prepared samples for experimental program no. 1

Mix Designation	Type of VMA	w/b	S/M	C (kg/m^3)	S (kg/m^3)	G (kg/m3)	w (kg/m^3)	VMA (%)
C0	-	0.55	0.46	373	743	1076	205	0
C1	Surf 20K	0.55	0.46	373	743	1076	205	1
C2	Surf 20K	0.55	0.46	373	743	1076	205	3
C3	Surf 20K	0.55	0.46	373	743	1076	205	5
C4	Surf 20K	0.55	0.46	373	743	1076	205	7
C5	Starch	0.55	0.46	373	743	1076	205	0.25
C6	Starch	0.55	0.46	373	743	1076	205	0.5
C7	Starch	0.55	0.46	373	743	1076	337	0.75
M0	-	0.55	0.46	613	1187	-	337	0
M1	Surf 20K	0.55	0.46	613	1187	-	337	1
M2	Surf 20K	0.55	0.46	613	1187	-	337	3
M3	Surf 20K	0.55	0.46	613	1187	-	337	5
M4	Surf 20K	0.55	0.46	613	1187	-	337	7
M5	Starch	0.55	0.46	613	1187	-	337	0.25
M6	Starch	0.55	0.46	613	1187	-	337	0.5
M7	Starch	0.55	0.46	613	1187	-	337	0.75

C: cement, S: sand, G: Gravel, w: water, b: binder, M: Mortar, VMA: viscosity modifying agent

where, the dosage of VMA was calculated as follows; the dosage of Surf 20K was calculated by weight percentage in unit water content. For example, in concrete mixture C3, 5% dosage of Surf 20K in the mixture indicates that the total unit water contains 5 parts of Surf 20K and 95 parts of water. This means 10.25 kg/m^3 of Surf 20K and 194.75 kg/m^3 of water in the 205 kg/m^3 of total amount of unit water content. In the case of starch, the original starch having 5% concentration was diluted to 0.25%, 0.5% and 0.75% concentration and used as the dosage of starch. The dosage of starch was calculated in terms of the concentration of starch in unit water content in solution. i.e., 0.5% concentration of starch indicates the 0.5 parts of starch with 99.5 parts of water in the total unit water content in the mixture. As an example, it can be made by mixing 20.5 kg/m^3 of starch having 5% concentration in solution with 184.5kg/m^3 water to produce 205kg/m^3 of unit water content in the mixture.

The mixing procedure of mortar and concrete with surfactant type VMA was as follows; (1) dry constituents were mixed for 1 min at low speed. (2) Water was added and mixed for 1 min at low speed. (3) VMA (Surf 20K) was added and mixed for 2 mins at high speed.

On the other hand, for starch ether type VMA, the mixing procedure was; (1) dry constituents were mixed for 1 min at low speed. (2) Starch was well mixed with the mixing water then added to the dry mixture and mixed for 3 mins at high speed.

The total mixing time of mortar and concrete with or without VMA (Surf 20K and starch) was 4 mins.

Experimental program no. 2 and Experimental program no.3

In these programs, all of the mixtures of concrete and mortar were prepared by using a water to binder ratio of 0.45. The control mix of concrete was prepared by using only type D and type F admixtures in experimental program no.2 and experimental program no.3, respectively. The concrete mix containing no VMA having a slump of 175±25 mm was used as a control mix for both experiment no.2 and experiment no.3. It should be noted that since the different water reducing admixtures are of different nature, it is not possible to apply at the same dosage. Therefore, different dosages of water reducing admixtures were used in order to obtain the slump of 175±25 mm. Surfactant type VMA was used in the concrete mixtures in order to evaluate its effect on initial slump, bleeding, setting time and compressive strength of concrete. The mortar mixtures, M1 to M6, were prepared as representative samples of corresponding concrete, C1-C6, having same sand to mortar ratio by volume of 0.49. The mortar mixtures were tested to measure the dewatering under high pressure. Further details about the mix proportions of the tested concrete and mortar samples of experimental program no.2 and program no.3 are shown in Table 3.6 and Table 3.7, respectively.

Table 3.6 Mix proportions of prepared samples for experimental program no.2

Mix Designation	Types of WRA	w/b	S/M	C (kg/m^3)	S (kg/m^3)	G (kg/m^3)	w (kg/m^3)	WRA/b (%)	Surf 20K (%)
C1	Lig-D	0.45	0.49	425	815	743	1076	1	0
C2	Lig-D	0.45	0.49	425	815	743	1076	1	7
C3	Lig-M	0.45	0.49	425	815	743	1076	1	0
C4	Lig-P	0.45	0.49	425	815	743	1076	1	7
C5	Lig-M	0.45	0.49	425	815	743	1076	0.6	0
C6	Lig-M	0.45	0.49	425	815	743	1076	0.6	5
M1	Lig-D	0.45	0.49	665	1269	-	299	1	0
M2	Lig-D	0.45	0.49	665	1269	-	299	1	7
M3	Lig-M	0.45	0.49	665	1269	-	299	1	0
M4	Lig-P	0.45	0.49	665	1269	-	299	1	7
M5	Lig-M	0.45	0.49	665	1269	-	299	0.6	0
M6	Lig-M	0.45	0.49	665	1269	-	299	0.6	5

C: cement, S: sand, G: Gravel, w: water, b: binder, M: Mortar SP: superplasticizer, VMA: viscosity modifying agent

Table 3.7 Mix proportions of prepared samples for experimental program no.3

Mix Designation	Type of WRA	w/b	S/M	C (kg/m^3)	S (kg/m^3)	G (kg/m^3)	W (kg/m^3)	SP /b (%)	Surf 20K (%)
C1	PC-V	0.45	0.49	425	815	743	1076	0.45	0
C2	PC-V	0.45	0.49	425	815	743	1076	0.45	5
C3	PC-M	0.45	0.49	425	815	743	1076	0.35	0
C4	PC-M	0.45	0.49	425	815	743	1076	0.35	5
C5	NL-M	0.45	0.49	425	815	743	1076	0.45	0
C6	NL-M	0.45	0.49	425	815	743	1076	0.45	5
M1	PC-V	0.45	0.49	665	1269	-	299	0.45	0
M2	PC-V	0.45	0.49	665	1269	-	299	0.35	5
M3	PC-M	0.45	0.49	665	1269	-	299	0.35	0
M4	PC-M	0.45	0.49	665	1269	-	299	0.45	5
M5	NL-M	0.45	0.49	665	1269	-	299	0.45	0
M6	NL-M	0.45	0.49	665	1269	-	299	0.45	5

The mixing procedure for mortar and concrete with only water reducing admixtures was as follows; (1) dry constituents were mixed for 1 min at low speed. (2) 70% of mixing water was added and mixed for 1 min at low speed. (3) Admixture with the remaining 30% of mixing water was added and mixed for 2 mins at high speed.

On the other hand, the mixing procedure for mortar and concrete with water reducing admixtures and Surf 20K was as follows; (1) dry constituents were mixed for 1 min at low speed. (2) 70% of water was added and mixed for 1 min at low speed. (3) SP with 30% of water was added and mixed for 2 mins at high speed. (4) VMA (Surf 20K) was added and mixed for 2 mins at high speed.

Experimental program no. 4

In this experimental program, all the mixtures of concrete and mortar were prepared with a water to binder ratio of 0.39 and sand to mortar ratio by volume of 0.43. Fly ash (FA) was used as a cement replacement material at the level of 35% by weight of total binder. From Table 3.8, the mixtures of concrete (C1-C4) were used to evaluate the initial slump, stetting time, compressive strength of concrete. The control mixtures (C1 and C3), containing no VMA, were made by using 0.35% of PC-M and 0.45% of PC-M3 by weight of binder, respectively, in order to obtain concrete with a slump of 170±10 mm. Furthermore, 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 mixtures C2 and C4, whereas 0.5% concentration of starch solution in unit water content was used in mixture C5. 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 the control mixture (C0). It should be noted that since the 2 types of VMA are of different nature, it is not possible to apply and compare at the same dosage. It was found from a preliminary study that 5% and 0.5% are the optimum dosages for the surfactant type and starch ether, respectively, by considering deformability and viscosity.

On the other hand, the mortar mixtures (M1–M5) were prepared as representative mortar samples of concrete (C1-C5), having same sand to mortar ratio by volume of 0.43. The mortar mixtures were tested to measure the dewatering under high pressure. Further details about the mix proportions of the tested concrete and mortar samples are shown in Table 3.8

Table 3.8 Mix proportions of prepared samples for experimental program no. 4
(w/b 0.39 and S/M 0.43)

Mix Designation	Type of WRA	Types of VMA	C (kg/m^3)	FA (kg/m^3)	S (kg/m^3)	G (kg/m^3)	W (kg/m^3)	SP /b (%)	VMA (%)
C1	PC-M	Surf 20K	312	168	715	1015	187	0.35	0
C2	PC-M	Surf 20K	312	168	715	1015	187	0.35	5
C3	PC-M3	Surf 20K	312	168	715	1015	187	0.45	0
C4	PC-M3	Surf 20K	312	168	715	1015	187	0.45	5
C5	PC-M	Starch	312	168	715	1015	187	0.6	0.5
M1	PC-M	Surf 20K	490	264	1114	-	294	0.35	0
M2	PC-M	Surf 20K	490	264	1114	-	294	0.35	5
M3	PC-M3	Surf 20K	490	264	1114	-	294	0.45	0
M4	PC-M3	Surf 20K	490	264	1114	-	294	0.45	5
M5	PC-M	Starch	490	264	1114	-	294	0.6	0.5

The mixing procedures for mortar and concrete in this experiment were similar to the mixing procedures for mortar and concrete of experimental program no.3.

Experimental program no. 5

In this experimental program, all the concrete mixtures were prepared by using same water to binder ratio of 0.39 and sand to mortar ratio by volume of 0.43. Fly ash (FA) was used as a cement replacement material at the level of 35% by weight of total binder. The control mixture (C1), containing no VMA, was made by using 0.35% of PC-M by weight of binder in order to obtain the concrete with a slump of 170±10mm. To investigate the effect of surfactant type VMA on blending of concrete mixtures with bentonite fluid, 5% dosage of Surf 20K by weight in unit water content was used in mixture C2. The bentonite slurry was prepared by using the bentonite to water ratio of 5% by the weight of water. For example, 5% concentration of bentonite slurry indicates that the 5kg of bentonite powder is mixed with 100kg of water. The details of mix proportion of the tested concrete is shown in Table 3.9.

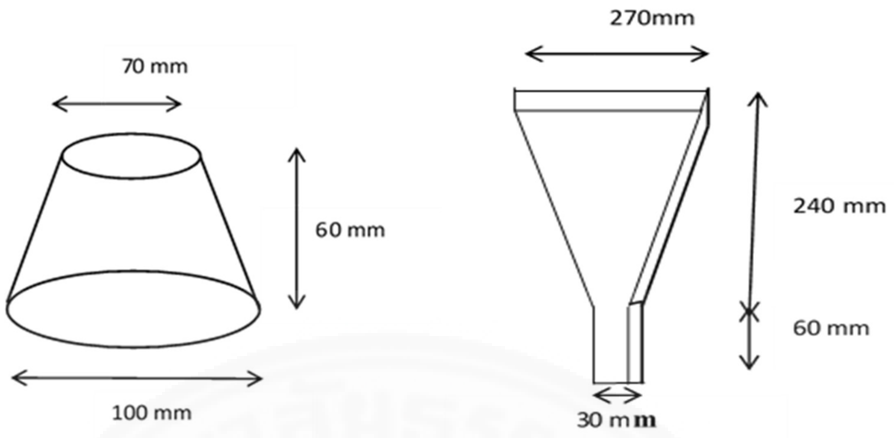
Table 3.9 Mix proportions of tested concrete on bentonite fluid for experiment no.5 (5% bentonite slurry concentration)

Mix Designation	WRA	W/b	C (kg/m^3)	FA (kg/m^3)	S (kg/m^3)	G (kg/m^3)	W (kg/m^3)	SP /b (%)	Surf 20K (%)
C1	PC-M	0.39	312	168	715	1015	187	0.35	0
C2	PC-M	0.39	312	168	715	1015	187	0.35	5

3.3 Experimental Methods

3.3.1 Flow properties of mortars

A mini slump cone according to European standard EN 1015-3 having a height of 60 mm, a top and a bottom diameter of 70 mm and 100 mm, respectively, was used to determine the maximum spreading diameter of mortar flow. The flow time of the mixtures was measured by using the v-funnel test. The geometries and dimensions of the mini slump cone and the v-funnel are shown in Fig. 3.3(a) and Fig. 3.3(b), respectively.



(a) Mini slump cone (b) V-funnel

Fig. 3.3 Apparatus for measuring the flow properties of mortars

3.3.2 Measurement of bleeding

A sample consolidated by a tamping method according to ASTM C232 was prepared to measure the bleeding of concrete. A cylindrical container having an inside diameter of 255±5mm 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 percentage is calculated according to ASTM- C232 (Kim et al., 2014; Yim et al., 2014). The accumulated bleeding percentage, b(t), is expressed as the percentage of the unit water content in the mixture, as follows

$$\mathrm{b(t)} = \frac{w\,(t)}{WAH}\,x100 \qquad (1)$$

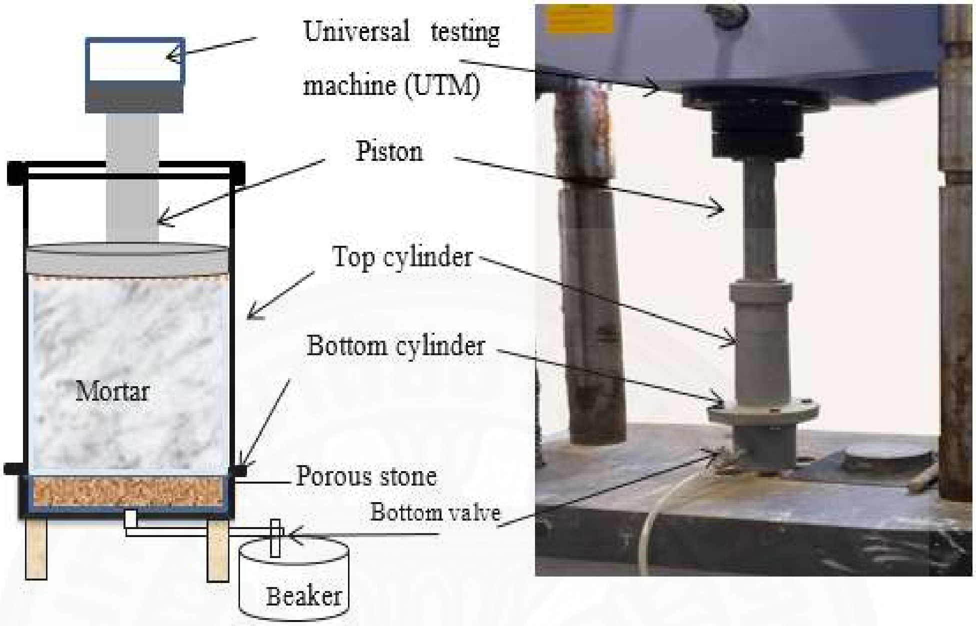
where w (t) is the weight of bleeding water (kg) at time t (min), W is unit water content of the tested mixture (kg/m^3), A is the cross-sectional area of the sample (m^2) and H is the height of the sample (m).

3.3.3 Measurement of air content in concrete

An air meter according to ASTM C231 was used to measure the air content of the tested fresh concrete by using pressure method. The effect of VMA on air content of concrete was determined from the concrete mixtures containing various dosages of VMA.

3.3.4 Instrument for dewatering test and test methods

To measure the dewatering of the mortar mixtures under high pressure, a cylindrical pressure vessel was developed in this study. The schematic and experimental setup of the developed device are shown in Fig. 3.4(a) and Fig. 3.4(b), respectively. The device with an internal diameter of 80 mm and a height of 330 mm was fabricated using stainless steel. The cross sectional area of the test sample was thus 5024 mm^2. A porous stone (100 mm in diameter and 6 mm in thickness) was fixed at the bottom of the device to filter 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 for protecting the porous stone from clogging. Drained water from the samples was collected and measured periodically with a weight balance.



(a) Schematic test setup (b) Laboratory test setup

Fig. 3.4 Dewatering device for dewatering test

Before conducting the dewatering test of mortar, the hydraulic conductivity of a proposed porous stone was tested in order to confirm that the flow of water through the porous disc linearly increases with time. The test was carried out as follows; the vessel was filled with water up to the height of 250 mm and maintain a same level of water in a vessel throughout the experiment. The drained water from the bottom nozzle through the porous stone was measured by opening the bottom valve. The flow rate of water through the proposed porous stone over the time was measured periodically. It is observed that the amount of drained water from the bottom nozzle through the porous stone linearly increases with time (see Fig 3.5). This indicates that the proposed porous stone can be used in the dewatering device as a porous medium for filtering water from the samples.

