Experimental Study on Bleeding of Fly Ash Concrete with Water Reducing Admixtures

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Abstract

This article outlines the experimental studies on bleeding of fly ash concrete with water reducing admixtures. Bleeding is a form of segregation occurring from rising of free water in the mix to the surface of freshly placed concrete. Bleeding in concrete causes low abrasive resistance and high porosity of the top surface of concrete. The mix proportion of concrete in this experiment was designed based on variation of water to binder ratio, replacement percentage of fly ash, and type and dosage of water reducing admixture in order to investigate the effect of these practical parameters on bleeding of concrete with water reducing admixture.

Moreover, as the analytical parameters, average degree of reaction, the amount of free water, effective surface area of solid particles, and water retainability coefficient of powder materials can be computed and investigated for their effects on bleeding.

From this study, it is found that for mixtures with the same water to binder ratio and unit water content, the higher bleeding is caused by the higher ability of particle dispersion which depends on type and dosage of water reducing admixture. The mixtures with fly ash which have lower water retainability produce higher bleeding than those with cement only.

1. Introduction

Properties of fresh concrete are important for durability of concrete in long term state. One of the problems of fresh concrete causing the durability problem is bleeding. Bleeding is a form of segregation in which some water in the mix rises to the surface of freshly placed concrete. This is caused by the inability of the solid constituents of the mix to hold all of the mixing water when they settle downwards [1].

Bleeding of fresh concrete can adversely affect certain properties of the hardened mass [2]. The initial bleeding proceeds at a constant rate, but subsequently the rate of bleeding decreases steadily. Rising of water to the top of a slab causes a porous surface with a subsequently dusty surface. At the top of a lift a plane of weakness would form and the bond with the next lift would be inadequate. Bleeding of concrete continues until the cement paste has stiffened sufficiently to put an end to the process of sedimentation [1].

Ghosh [3] found that bleeding capacity is higher as the workability of the concrete is greater and generally the higher is the water-cement ratio; the lower is the cement content. In some occasions, bleeding can be beneficial, especially during hot and windy weather conditions. If the rate of evaporation exceeds the bleeding rate, plastic cracks may develop.

The influence of admixtures is not straightforward. Superplasticizers generally decrease bleeding except at a very high slump [4]. However, if they are used with a retarder, increased bleeding may occur [5]. Furthermore, it was found that water-reducing admixtures containing lignosulphonates reduce bleeding, while those based on hydroxycarboxylic acids increase the bleeding rate [3].

Tangtermsirikul [6] studied the influencing factors of bleeding which were surface area of solid particles, water to cement ratio, and air content on bleeding rate and bleeding capacity and found that the larger the total surface area of solid particles in the fresh concrete mixture was, the lower permeability of the fresh

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concrete mixture would be. Therefore, smaller bleeding rate could be expected. For effect of water to cement ratio w/c, cement pastes with higher w/c ratio give higher value of bleeding rate for cement pastes made from same cement and it can be expected that the cement paste with higher w/c ratio usually gives higher bleeding capacity than that with lower w/c ratio since cement paste with higher w/c ratio contains larger amount of water in the mixture. For effect of sample height, the higher sample gives rise to larger bleeding capacity [7].

In Thailand, fly ash has been used in concrete for a number of years. However, understanding about fly ash concrete properties is still not up to a satisfactory level. With this level of understanding, fly ash has been refused for being used in many construction projects. Low abrasive resistance and dusty surface of fly ash concrete are common problems heard during these days. These problems are considered to be caused by excessive bleeding which may be accompanied by the prolonged setting time of the fly ash concrete, especially when the fly ash concrete has high w/b ratio or high water content (relatively low strength concrete).

The objective of this study is to conduct comprehensive experiments to clarify the mechanisms of bleeding of fly ash concrete with water reducing admixtures and to illustrate the influence of analytical parameters on bleeding for creating a bleeding prediction model in the future.

2. Experimental Program

The experiments are conducted to investigate the effect of the analytical parameters i.e. amount of free water, effective surface area, and average degree of reaction on the bleeding of fresh concrete with different content of fly ash, type and dosage of water reducing admixture, water to binder ratio (w/b), and the ratio of paste volume to void volume of aggregate phase (γ).

2.1 Mix proportion of concrete

A total of 45 mixtures were tested in this study. The test results of 35 mixtures without water reducing admixture had been reported elsewhere [8]. In this paper, another 10 mixtures with water reducing admixtures were tested. Their mixture proportions are shown in Table 1.

The mix proportion had difference in type of admixture. The dosage of admixture was varied in some cases and a type of fly ash was used to study its effect on the bleeding.