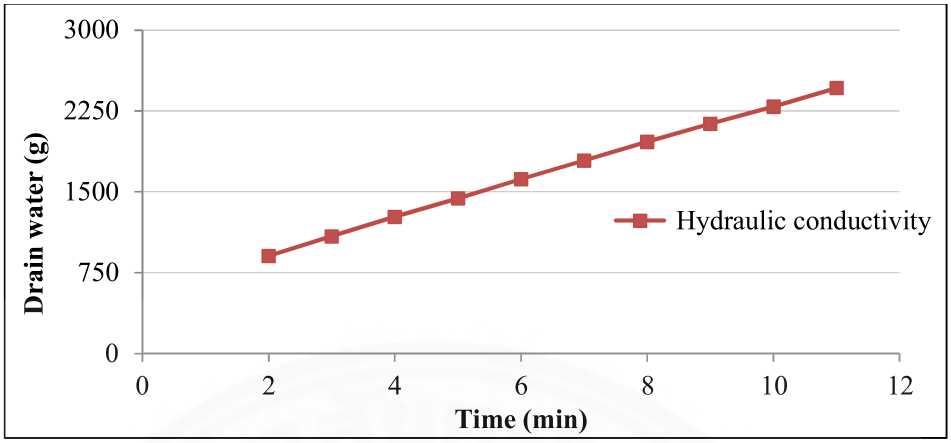


Fig. 3.5 Drainage of water through porous stone with filter paper

Five steps of dewatering measurements were conducted to evaluate the dewatering of each mortar sample; these were (1) a freshly mixed mortar sample was placed in the dewatering device up to the height of 250 mm while the bottom valve was closed. (2) A force of 3.62kN 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 a bored pile at 30 m deep. (3) Apply the force and sustain it on the sample till reaching 0.72MPa while the bottom valve was closed. (4) 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 as shown in Fig 3.6. The deviation of load during the test was ±5.64% of targeted load of 3.62kN. (5) 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 (Kim et al., 2014; Yim et al., 2014), as follows

$$\mathrm{d(t)} = \frac{w(t)}{WAH}\, x100 \qquad (1)$$

where w(t) is the total amount of drained water (kg) at time t (min), W is unit water content of the mixtures (kg/m^3), A is the cross-sectional area of the sample (m^2) and H is the initial height of the sample (m).

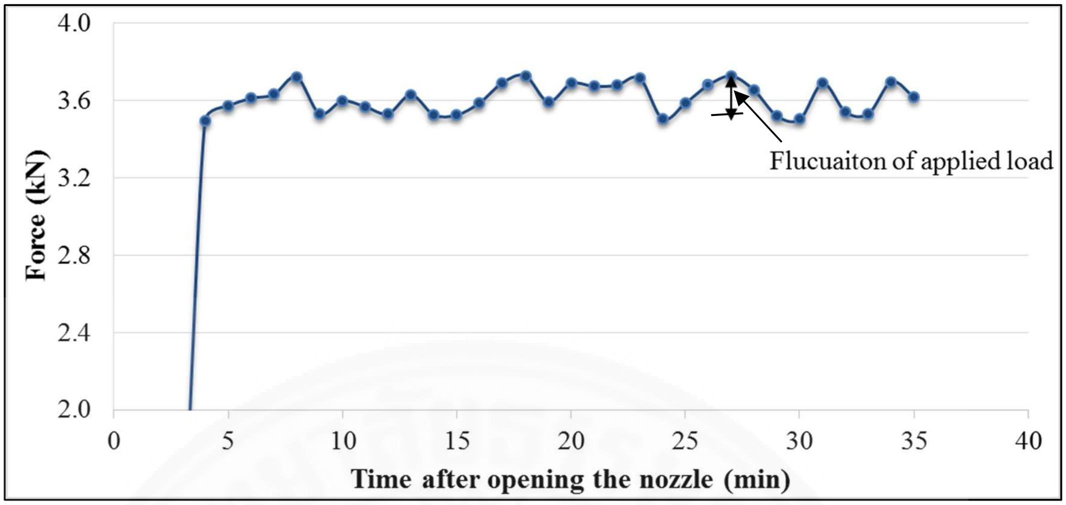


Fig. 3.6 Flucuation of load during pressurized dewatering test

3.3.5 Measurement of initial slump

The initial slump of fresh concrete was measured according to ASTM C143. The effect of VMA on workability (initial slump and concrete flow) of concrete was evaluated by using the surfactant type VMA (Surf 20K 5% by the weight of water) with different dosages and types of admixture (ASTM type D and ASTM type F) in concrete mixtures.

3.3.6 Measurement of setting time

A standard penetration test method according to ASTM C403 was used to measure the setting time of concrete. A mortar sample was extracted by sieving a representative sample of fresh concrete and placed in a rectangular steel mould for measuring the setting time of concrete. At a regular time interval, standard needles were used to measure the penetration resistance of the mortar. The initial and final setting times were determined from a graph showing the relationship between penetration resistance vs elapsed time of corresponding samples.

3.3.7 Measurement of compressive strength

The compressive strength of cylindrical concrete specimens having a diameter of 100 mm and a height of 200 mm at the ages of 7 and 28 days were measured according to ASTM C39. Three specimens were tested for obtaining an average compressive strength at a specific concrete age. The effect of surfactant type VMA on compressive strength was determined from the different concrete mixtures with different water reducing admixtures (ASTM type D and ASTM type F).

3.3.8 Blending effect between bentonite and concrete

Visual inspection and visual judgement method were conducted in order to evaluate the blending effect between bentonite fluid and the fresh concrete. A concrete mixture was cast in a mould having a diameter of 150 mm and a height of 300 mm in order to examine the blending of bentonite with concrete as shown in Fig.3.7. Following steps were carried out to evaluate the mixing of bentonite with concrete. (1) A freshly mixed bentonite solution was filled in the cylindrical mould. (b) A freshly mixed concrete sample was placed continuously in the mould containing bentonite fluid. (3) Demould the concrete specimens after two days. (4) Break the specimens longitudinally and observe the presence of bentonite inside the hardened concrete.

a) Filling bentonite in a mould

b) A concrete sample in the mould containing bentonite fluid

Fig. 3.7 Concrete with bentonite fluid

Chapter 4

Results and Discussion

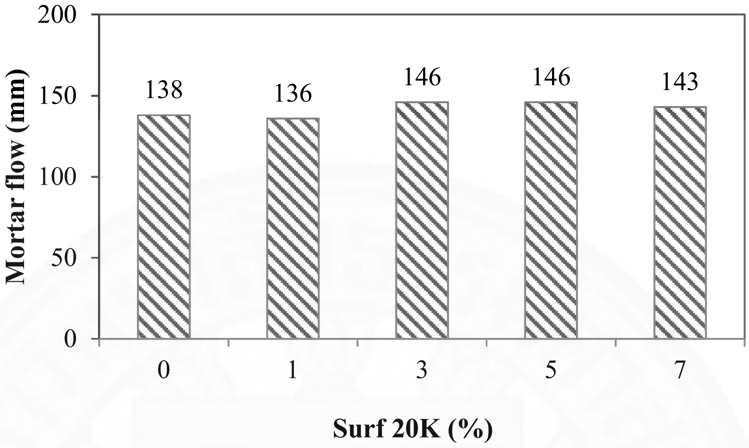
This chapter presents the experimental results and discussions of tests related to the effect of viscosity modifying agents on concrete and mortar properties. The results of the effect of VMAs on mortar and concrete performances are shown in the sections 4.1 to 4.5, respectively.

4.1 Experimental Program no. 1

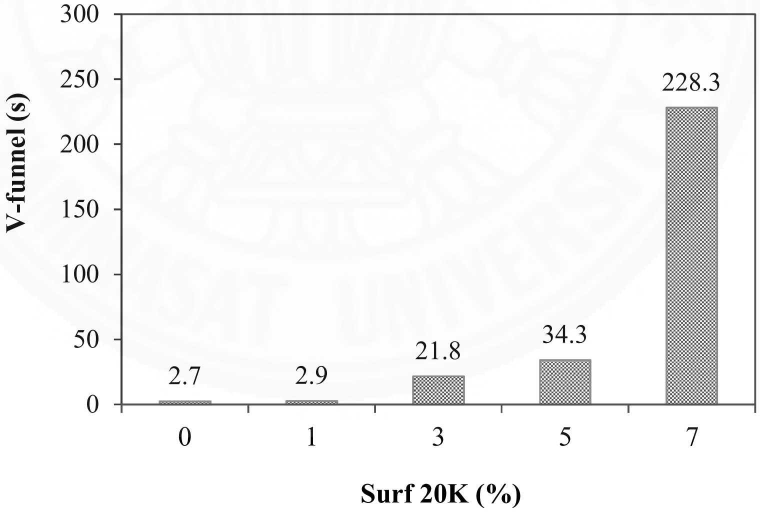
The results of experimental program 1; i.e., flow properties, dewatering of mortar under high pressure, and air content in concrete are shown in the following sections.

4.1.1 Effect of VMAs on mortar flow

The effect of surfactant type VMA on mortar flow and v-funnel flow time are shown in Fig.4.1 (a) and Fig. 4.1(b), respectively. It can be seen that the surfactant type VMA (Surf 20K) slightly increases the mortar flow and prolongs the v-funnel flow time. The mortar flow of control mortar with 0% surfactant was 138 mm whereas mortar containing 1% surfactant type VMA reduces the mortar flow from 138mm to 136 mm, while after that it slightly increases the mortar flow as compared to the control mortar. By considering the same mortar mixtures, v-funnel flow time increases with increasing the dosages of Surf 20K. Between 0% to 5%, the v-funnel flow time increases moderately, while after that it rises significantly at 7%. This is because the surfactant molecules have a hydrophilic head and a hydrophobic ends as shown in Fig. 4.2. It reduces the surface tension of the liquid phase and makes it easier to produce air bubbles in the mixtures (Du, 2005). These air bubbles contribute to increase the mortar flow (Dodson, 1990). At the same time, surfactant forms micelle net structures in the liquid phase, which increases the viscosity of mixtures. Therefore, mortars with surfactant have longer v funnel time.



a) Mortar flow



(b) V-funnel time

Fig. 4.1 Effect of surfactant type VMA on flow properties of mortars

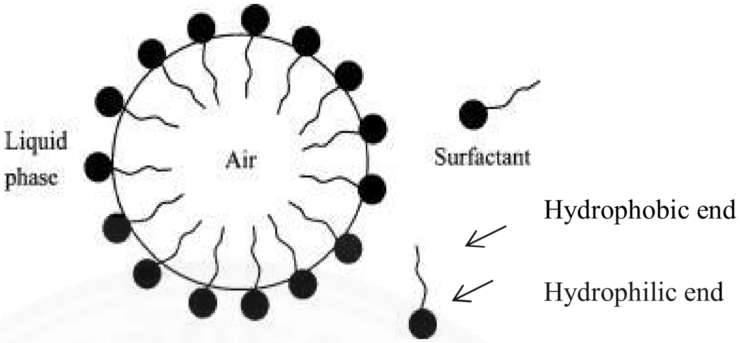
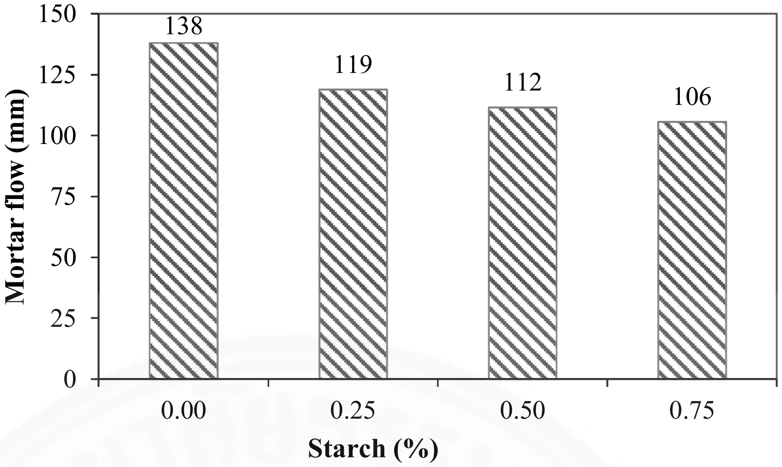
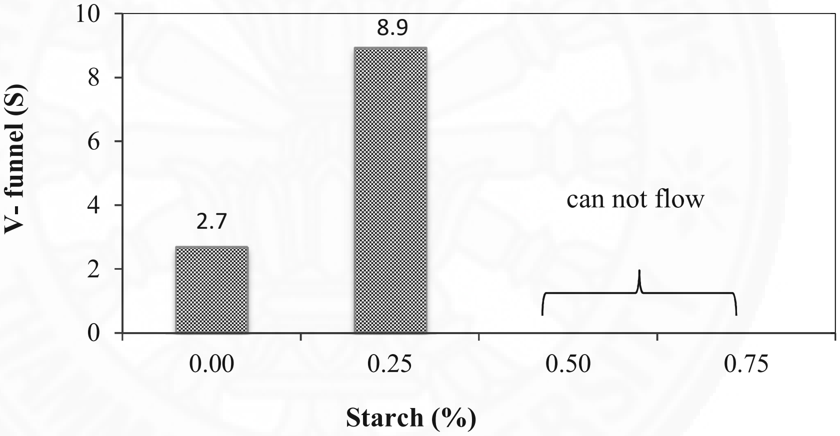


Fig. 4.2 Distribution of surfactant molecules at the water–air interface (Du, 2005)

The influences of the addition of starch on flow properties, mortar flow and v funnel time, are presented in Fig. 4.3(a) and Fig. 4.3(b), respectively. Increasing the concentration of starch solution in unit water content from 0% to 0.75% significantly reduces the mortar flow. The mortar without starch shows a mortar flow of 138 mm whereas mortar containing 0.25% starch concentration has a flow of 118 mm. By increasing the concentration of starch to 0.5% and 0.75%, the mortar flow values are just slightly above 100 mm, indicating very low deformability. On the other hand, the v-funnel flow time of mortar increases with increasing dosages of starch. The v-funnel flow time of mortars was not measurable at the concentration of starch equal or exceeding 0.5% because the mixtures had too high viscosity. It is because starch makes the mortar more viscous by increasing the viscosity of the liquid phase.



(a) Mortar flow



(b) V-funnel time

Fig. 4.3 Effect of starch on flow properties of mortars

4.1.2 Effect of VMAs on air content of concrete

The effect of Surf 20K on air content of concrete is presented in Fig.4.4. It can be seen that increasing the dosages of surfactant type VMA increases air content of the concrete mixtures. It is because the surfactant type VMA stabilizes air bubbles in concrete by reducing the surface tension of mixing water. Moreover, the surfactant can be adsorbed on cement surfaces which can also contribute to formation of some air bubbles in the mixtures (Du, 2005).

Fig.4.5 illustrates the effect of starch on air content of concrete. It can be observed that the use of starch only slightly increases air content in concrete. Air content of concrete without starch is 1.4%. By increasing the concentration of starch to 0.75% in the same mixture, air was increased to 2.0%. The increase of air content is less significant when compared to the case of surfactant VMA. Therefore, starch is not able to increase the mortar flows, but on the other hand, reduces the mortar flow due to increase of viscosity.

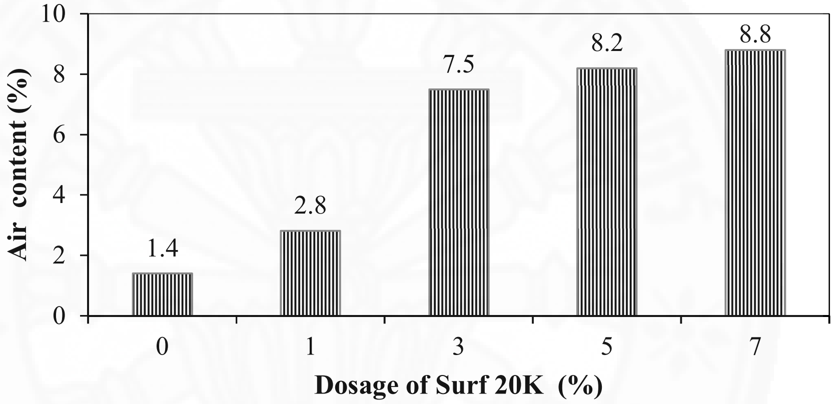


Fig. 4.4 Effect of surfactant type VMA on air content of concrete

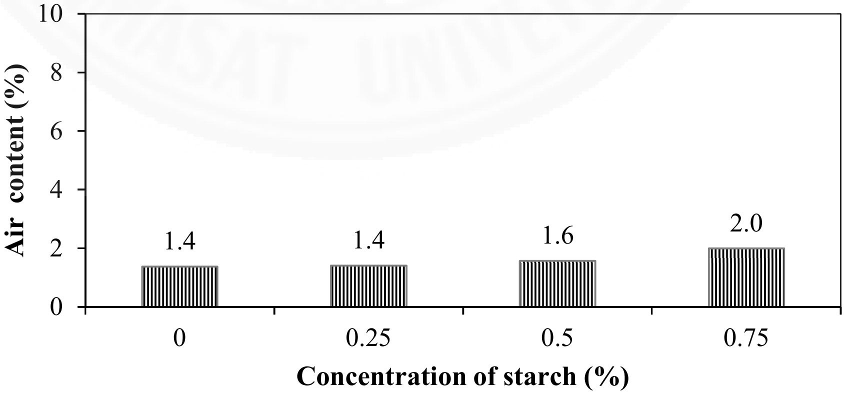
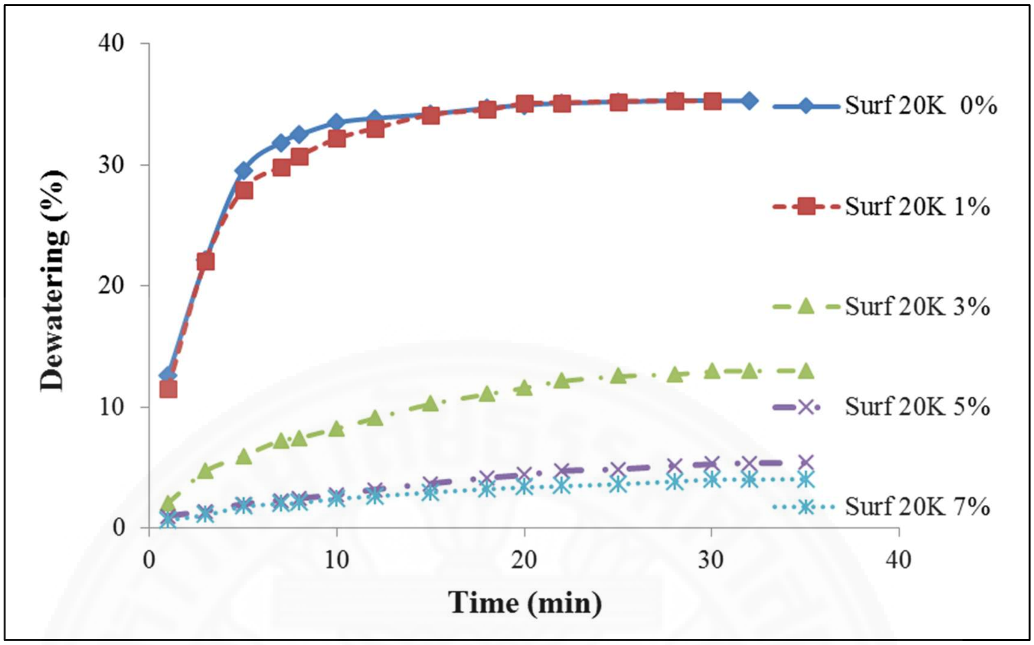


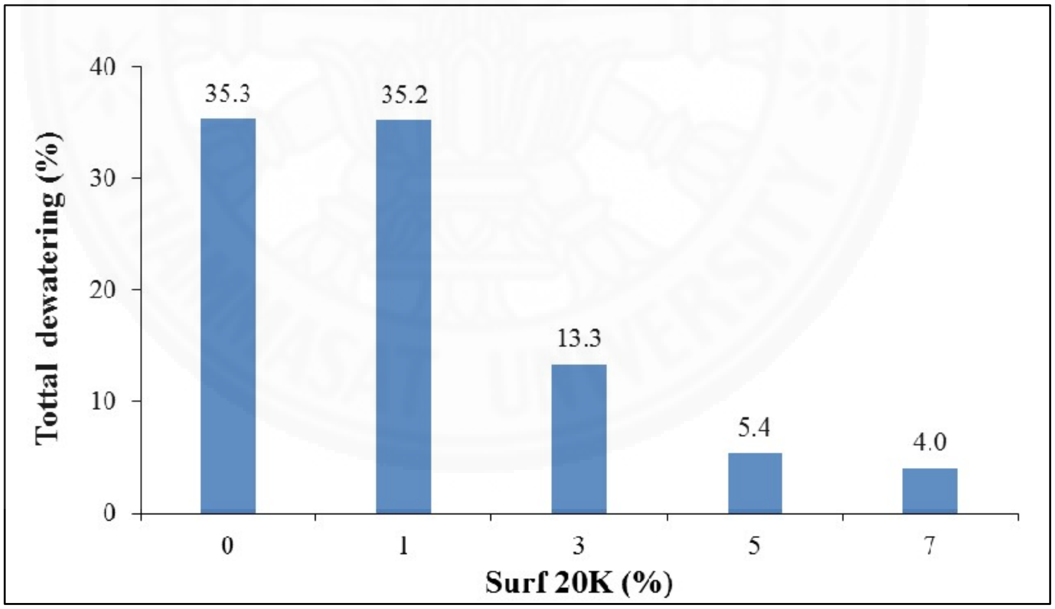
Fig. 4.5 Effect of starch on air content of concrete

4.1.3 Effect of VMAs on pressurized dewatering of mortar

The influence of surfactant type VMA (Surf 20K) on dewatering of mortar under high pressure (0.72 MPa) and their total accumulated pressurized dewatering percentage are shown in Fig. 4.6(a) and Fig. 4.6(b). It can be observed that the accumulated dewatering of the control mortar without Surf 20K is 35.3% and by adding 1% dosage of Surf 20K, there is no significant effect on dewatering. However, with an increase of the Surf 20K dosages from 3% to 7%, the dewatering reduces drastically to 13.0% and 4.1%, respectively. This is because the surfactant forms a higher order molecular structure by micelle aggregation of two different parts of surfactant molecule, which are a hydrophilic and a hydrophobic end as shown in Fig.4.7. Moreover, the surfactant produces threadlike micelle net structures in the cement paste mixture as can be confirmed by a SEM image in Fig.4.8. It can be observed that the network of threadlike micelles in the liquid phase covers the cement particles throughout the mixtures. This micelle net structure lowers the amount of free water in the cement paste mixtures by holding the water within its structure, reducing the permeability of the fresh mixtures and increasing the stiffness of the fresh paste mixtures. When pressured, mixtures having low amount of free water, lower permeability and higher solid phase stiffness expel lower amount of water. Therefore, the pressurized dewatering amount of the mortar reduces by using the Surf 20K.



(a) Pressurized dewatering of mortar



(b) Total accumulated pressurized dewatering of mortar

Fig. 4. 6 Effect of Surf 20K on pressurized dewatering of mortar

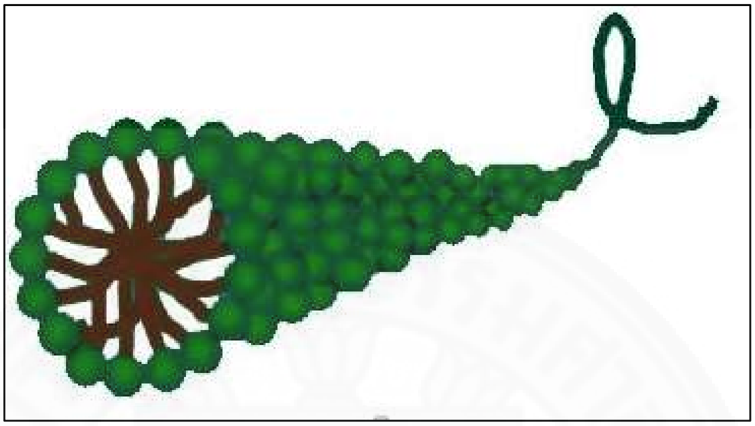


Fig. 4.7 Thread like micelle net structure of surfactant molecule (Kao, 2016)

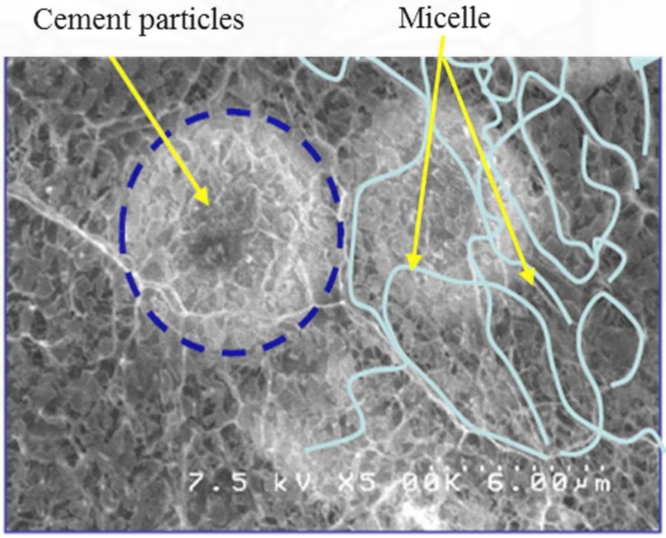


Fig. 4.8 Network of threadlike micelle in water phase covering cement particles (Kao, 2016)

A Rheometer MCR 301 (see in Fig. 4.9) was used to measure the rheological properties of cement paste in order to find the elastic modulus of pastes. The mix proportions and test conditions of cement paste samples are shown in Table 4.1. The elastic modulus of material can be determined by using the Maxwell model. This is a mechanical model in which a spring and a dashpot are connected as shown in the Fig.4.10. The spring and dashpot comply with the Hooke’s law and Newton’s law of viscosity, respectively (Roylance, 2001). Shedge (2012) explained the viscoelastic characteristic of material in term of total shear modulus (G). It is the ratio of shear stress to shear strain. It has two components, which are a storage modulus and a viscous modulus. The storage modulus (G’) indicates the ability of material to store the energy which measures the elasticity of material and the viscous modulus (G’’) indicates the ability of material to dissipate energy. By using the data of Maxwell’s model, the shear elastic modulus (G), storage modulus and viscous or loss modulus can be calculated as follows,

$$T = \frac{\eta}{G} \tag{1}$$

$$G' = \frac{G\,(\omega T)^2}{(1+(\omega T)^2\,)} \tag{2}$$

$$G'' = \frac{G\,\omega T}{(1+(\omega T)^2\,)} \tag{3}$$

where T is the relaxation time (s), η is the viscosity (N-s/m^2), G is the shear modulus (Pa), G' is the storage modulus of spring (Pa), G" is the loss modulus (Pa), ω is the angular frequency (rad/s) (Shedge, 2012).

Fig. 4.9 Rheometer MCR 301 (NTNU, 2008)

Table 4.1 Mix proportions of the tested cement-only paste mixtures (w/c=100%)

Mix No	Types of VMA	VMA (%)	Temperature (^{0}C)
1	-	0	30
2	Surf 20K	3	30
3	Surf 20K	5	30
4	Starch	0.25	30
5	Starch	0. 5	30

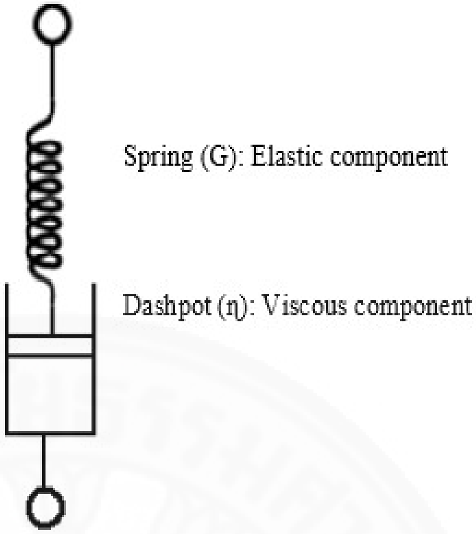


Fig. 4.10 Maxwell model

Table 4.2 illustrates the rheological properties of the tested cement pastes containing different dosages of surfactant type VMA and their effect on elastic modulus of cement pastes are presented in Fig 4.11. It can be observed that surfactant type VMA increases the elastic modulus of the fresh cement paste as compared to the paste without Surf 20K. By adding 3% and 5% dosages of Surf 20K on cement paste, the elastic modulus is effectively increased to 130Pa and 250Pa, respectively. The enhancement of the elastic modulus of mixtures indicates an increase in stiffness of such mixtures, as a consequence, dewatering resistance of the mixtures is improved by increasing the dosage of Surf 20K.

Table 4.2 Rheological properties of the tested cement pastes containing different dosage of Surf 20K

Surf 20K/W (%)	0	3	5
Relaxation time (s)	0.4	4.0	6.7
Elastic modulus, G_N (Pa)	2.8	130	250
Zero shear viscosity, η_0 (Pa.s)	1.12	520	1675

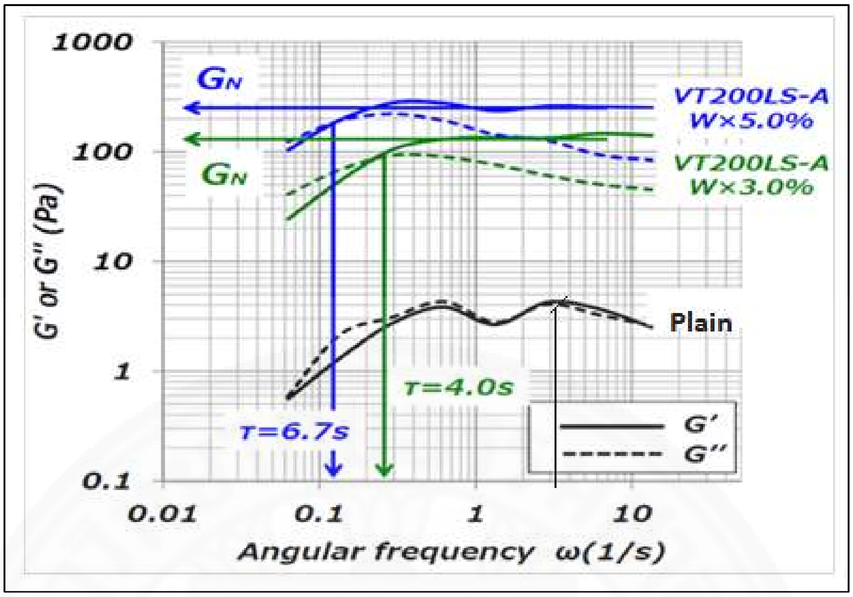
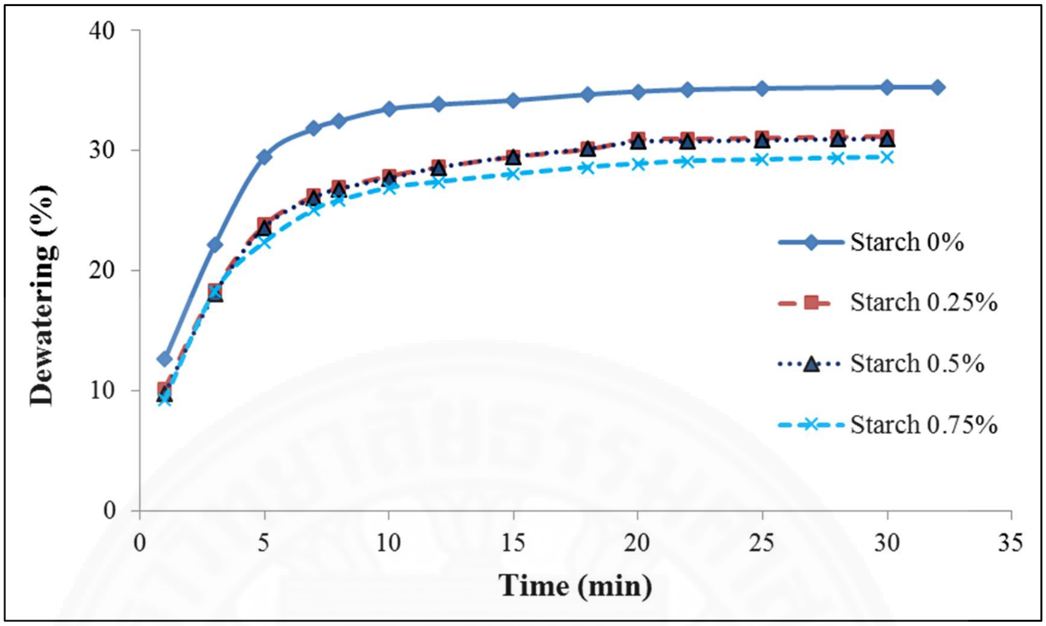
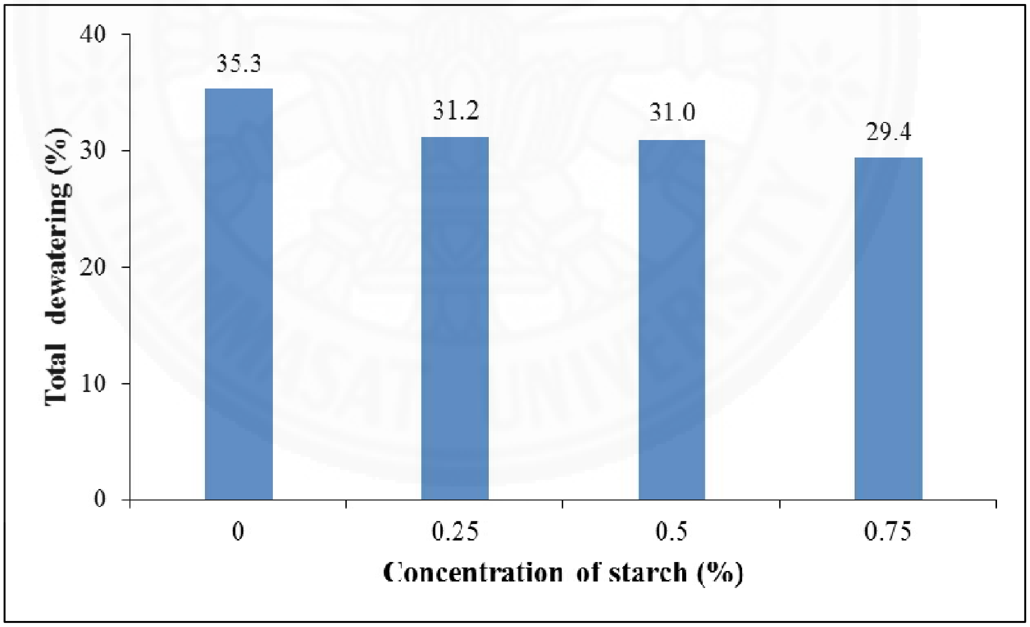


Fig. 4.11 Effect of surfactant type VMA on elastic modulus of cement pastes (Kao, 2016)

The second group of mortars samples having concentration of starch ranging from 0% to 0.75%, were tested to measure dewatering of the mortars under pressure. Fig.4.12 shows the dewatering results with various concentrations of starch from 0% to 0.75%. It can be observed that even adding high concentration of starch solution up to 0.75% of the unit water content, it only slightly reduces the dewatering under pressure. By comparing the dewatering of the control mortar with the mortar having 0.75% starch concentration, dewatering only decreases from 35.3 % to 29.4%. This is because, starch is not able to increase the elastic modulus of mixtures as can be seen from Fig 4.13. Additionally, Table 4.3 presents the rheological properties of the tested cement pastes containing different concentrations of starch. By adding 0.25% and 0.5% concentration of starch solution in unit water content of the cement pastes, the improvement of elastic modulus of fresh mixtures are not much when compared to those mixtures containing the surfactant type VMA as shown in Fig 4.11 and Table 4.2. It indicates that starch only increases viscosity of the mixing water without the abilities to restrain water, to reduce permeability and to increase stiffness of the mixtures when compared to those of the surfactant type VMA. Therefore; starch is not able to efficiently reduce dewatering under high pressure.



(a)Pressurized dewatering of mortars



b) Total accumulated pressurized dewatering of mortars

Fig. 4. 12 Effect of starch on pressurized dewatering of mortars

Table 4.3 Rheological properties of the tested cement pastes containing different concentrations of starch

Starch concentration (%)	0	0.25	0.5
Relaxation time (s)	0.4	16.7	16.7
Elastic modulus, G_N (Pa)	2.8	3.8	8
Zero shear viscosity, η_0 (Pa.s)	1.12	63.46	133.6

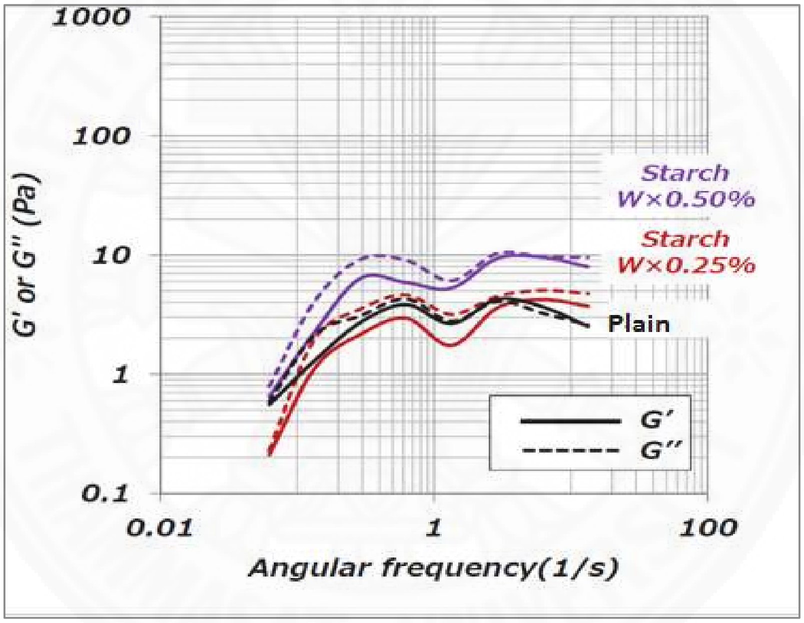


Fig. 4.13 Effect of starch on elastic modulus of cement pastes (Kao, 2016)

Comparison of the effect of VMAs with same viscosity on v- funnel flow time

The effect of starch and Surf 20K on zero shear viscosity and v-funnel flow time are shown in Fig. 4.14 and Fig.4.15, respectively. From the Fig. 4.14, it can be observed that increasing the concentration of starch solution in unit water content increases the v-funnel flow time of mortar and the zero shear viscosity of the cement pastes. On the other hand, Surf 20K significantly increases zero shear viscosity and moderately increases the v-funnel flow when increasing the dosages from 0% to 5% as can be seen from Fig.4.15. By comparing the effect of starch and Surf 20K on v-funnel flow time having a same zero shear viscosity condition, the impact of starch is higher than that of Surf 20K (see Fig.4.15). For example, for cement paste and mortar samples containing 0.5% concentration of starch solution in unit water content the zero shear viscosity and v-funnel flow time are 133.6 Pa and infinite, respectively. At the same zero shear viscosity (133.6 Pa), the v-funnel flow time of mortar sample containing Surf 20K is 12 seconds. Therefore, it can be concluded that based on same viscosity condition, Surf 20K makes the concrete mixture flow easier than that of starch. Since the surfactant type VMA (Surf 20K) increases the air content in the mixtures (see Fig. 4.4) whereas the air content in the mixtures containing starch (see Fig.4.5) is not significantly increased, the flow of mixtures containing Surf 20K is higher.

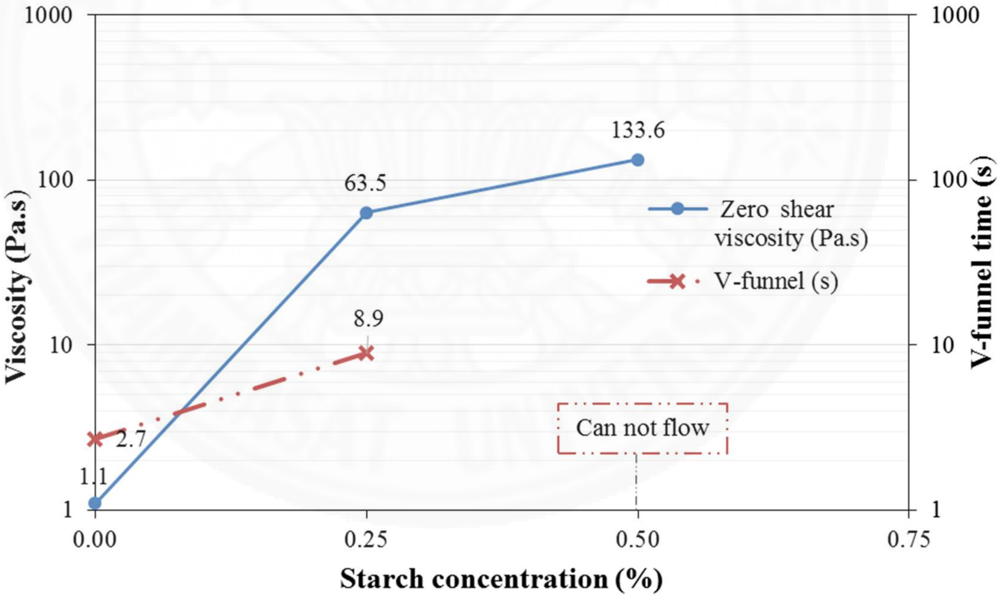


Fig. 4.14 Effect of starch on v-funnel time and zero shear viscosity of the mixtures

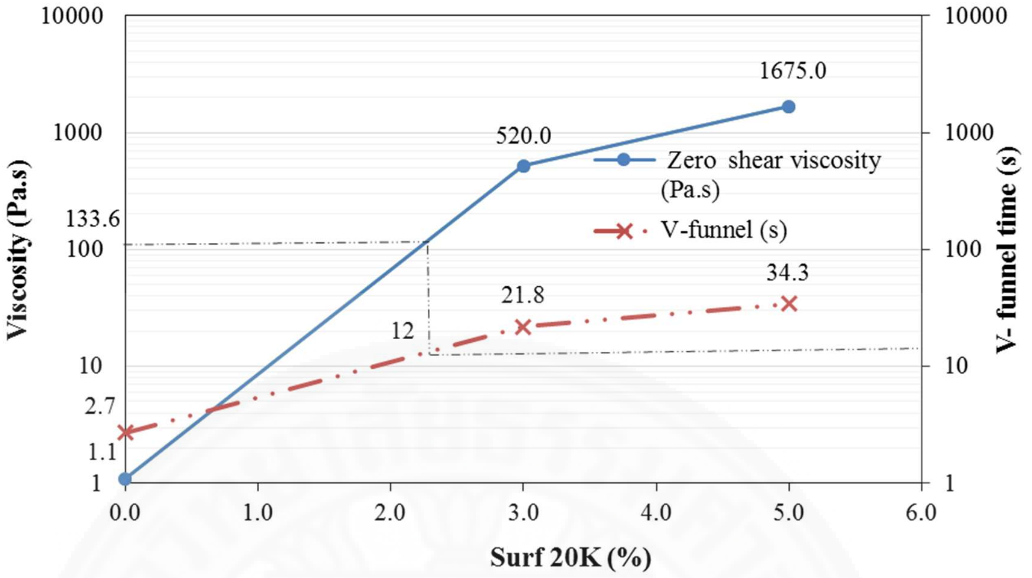


Fig. 4.15 Effect of Surf 20K on v-funnel time and zero shear viscosity of the mixtures

Summary of experimental program no.1

From this experimental program, it was found that surfactant type VMA slightly increased the mortar flow and increased the v-funnel flow time of mortar due to enhancement of air content and viscosity, respectively, of the mixtures. Surfactant type VMA effectively reduced the pressurized dewatering of mortar under pressure at the dosage equal to or higher than 3% by weight in unit water content. On the other hand, starch ether decreased the mortar flow and increased the v-funnel time due to increase of the viscosity of liquid phase. It only slightly increased the air content of the mixtures. Starch in mortar mixtures was ineffective to reduce the dewatering under pressure.

4.2 Experimental Program no. 2

This section presents the influences of surfactant type VMA with type D admixtures on the concrete properties such as initial slump, concrete flow, initial setting time, compressive strength of concrete and dewatering of mortars under high pressure.

4.2.1 Effect of surfactant type VMA with type D admixtures on initial slump of concrete

The influence of surfactant type VMA with type D lignosulphonate based admixtures (Lig-D, Lig-P, and Lig-M) on initial slump and concrete flow is shown in Fig.4.16. It can be seen that by adding the Surf 20K to the concrete mixtures, it slightly increases the initial slump of concrete as well as concrete flow. This is because surfactant molecules help to produce air bubbles in the mixtures. These air bubbles contribute to the increase of initial slump and flow of concrete. However, Surf 20K is not compatible with type D lignosulphonate based admixtures. When Surf 20K was used with Lignosulphonate based admixture in concrete mixture, it reduces the workability even it has higher slump. The pictures showing condition of concrete mixtures containing type D admixtures are in shown Fig 4.17 (a) and 4.17 (b). It can be seen that the mixtures look dry and lean. Increase of type D lignosulphonate based admixtures did not improve the workability condition, on the other hand, it reduced the compressive strength of concrete. Therefore, Surf 20K is not compatible with type D admixtures.

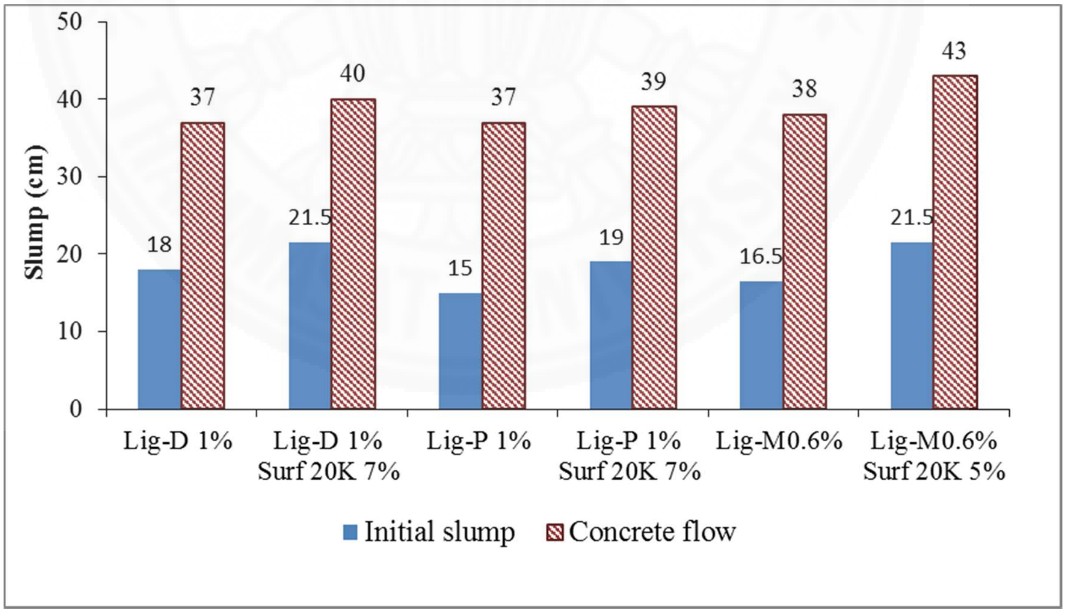


Fig. 4.16 Effect of Surf 20K with type D admixtures on initial slump and concrete flow

a) Surf 20K with Lig-D

b) Surf 20K with Lig-M

Fig. 4. 17 Condition of concrete samples containing Surf 20K with type D admixtures

This caused v-funnel flow time of the concrete mixtures not measureable through the v-funnel apparatus. Therefore, mortar mixtures were tested in place of the concrete mixtures to measure the v-funnel time. The mortar mixtures were prepared as representative samples of their corresponding concrete mixtures, having same sand to mortar ratio by volume. Fig.4.18 shows the effect of surfactant type VMA with lignosulphonate based water reducing admixtures on v-funnel flow time. It can be shown that the use of Surf 20K with type D admixture drastically increases the v-funnel flow time. The control mortar mixtures (M1, M3 and M5), containing no VMA, have v- funnel flow time of 3.4, 2.7 and 4.4 seconds, respectively. By adding 5% to 7% dosages of Surf 20K to those mixtures, the v-funnel time rises significantly. It is because surfactant forms micelle net structures in the liquid phase, which increase the viscosity of the mixtures. Therefore, mortars containing surfactant type VMA have longer v-funnel time than the control mixtures.

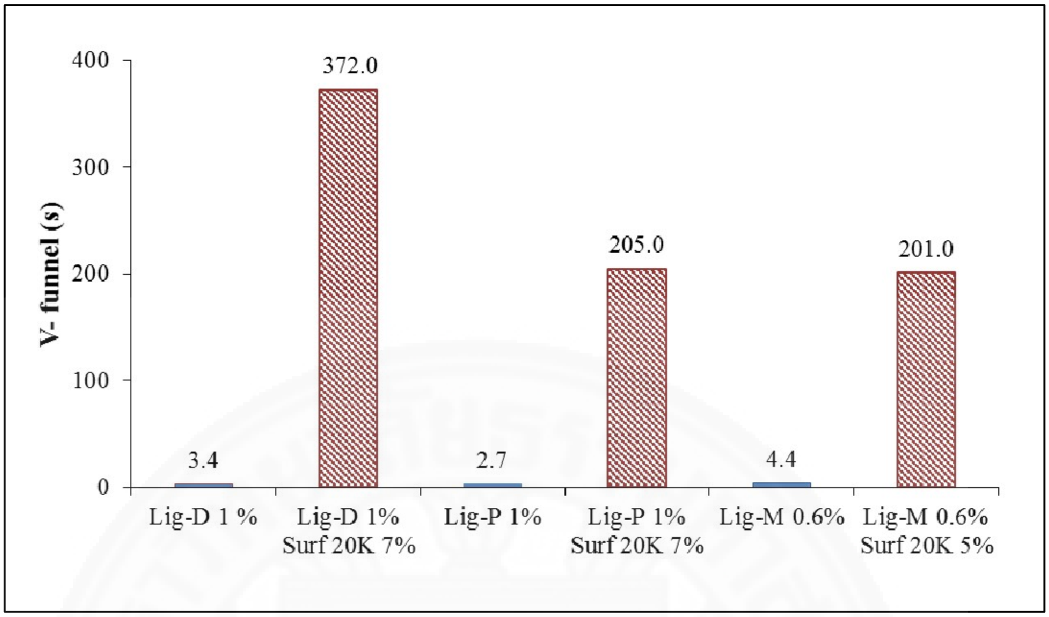
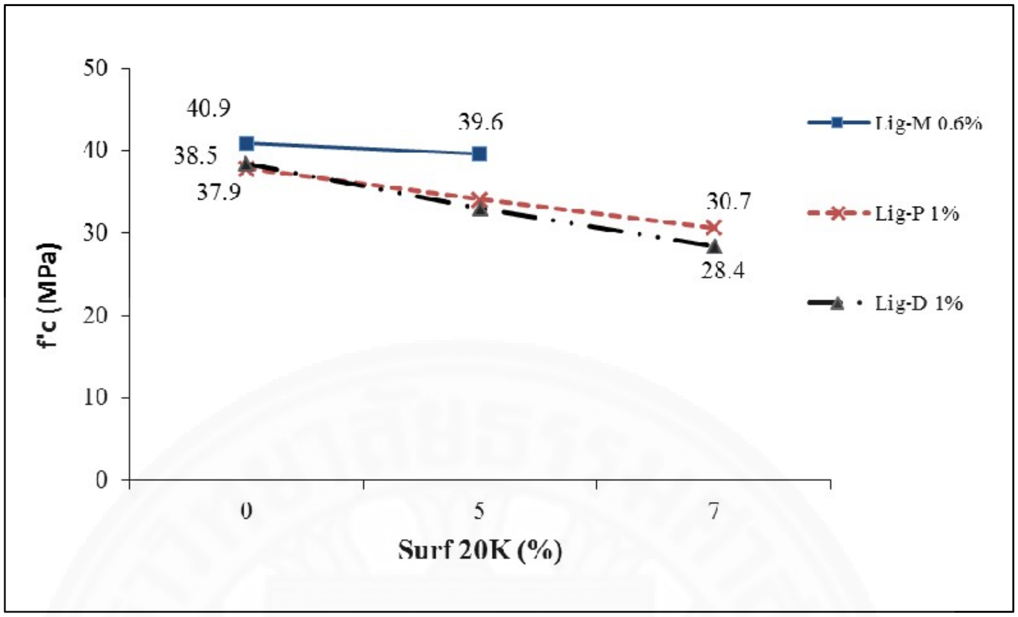


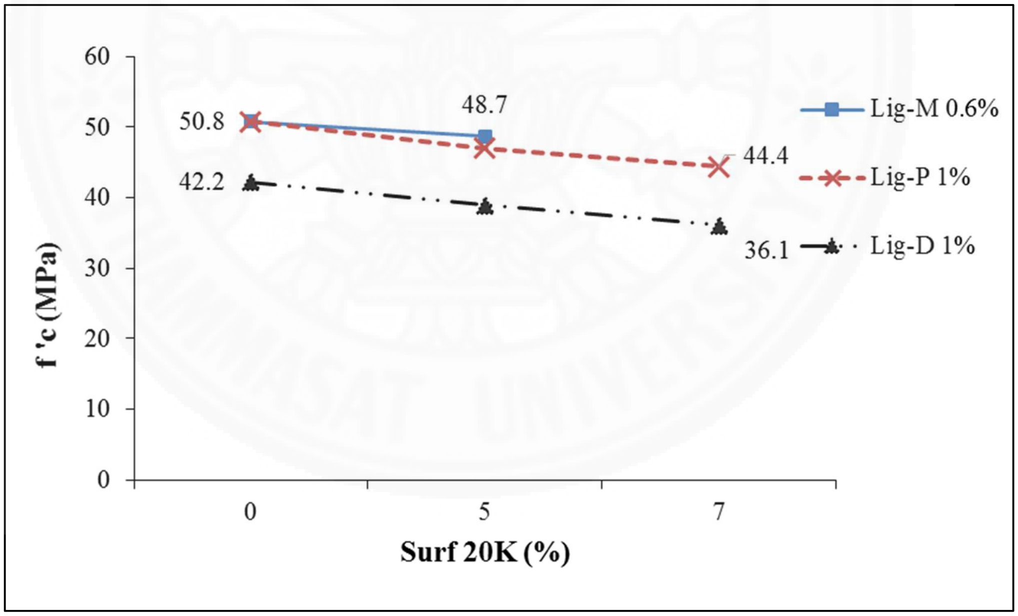
Fig. 4.18 Effect of Surf 20K with type D admixtures on v-funnel flow time of mortars

4.2.2 Effect of surfactant type VMA with type D admixture on compressive strength of concrete

The effect of surfactant type VMA with type D admxitures on compressive strength of concrete at 7 days and 28 days are shown in Fig.4.19 (a), and Fig 4.19 (b), respectively. It can be observed that use of surfactant type VMA (Surf 20K) with Lig-D and Lig-P moderalty reduces the compressive strength of concrete, wheras using Surf 20K with Lig-M admixutre in concrete only slightly reduces the 7- day and 28-day compressive strength of concrete. The strength reduction is considered to be because the surfactant type VMA produces air bubbles in the concrete mixtures (Du, 2005). These air bubbles increase air content in the concrete mixtures which contributes to reduction of the compressive strength of concrete (Mehta, 2006).



a) 7-day compressive strength of concrete



(b) 28-day compressive strength of concrete

Fig. 4.19 Effect of Surf 20K with type D admixtures on compressive strength of concrete

4.2.3 Effect of surfactant type VMA with type D admixtures on setting time of concrete

The effect of Surf 20K with lignosulphonate based water reducing admixtures (ASTM type D) on setting time of concrete is presented in Fig. 4.20. It can be seen that the initial setting time of concrete without Surf 20K, containing type D admixtures, Lig-D and Lig-M, are 387 minutes and 807 minutes, respectively. By applying the dosage of 7% and 5% Surf 20K in the same mixture condition, the setting time increases to 524 minutes and 826 minutes, respectively. It indicates that surfactant type VMA with type D lignosulphonate based admixtures prolongs the setting time of concrete.

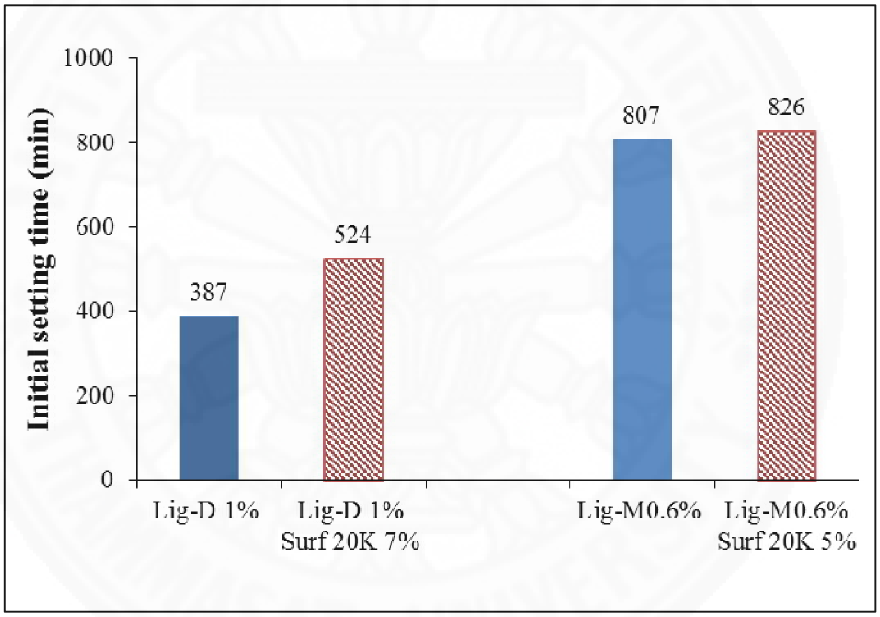
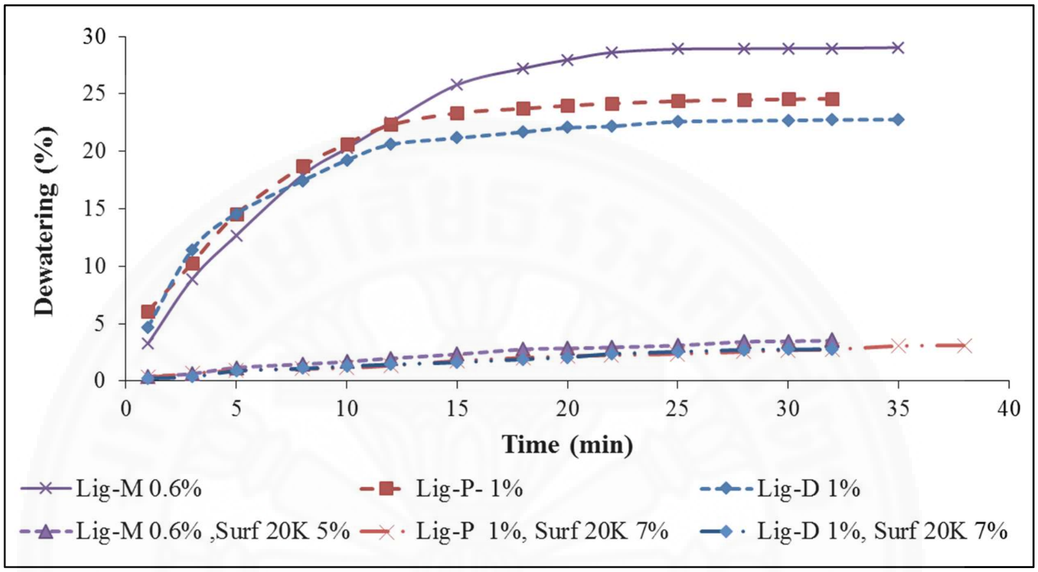


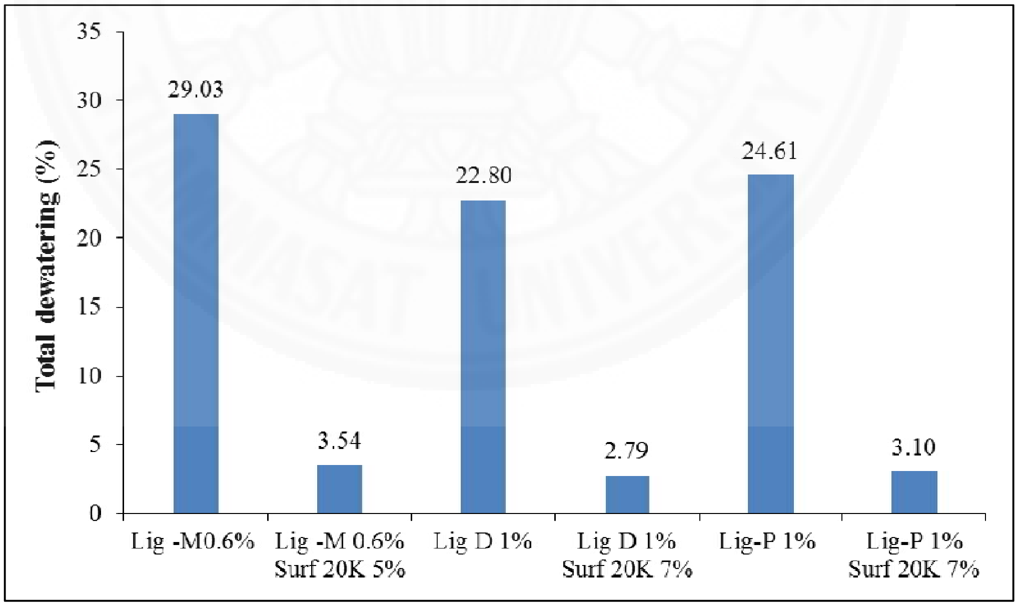
Fig. 4.20 Effect of surf 20K with type D admixtures on setting time of concrete

4.2.4 Effect of surfactant type VMA with type D admixtures on pressurized dewatering of mortars

The influence of Surf 20K with type D admixtures on dewatering of mortars under high pressure (0.72 MPa) and their total accumulated pressurized dewatering percentage are shown in Fig.4.21 (a) and Fig. 4.21 (b), respectively. It can be observed that the dewatering of control mortars with only Lig-D, Lig-P and Lig-M are 22.8%, 24.61% and 29.03%, respectively. By adding 7% dosage of Surf 20K in mortars with Lig–D and Lig-P, dewatering reduces effectively to 2.79%, and 3.1%, respectively. Similarly, 5% dosage of surfactant type VMA (Surf 20K) with Lig-M admixture in mortar reduces the dewatering to 3.54%.



a) Pressurized dewatering of mortars



(b) Total accumulated pressurized dewatering of mortars

Fig. 4.21 Effect of Surf 20K with type D admixtures on pressurized dewatering of mortars

Summary of experimental program no.2

From this experimental program, it was found that surfactant type VMA was not compatible with type D admixtures in the concrete mixtures. Even adding high dosages of type D admixtures with Surf 20K in concrete mixtures, it did not improve the workability condition. Surf 20K with type D admixtures in the concrete mixtures look dry and lean in fresh stage and reduced the compressive strength at hardened stage.

4.3 Experimental Program no. 3

This experimental program presents the results of the effect of surfactant type VMA with type F admixtures (superplasticizers) on concrete properties such as initial slump, concrete flow, initial setting time, compressive strength and dewatering of mortar under pressure as shown in the following sections.

4.3.1 Effect of surfactant type VMA with superplasticizers on initial slump of concrete

The influence of the surfactant type VMA (Surf 20K) with the superplasticizer on workability of concrete is shown in Fig.4.22. It can be observed that Surf 20K with polycarboxylate based superplasticizers (PC-V and PC-M) slightly increase the initial slump and flow of concrete. This is because surfactant molecule helps to produce air bubbles in the concrete mixtures. It contributes to the increase of initial slump and flow of concrete. On the other hand, Surf 20K with naphthalene based superplasticizer moderately reduces initial slump and concrete flow. The concrete mixtures without VMA, containing superplasticizer PC-V, PC-M and NL-M have slump of 19.5 cm, 18.5 cm and 15.5 cm, respectively. By adding the 5% dosage of Surf 20K in the above concrete mixtures, concrete containing PC based superplasticizers such as PC-V and PC-M slightly increase the slump and flow of about 3 cm to 4 cm. On the other hand, Surf 20K with NL based superplasticizer reduces the initial slump to 8 cm and also reduces the concrete flow from 38 cm to 35 cm. It can be consequently concluded that the PC superplasticizers are more compatible to be used with Surf 20K than the naphthalene based SP, when considering slump and concrete flow.

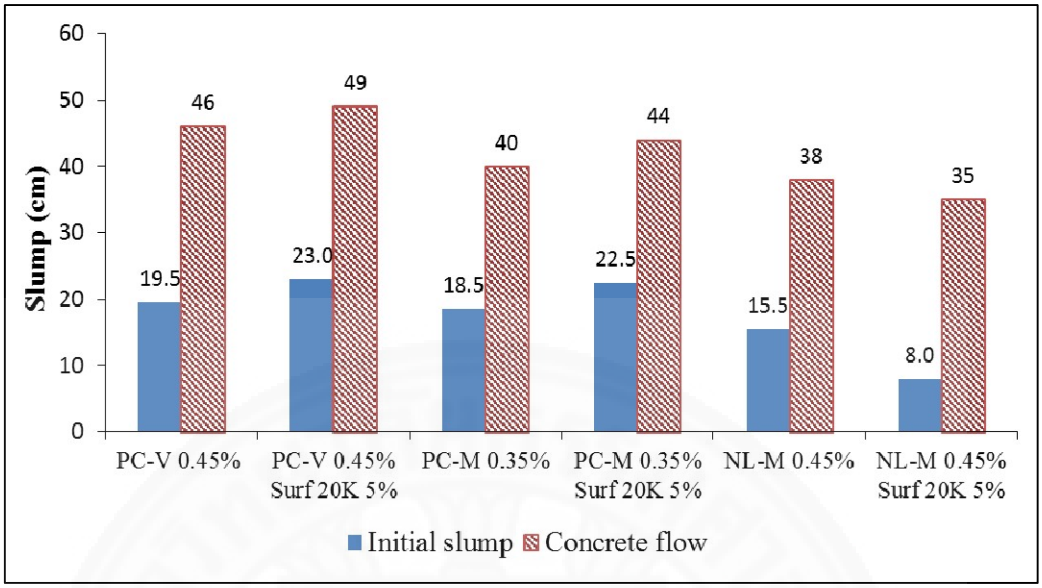


Fig. 4.22 Effect of Surf 20K with superplasticizers on initial slump of concrete

Due to blocking problem of fresh concrete in v-funnel apparatus, the flow time of concrete through the v-funnel apparatus cannot be measured. Therefore, mortar mixtures as representative samples of corresponding concrete mixtures, having same sand to mortar ratio by volume, were tested. Fig 4.23 shows the effect of surfactant type VMA with superplasticizer on v funnel flow time of the mortars. It can be seen that the use of Surf 20K significantly increases v-funnel flow time of the mortars. The concrete mixtures without VMA, containing only superplasticizers such as PC-V, PC-M and NL-M have v-funnel flow times of 2.3 seconds, 2.7seconds and 3.3 seconds, respectively. By adding 5% dosage of Surf 20K to the same mortar mixtures, v-funnel time increase significantly to 40.5 seconds, 185.9 seconds and 230 seconds, respectively. This is because surfactant forms micelle net structures in the liquid phase, which increase the viscosity of the mixtures. Therefore, mortars with surfactant have longer v-funnel time.

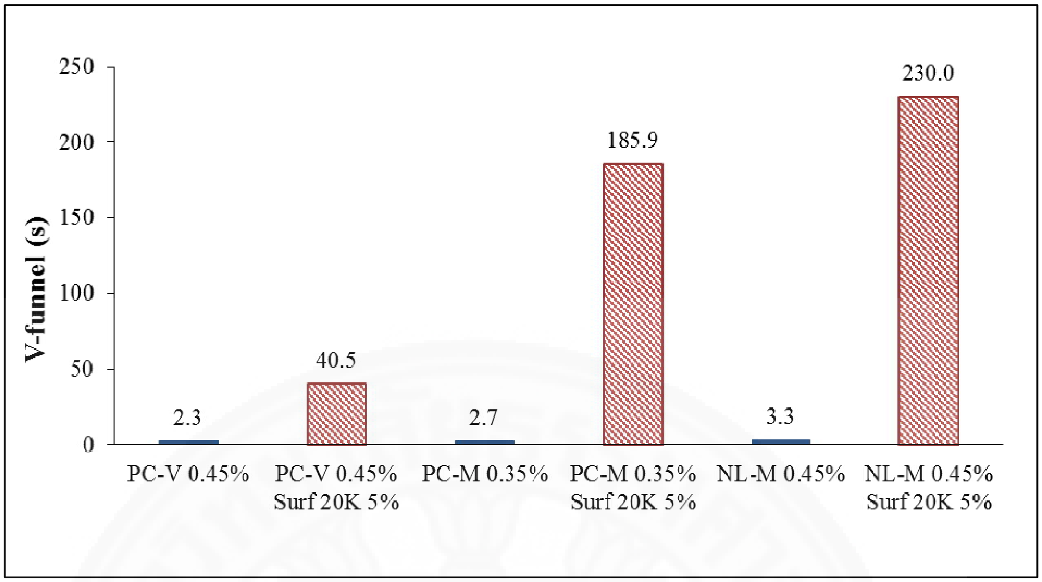


Fig. 4.23 Effect of Surf 20K with superplasticizers on v-funnel flow time of mortars

4.3.2 Effect of surfactant type VMA with superplasticizers on setting time of concrete

The effect of Surf 20K with different superplasticizers on setting time of concrete is presented in Fig.4.24. It can be observed that the initial setting times of concrete mixtures without VMA, containing superplasticizer such as PC-V and PC-M are 220 minutes and 213 minutes, respectively and final setting times of these concrete mixtures are 290 minutes and 283 minutes, respectively. By adding 5% dosage of Surf 20K in the same mixtures condition, the initial setting times increase to 239 minutes and 223 minutes, respectively. On the other hand, the initial and final setting times of concrete containing only NL-M are 200 minutes and 263 minutes, respectively. By applying 5% dosage of Surf 20K in the same concrete mixtures, the initial and final setting times increase slightly to 203 minutes and 269 minutes, respectively. It indicates that surfactant type VMA has negligible influences on setting time of concrete.

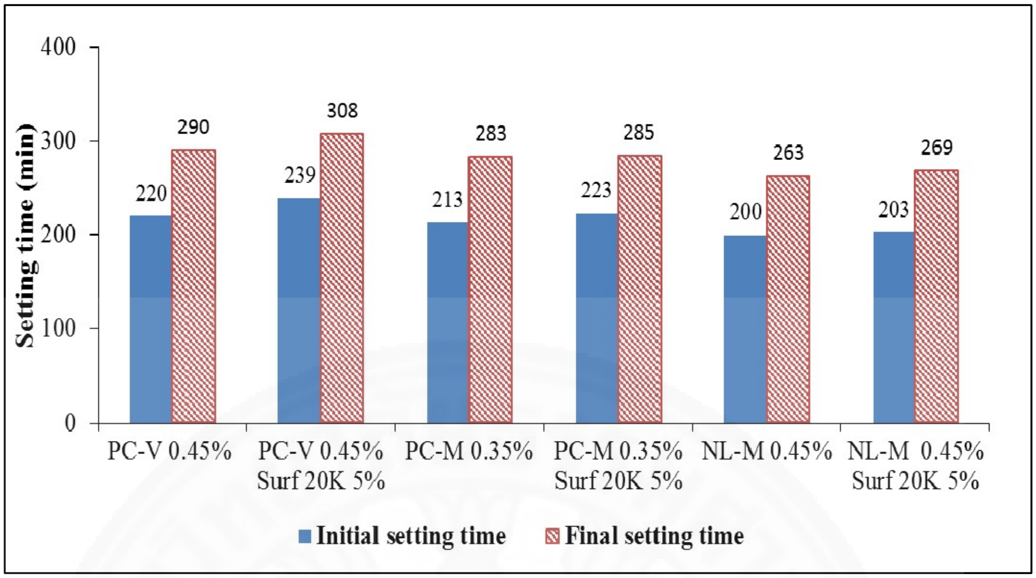
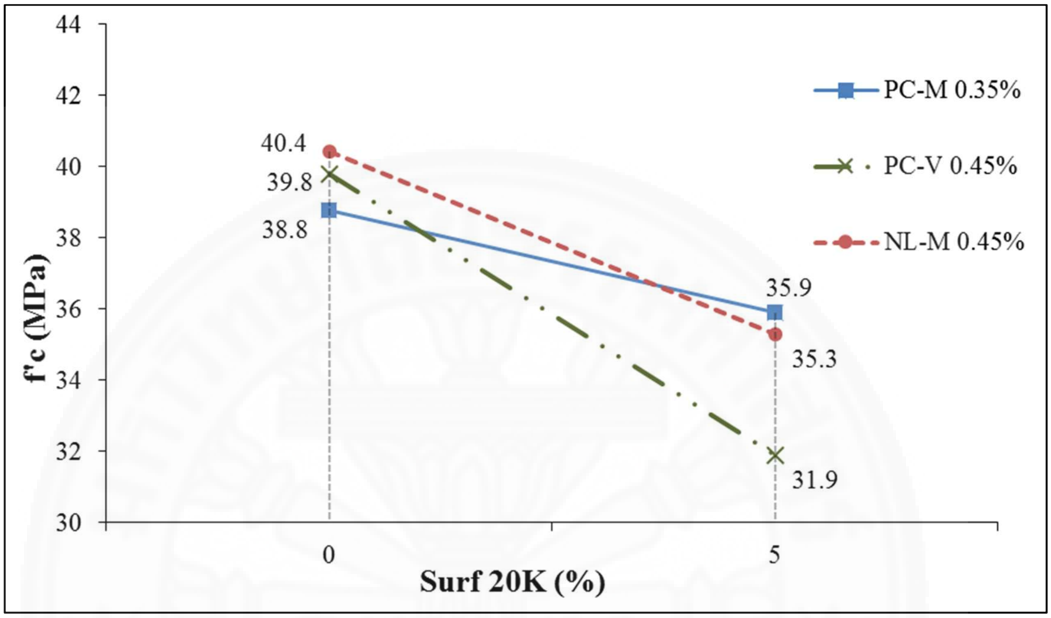


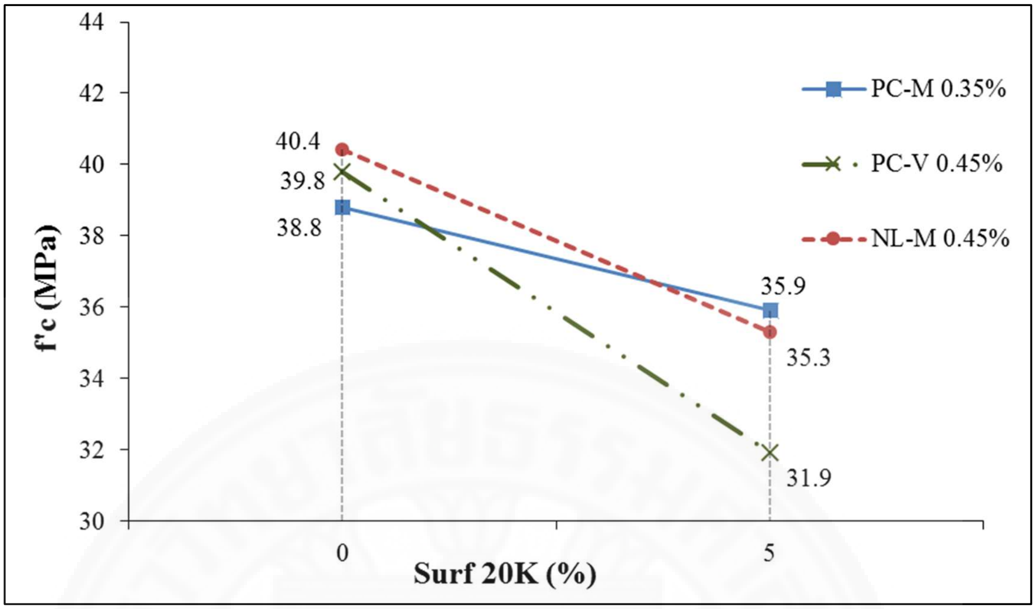
Fig. 4.24 Effect of Surf 20K with superplasticizers on initial and final setting times of concrete

4.3.3 Effect of surfactant type VMA with superplasticizers on compressive strength of concrete

The effect of Surf 20K with superplasticizer on compressive strength of concrete at the ages of 7 days and 28 days are shown in Fig.4.25 (a) and Fig.4.25 (b), respectively. It can be seen that the compressive strength of concrete with PC based superplasticizers (PC-V and PC-M) at 7 days are 39.8 MPa, 38.8 MPa and their 28-day strengths are 48.1 MPa and 50.1 MPa, respectively. By adding 5% dosage of Surf 20K in the same concrete mixtures, their compressive strengths at 7 days slightly reduce to 31.9 MPa and 35.9 MPa, respectively. The 28-day compressive strengths reduce to 42.4 MPa and 49.2 MPa, respectively. On the other hand, the compressive strength of control concrete with only NL-M at 7 days and 28 days are 40.4 MPa and 43.1 MPa, respectively. By adding 5% dosage of Surf 20K in the NL-M concrete mixtures, compressive strength of the concrete at 7days and 28 days reduce to 35.3 MPa and 38.8 MPa, respectively. Even though the air contents of mixtures Surf 20K with PC-M and PC-V are nearly equal (see Fig. 4.26), the reduction of compressive strength due to Surf 20K with PC-V is more rigorous than with PC-M. This means that air content may not be the only factor for the strength reduction. Therefore, it is noticeable that by considering strength property, the combination of Surf 20K with PC-M is the best combination for concrete with Surf 20K when compared to the PC-V and NL-M.



(a) 7-day compressive strength of concrete



(b) 28- day compressive strength of concrete

Fig. 4.25 Effect of Surf 20K with superplasticizers on compressive strength at 7 and 28 days of concrete

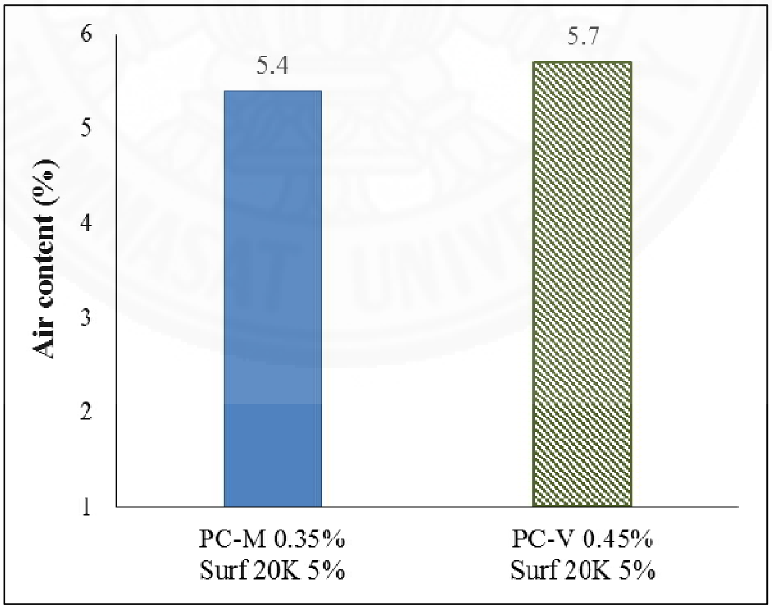
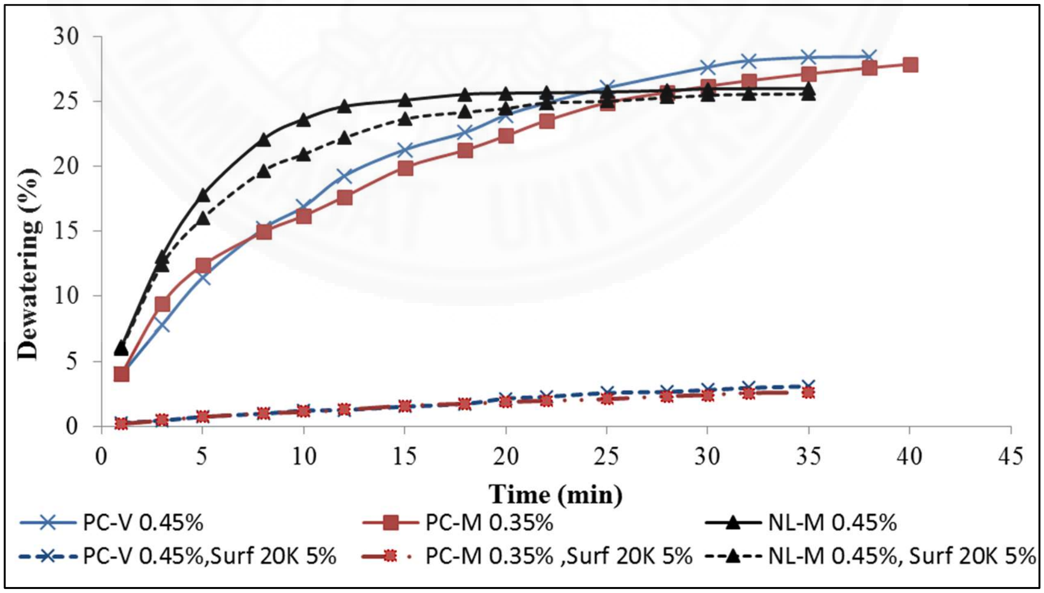


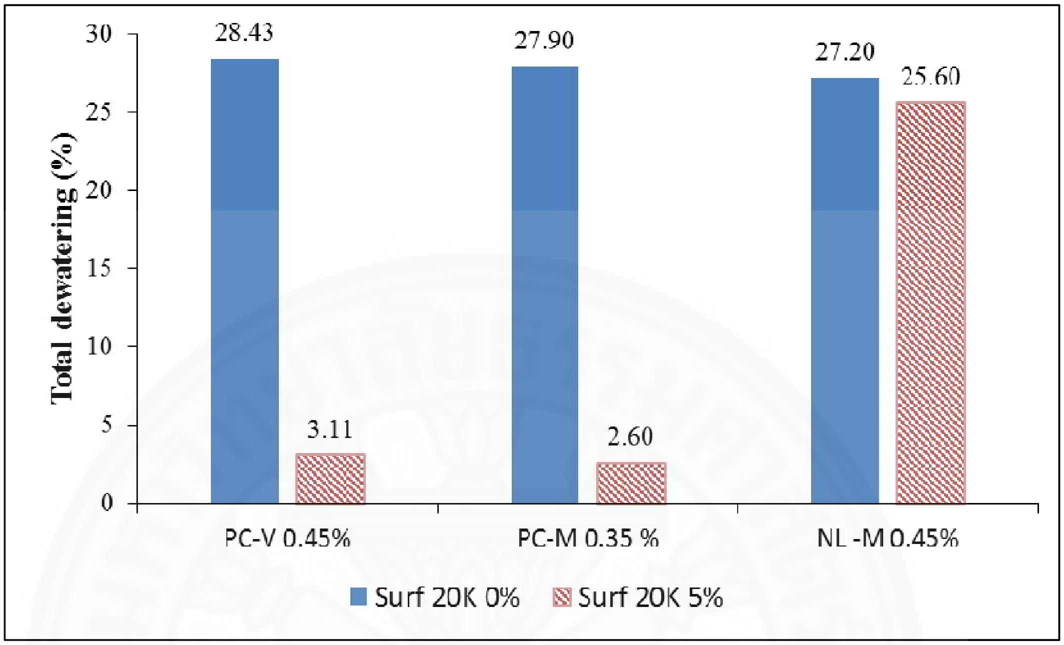
Fig. 4. 26 Effect of Surf 20K with PC based superplasticizers on air content of concrete

4.3.4 Effect of surfactant type VMA with superplasticizers on pressurized dewatering of mortars

The influence of Surf 20K on dewatering of mortars under high-pressure and their total accumulated pressurized dewatering percentage are shown in Fig.4.27 (a) and Fig. 4.27 (b), respectively. It can be observed that the final dewatering of control mortar with PC-V and PC-M are 28.43% and 27.9%, respectively. By adding 5% dosage of Surf 20K in the same mixture condition, dewatering reduces significantly to 3.11% and 2.6%, respectively. On the other hand, use of Surf 20K with NL based superplasticizer is not able to improve the dewatering resistance under high pressure. By adding the 5% dosage of Surf 20K with NL based superplasticizer, the dewatering of mortar only reduces from 27.2% to 25.6%. It is because Surf 20K has the optimum molar ratio of anionic and cationic mole. When it is mixed with NL based superplasticizers, the cationic part of the surfactant creates the interaction with NL based superplasticizer (see Fig. 4.28) instead of interacting with anionic part for forming the micelle net structures. As a result, free anionic part of surfactant increases and it prohibits the formation of the micelle structures. Therefore, the use of Surf 20K with NL based superplasticizer is not effective to increase the dewatering resistance of fresh mortar mixtures.



a) Pressurized dewatering of mortars



b) Total accumulated pressurized dewatering of mortars

Fig. 4. 27 Effect of Sur20K with superplasticizers on dewatering of mortars under high pressure

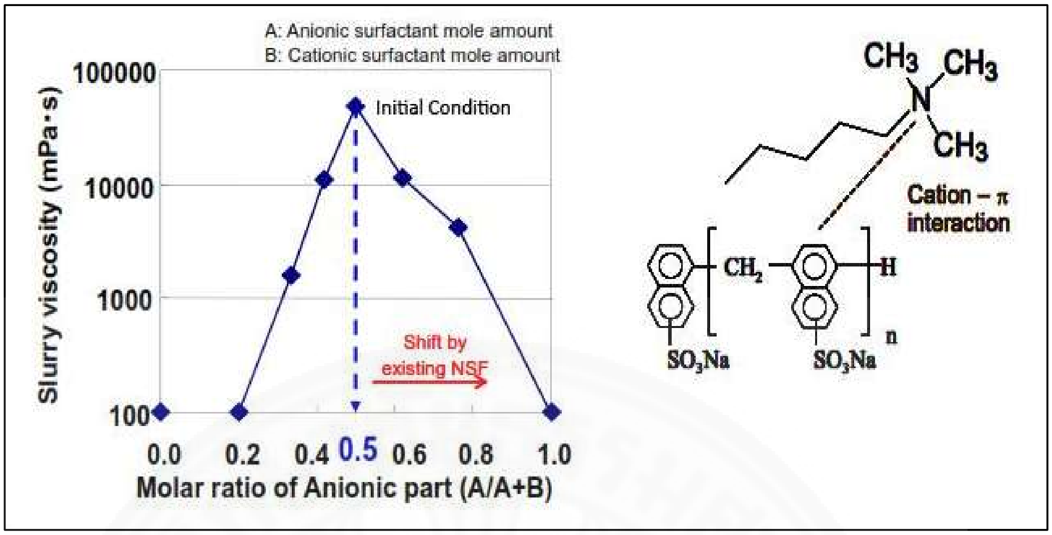


Fig. 4.28 Optimum molar ratio of Surf 20K (Kao, 2016)

Summary of Experimental no.3

From this experimental program, it was found that the surfactant type VMA with PC based superplasticizer slightly increased the initial slump, concrete flow and had a negligible effect on setting time of the concrete. It significantly reduced the pressurized dewatering of mortar under high pressure. On the other hand, use of Surf 20K in mortar mixtures with NL-based superplasticizer reduced initial slump, concrete flow and was not able to reduce the pressurized dewatering of mortar under high pressure.

It can be concluded that surfactant type VMA with PC based superplasticizers had better performances on fresh and hardened properties of concrete than NL-based superplasticizer and type D admixtures.

4.4 Experimental Program no. 4

This section presents the effect of VMAs (Surf 20K and starch) with PC-based superplasticizers on performances of concrete containing 35% fly ash. The results are presented in terms of initial slump, concrete flow, bleeding, compressive strength of concrete and dewatering of mortar under pressure. Additionally, the effect of surfactant type VMA on setting time was examined.

4.4.1 Effect of VMAs with superplasticizers on initial slump of concrete

Fig 4.29 illustrates the effect of VMAs on initial slump and concrete flow. It can be observed that Surf 20K slightly increases the initial slump. The initial slump of control concrete containing only PC-M and PC-M3 are 16cm and 18cm, respectively. By adding 5% dosage of Surf 20K in the same mixtures, the initial slump is increased to 18 cm, and 18.5cm respectively. On the other hand, starch significantly reduces the initial slump of concrete. By applying 0.5% concentration of starch in unit water content in the same control mixture, the initial slump is reduced from 16 cm to only 3.5 cm. Therefore, to evaluate the effect of starch in concrete properties, 0.5% concentration of starch solution in unit water content was used in concrete mixtures with PC-M at the dosage of 0.6% of binder in order to control the slump at 17±1 cm as that of the control mixture.

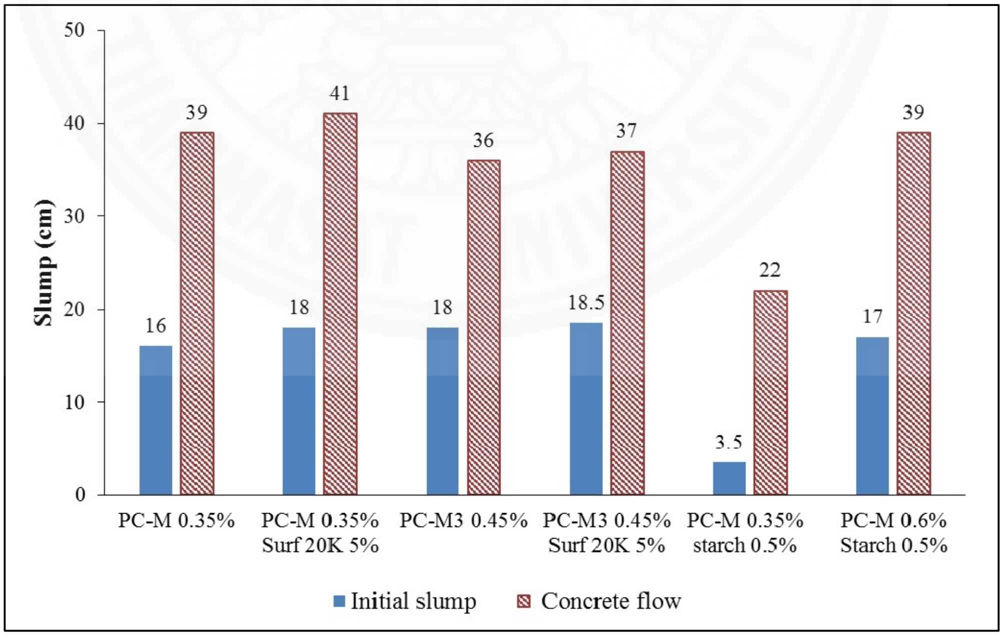


Fig. 4.29 Effect of VMAs on initial slump of concrete containing fly ash

As mentioned, the v-funnel flow time of fresh concrete cannot be measured by the v-funnel apparatus, therefore, mortar mixtures were tested as a representative sample of corresponding concrete mixtures, having the same sand to mortar ratio by volume as that of the corresponding concrete. Fig.4.30 illustrates the effect of surfactant type VMA with PC based superplasticizer on v-funnel flow time. It can be seen that the use of Surf 20K significantly increases v-funnel flow time. The control mortar mixtures with PC-M 0.35% and PC-M3 0.45% without Surf 20K have v-funnel flow times of 3 seconds and 4 seconds, respectively. By adding 5% dosages of Surf 20K to the same mixtures of concrete containing PC-M and PC-M3, the v-funnel times increase significantly to 188 seconds and 241 seconds, respectively. On the other hand, the v-funnel flow time of mortar containing 0.5% concentration of starch with the PC-M 0.35% was not measurable due to too high viscosity of the mortar mixture. Therefore, the dosage of PC-M was increased to 0.6% for mortar mixture with 0.5% starch, of which the v-funnel flow time was measured to be 18 seconds.

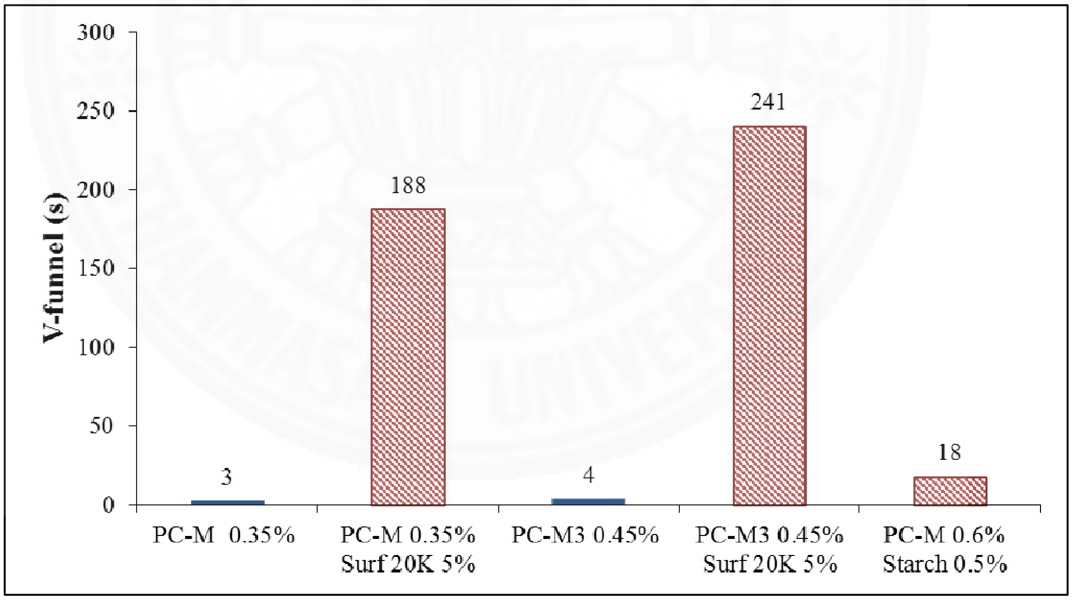


Fig. 4.30 Effect of VMAs with superplasticizers on v-funnel flow time of mortars containing fly ash

4.4.2 Effect of VMAs on bleeding of concrete

The influence of VMAs with PC-M superplasticizer on bleeding of concrete is shown in Fig.4.31. It can be observed that the accumulated bleeding percentage of concrete (C0) without VMA is 2.5%, whereas the same concrete containing 5% dosage of Surf 20K shows no bleeding. 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. On the other hand, concrete containing 0.5% concentration of starch solution in unit water content is used in the mixture C2 with PC-M at the dosage of 0.6% of binder in order to control the slump at 17±1 cm as that of the control mixture (C0). Starch moderately reduces the bleeding of concrete from 2.5% to 1.7%. It is because starch only increase the viscosity of the mixing water without abilities to hold the water and to increase the stiffness of the paste structure.

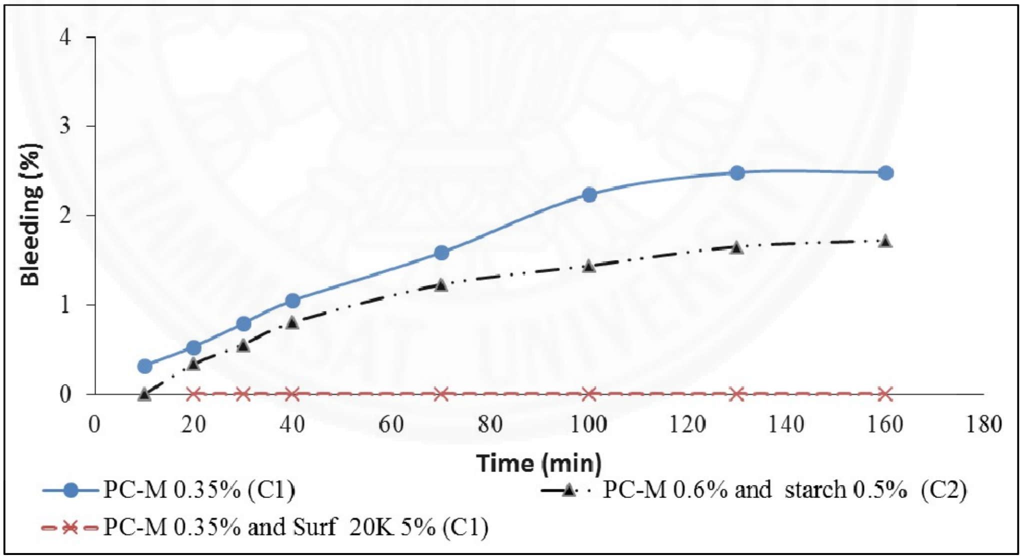


Fig. 4.31 Effect of VMAs on bleeding of concrete

4.4.3 Effect of VMAs with superplasticizers on compressive strength of concrete

The effect of VMAs on compressive strength of concrete at 7 days and 28 days is shown in Fig 4.32. It can be observed that the compressive strengths of concrete without VMA, containing PC-M (C1) and PC-M3 (C3) are 35.2MPa and 35.5 MPa respectively, while the 28-day compressive strengths of the corresponding concrete are 45.8 MPa and 46.3 MPa, respectively. By adding 5% dosage of Surf 20K in the concrete mixtures, their compressive strengths at 7 days only slightly reduce to 33.1MPa, 35.1MPa and their 28-day strengths are 44.2 MPa and 43.2 MPa, respectively. On the other hand, for concrete containing 0.5% concentration of starch solution in unit water content in the concrete mixture (C5), the compressive strengths of concrete at 7 days and 28 days reduce to 31.3 MPa and 39.6 MPa, respectively. It is indicated that VMAs slightly reduces compressive strength of concrete. It is clear that the surfactant type VMA has smaller effect on compressive strength than the starch ether type VMA.

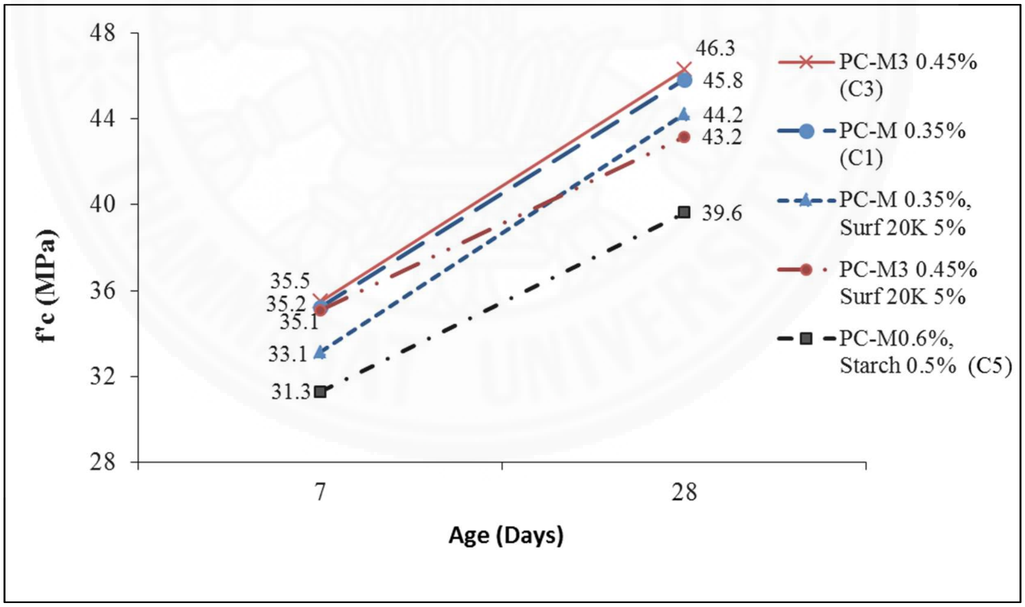
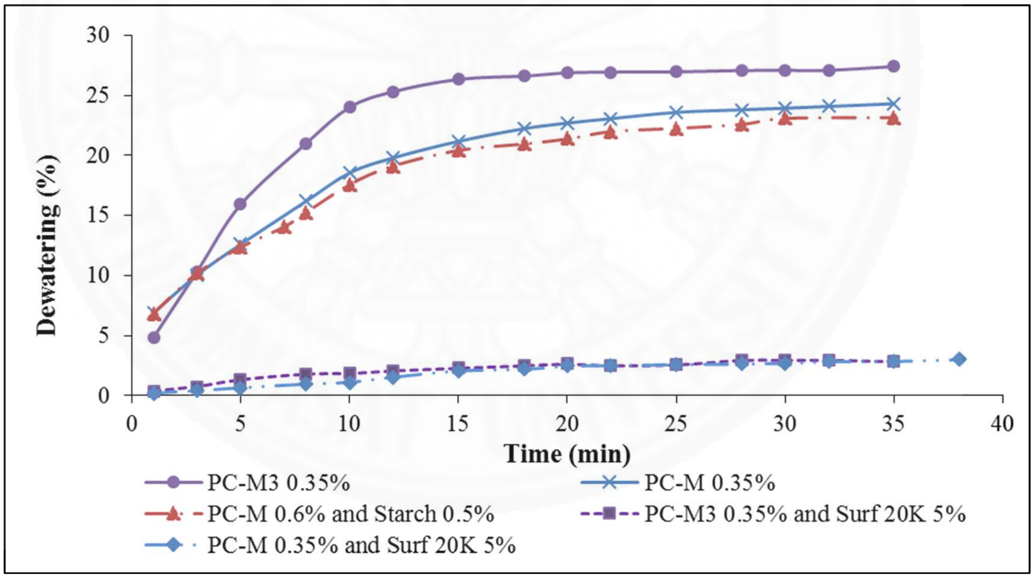


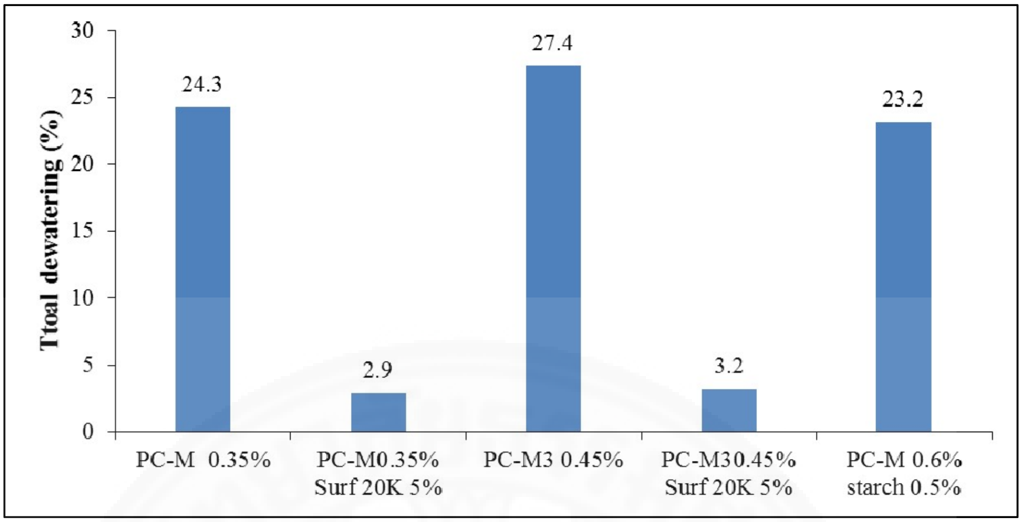
Fig. 4.32 Effect of VMAs on compressive strength at 7 and 28 days of concrete

4.4.4 Effect of VMAs with superplasticizers on pressurized dewatering of mortar

The effect of VMAs on dewatering of mortars under high-pressure (0.72 MPa) and their total accumulated dewatering percentage are presented in Fig.4.33 (a) and Fig. 4.33(b), respectively. It can be seen that the absolute dewatering of the control mortars (C1 and C3) without VMA, containing superplasticizers PC-M and PC-M3 are 24.3% and 27.4%, respectively. By adding 5% dosage of Surf 20K, the dewatering reduces significantly to 2.9% and 3.2%, respectively. On the other hand, by adding 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%. It indicates that starch only slightly reduces the dewatering under high pressure as comparing to the control mixture containing no VMA, while Surf 20K is very effective in reducing the dewatering under pressure.



(a) Pressurized dewatering of mortars



(b)Total accumulated pressurized dewatering of mortars

Fig. 4.33 Effect of VMAs with superplasticizers on pressurized dewatering of mortars

4.4.5 Effect of surfactant type VMA with super plasticizers on setting time of concrete

The influence of Surf 20K on initial setting time of concrete is presented in Fig. 4.34. It can be seen that the initial setting time of concrete mixtures containing only PC-M and PC-M3 superplasticizers are 285 minutes and 255 minutes, respectively. Addition of 5% dosage of Surf 20K in the same concrete mixtures increases initial setting times to 366 minutes and 343 minutes, respectively. It is indicated that Surf 20K increases the setting time of fly ash concrete. However, setting times are still within the acceptable range for bored pile concrete application.

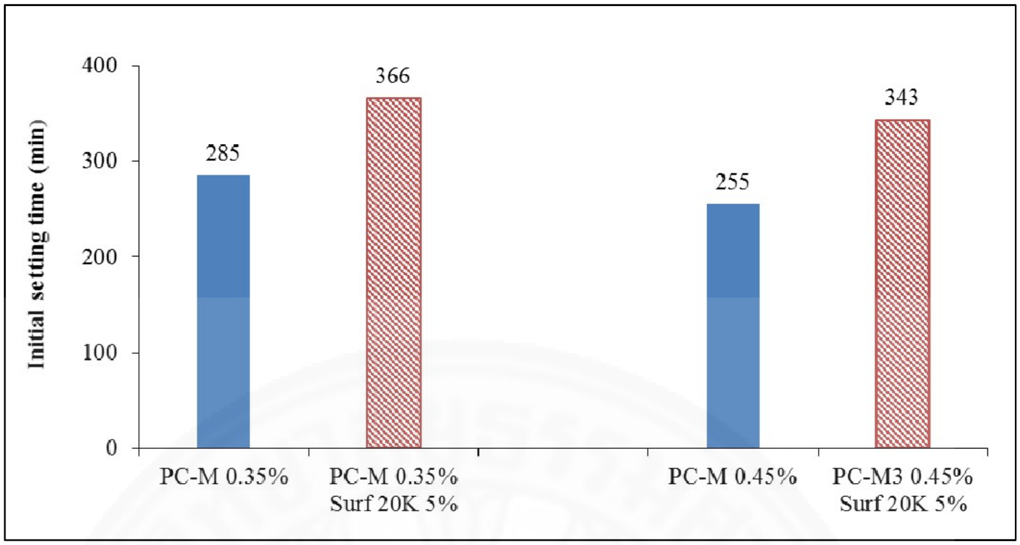


Fig. 4.34 Effect of Surf 20K on initial setting times of concrete containing fly ash

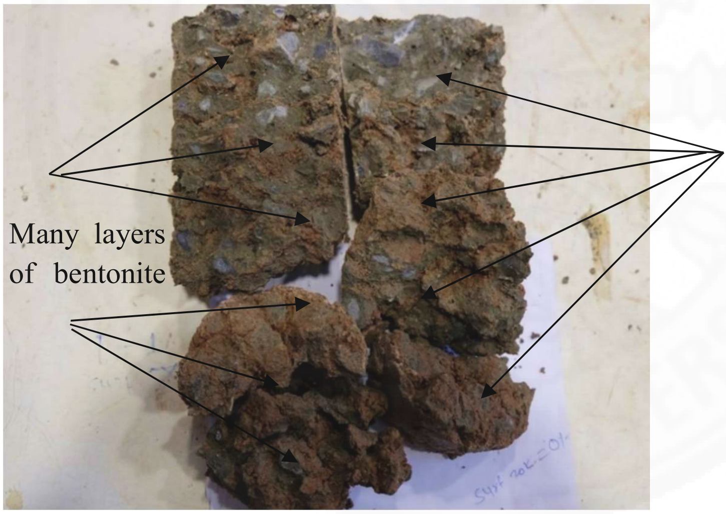
Summary of Experimental no.4

From this experimental program, it was found that the surfactant type VMA (Surf 20K) at the dosage of 5% with PC based superplasticizers slightly increased the initial slump, completely inhibited bleeding, and drastically reduced dewatering and slightly reduced the compressive strength of fly ash concrete. Additionally, Surf 20K with PC based superplasticizer slightly increased the initial setting time of fly ash concrete. The setting times are still within the acceptable range for bored pile concrete application. It is indicated that for bored pile application, the surfactant type VMA had better performance on setting time of fly ash concrete when compared to the cement-only concrete because for bored pile concrete application, longer setting time is required. On the other hand, starch moderately reduced the bleeding of concrete and was not able to improve the pressurized dewatering resistance under high pressure. The surfactant type VMA has smaller effect on compressive strength than the starch ether type.

4.5 Experimental Program no. 5

Effect of surfactant type VMA on blending between bentonite fluid and concrete

The effect of surfactant type VMA (Surf 20K) on blending between bentonite fluid and concrete is shown in Fig.4.35 (a) and Fig 4.35 (b). The fresh concrete mixtures were continuously poured in to a cylindrical mould fully filled with bentonite fluid. In normal concrete mixtures, containing no Surf 20K, many layers of bentonite are seen blended in concrete as can be detected by visual inspection in Fig 4.35(a). Whereas, by adding 5% dosage of Surf 20K in the concrete mixture, the occurrence of blending between bentonite and concrete is significantly reduced to the level that is hardly visible (see Fig 4.35 (b)). It is indicated that surfactant type of VMA is effective for bored pile concrete in order to prevent the blending of concrete with bentonite fluid at the concrete-bentonite contact.



Many layers of bentonite are visible in the normal concrete.

(a) Concrete with PC-M 0.35%

Bentonite layers drastically decrease by using the Surf 20K in the concrete mixtures

(b) Concrete with PC-M 0.35% Surf 20K

Fig. 4.35 Visual inspection of blending between bentonite and concrete

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4.6 Summary of Test Results

The summary of all experimental programs and corresponding test results related to the effect of VMAs on fresh and hardened properties of the tested mortar and concrete mixtures are presented in the Table 4.4.

Table 4.4 Summary of experimental results

Program No	Descriptions	Type of Specimen	Studied properties	Effect on mortar and concrete properties
1	Effect of both VMAs on mortar and concrete performances	Mortar	Flow properties	Surf 20K: slightly increases the mortar flow and increases the v-funnel flow time Starch: decreases the mortar flow and increases the v-funnel flow time
			Dewatering	Surf 20K: significantly reduces dewatering of mortars Starch: ineffective to reduce dewatering of mortars
		Concrete	Bleeding	Surf 20K: completely inhibited Starch: moderately reduces
			Air content	Surf 20K: increases Starch: slightly increases

2	Effect of Surf 20 with type D admixtures on cement-only concrete	Concrete		Surf 20K is not compatible with type D admixtures
3	Effect of Surf 20K with type F admixtures on cement-only concrete	Concrete	Initial slump	PC- based superplasticizer: slightly increases NL- based superplasticizer: reduces
			Compressive strength	PC- based superplasticizer: slightly increases NL- based superplasticizer: slightly reduces
			Setting time	PC- based superplasticizer: small effect NL- based superplasticizer: small effect
		Mortar	Dewatering	PC- based superplasticizer: drastically reduces NL- based superplasticizer: negligible (very small reduction)
4	Effect of VMAs with type F admixtures on concrete containing fly ash	Concrete	Initial slump	Surf 20K : slightly increases Starch: reduces
			Compressive strength	Surf 20K : slightly reduces Starch: slightly reduces
			Bleeding	Surf 20K : completely inhibited Starch: moderately reduces
			Setting time	Surf 20K: slightly increases

		Mortar	Dewatering	Surf 20K: significantly reduces Starch: ineffective
5	Effect of Surf 20K on blending between bentonite and concrete	Concrete	Blending observation	Significantly reduces (almost no blending)

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Chapter 5

Conclusions and Recommendations for Future studies

5.1 Conclusions

The following conclusions can be drawn based on the results obtained from this experimental study.

1. Surf 20K slightly increases the mortar flow because surfactant molecule has a hydrophobic and a hydrophilic part which help to form small air bubbles in the mortars. However, it increases the flow time (v-funnel test) due to an increase of viscosity. On the other hand, starch decreases the mortar flow and increases flow time, because starch only increase viscosity of mortars.
2. Surf 20K is not compatible with type D admixtures in concrete mixtures. However, it is compatible with superplasticizers, especially PC based. The most tested compatible superplasticizer was PC-M.
3. Surf 20K with PC based superplasticizer slightly reduces the compressive strength of concrete because surfactant molecules help to form small air bubbles in the concrete.
4. The use of Surf 20K with superplasticizers has a small effect on setting time of concrete by slightly prolonging the setting time.
5. Bleeding of concrete is completely inhibited by using the surfactant type VMA at the dosage of 5% whereas starch moderately reduces bleeding of the concrete.
6. Dewatering resistance of fresh mortar increases with an increase of dosage of surfactant type VMA. The dosage of Surf 20K at 3% or higher effectively reduces dewatering under pressure. On the other hand, starch ether is not able to effectively improve dewatering resistance of mortar under high pressure.
7. Dewatering resistance of fresh mortar increases effectively by using the surfactant type VMA with polycarboxylate based super plasticizer. On the other

hand, surfactant type VMA with naphthalene based superplasticizer is not able to improve the dewatering resistance under pressure.

8. Surf 20K with PC based superplasticizer can be used for concrete containing fly ash as a cement replacement material.
9. Surf 20K can be effectively utilized to prevent blending between bentonite fluid and concrete.

5.2 Recommendations for Future Study

1. It is necessary to estimate the cost of Surf 20K with PC application in concrete mixtures for obtaining good dewatering resistance performance. The cost comparison between using Surf 20K with PC and overcasting concrete should be also determined.
2. The effect of Surfactant type VMA on durability of concrete should be investigated.
3. The reduction of compressive strength of concrete by using VMAs with admixtures should be further investigated in order to determine the major factor which is responsible for compressive strength reduction of concrete.
4. A dewatering prediction model with respect to the pressure gradient on fresh concrete should be developed in order to optimize the dosage of VMA.
5. Micelle net structure increases the dewatering resistance by retaining water within its structure, reducing permeability and increasing the stiffness of the fresh paste mixtures. However, only stiffness of paste mixtures was determined in this study. Therefore, the water retainability and permeability of micelle net structures in cementitious mixtures should be investigated in order to know the key determinant to reduce the pressurized dewatering of concrete among these three factors.
6. Effect of surfactant type VMA (Surf 20K) on blending between bentonite and concrete is not determined quantitatively in this study. The method for determination of blending between bentonite fluids with concrete should be developed.

7. Stress-strain model of solid phase of concrete and permeability model of fresh concrete mixtures should be developed in order to simulate the dewatering of concrete under high pressure.
8. Real construction tests should be conducted to evaluate the site performance of the concrete with Surf 20K and PC based superplasticizer.

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