Table 1 Mix proportion of concrete with water reducing admixtures

No.	%adm	γ	w/b	%r	C	F	W	G	S	Slump (cm)
Naphthalene (Source A)										
adm-1	0.50	1.2	0.5	0	325	0	163	1071	854	9.0
adm-2	0.50	1.2	0.5	30	215	92	154	1071	854	9.5
adm-3	0.75	1.2	0.5	0	325	0	163	1071	854	10.4
adm-4	1.00	1.2	0.5	0	325	0	163	1071	854	17.0
Polycarboxylic (Source A)										
adm-5	0.50	1.2	0.4	0	371	0	148	1071	854	8.5
adm-6	0.50	1.2	0.4	30	243	104	139	1071	854	11.0
Polycarboxylic (Source B)										
adm-7	0.50	1.2	0.4	0	371	0	148	1071	854	18.5
adm-8	0.50	1.2	0.4	30	243	104	139	1071	854	18.7
Lignosulfonate (Source B)										
adm-9	0.50	1.2	0.5	0	325	0	163	1071	854	4.0
adm-10	0.50	1.2	0.5	30	215	92	154	1071	854	6.0

Note: %adm denotes percentage of water reducing admixture by weight of powder, γ denotes the ratio of paste content to the total void of compacted aggregate phase and w/b is water to binder ratio. %r denotes percentage of fly ash contained in binder. C, F, W, G, and S denote weight of cement, fly ash, water, coarse aggregate, and sand in 1 m^3 of concrete (kg/m^3), respectively.

2.2 Sources and properties of materials

(i) Cementitious materials

1. Ordinary Portland cement type 1 conforming to ASTM C150-92 type 1 was used. The chemical composition and physical properties of the cement are shown in Table 2.
2. A fly ash sample was collected from Mae-Moh electric power plant. The chemical composition and physical properties of the fly ash are shown in Table 2.

Table 2 Properties of cementitious materials

Compound	Cement	Fly Ash
Chemical Composition by Weight (%)		
Silicon dioxide (SiO_2)	20.99	43.12
Aluminum oxide (Al_2O_3)	5.18	22.04
Iron oxide (Fe_2O_3)	3.20	9.78
Calcium oxide (CaO)	64.63	12.55
Magnesium oxide (MgO)	1.30	3.09
Sulfur trioxide (SO_3)	2.61	2.76
Insoluble residue	0.13	-
Sodium oxide (Na_2O)	0.04	1.30
Potassium oxide (K_2O)	0.40	5.22
Titanium dioxide (TiO_2)	0.25	-
Phosphorus pentaoxide (P_2O_5)	0.05	-
Free lime	0.75	-
Gypsum content	5.60	-
Physical Properties		
Specific gravity	3.15	2.07
Loss on ignition (%)	1.17	0.01
Water retainability coefficient	0.230	0.156
Blaine fineness (cm^2/g)	3150	2809

(ii) Aggregates

1. The natural river sand, passing sieves No.4, was used as fine aggregate. Specific gravity was tested in accordance with the ASTM C128 which was 2.62 in SSD condition.
2. The crushed limestone with the maximum size of 25 mm was used as coarse aggregate. Specific gravity was tested in accordance with the ASTM C127 which was 2.69 in SSD condition.
3. The compacted void content of binary mixture of aggregates was performed according to the ASTM C29/C29M-91a. Sand to total aggregate ratio of 0.45, which gave void ratio of 0.23, was selected for the mix proportions.

(iii) Water reducing admixtures

Three types of water reducing admixture were used in the mix proportion in order to investigate their effect on bleeding. They were Naphthalene based water reducing admixture, Polycarboxylic based water reducing admixture, and Lignosulfonate based water reducing admixture. Their water reducing efficiencies can be seen in Table 3 (tested using the method proposed by Wangchuk S. et al. [9]).

Table 3 Efficiency of water reducing admixtures

Base	ASTM Type	Source	Water Reducing efficiency
Naphthalene	F	A	0.32
Polycarboxylic	F		0.38
Polycarboxylic	F	B	0.47
Lignosulfonate	D		0.11

2.3 Experimental investigation

Measurement of bleeding water was performed following ASTM C232-99 Method A (sample consolidated by tamping). After casting concrete into the container, draw off (with pipet or similar instrument) the water that had accumulated on the surface, at 10 minutes intervals during the first 40 minutes and at 30 minutes intervals thereafter until bleeding stops.

The standard cylindrical container of approximately 14 liters capacity and the major apparatus used in the experiment are shown in Fig. 1.

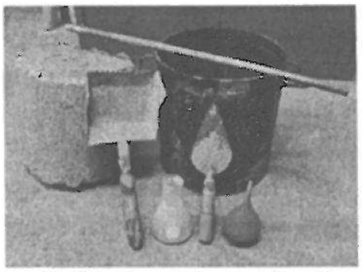

Fig. 1 The cylindrical container and major apparatus for bleeding test

3. Results and Discussions

The experimental results of bleeding are shown in Fig. 2 to Fig. 4.

3.1 Effect of type of water reducing admixture

The ability of particles dispersion for each type of water reducing admixture is defined by water-reducing efficiency. A method for determining this efficiency is adopted by Meyer and Perenchio [10]. The water-reducing efficiency of the water-reducing admixtures is determined by using a metal mold in the form of a frustum of a cone with dimensions as follows: 40±3 mm in inside diameter at the top, 90±3 mm in inside diameter at the bottom and 75±3 mm in height.

The test is performed as follows: Cement paste, with a guessed value of water-cement ratio that would give a flow diameter about 180±5 mm is placed in the mold. After filling, the mold is removed immediately by raising it carefully in the vertical direction and the diameter of the flow of the cement paste is measured. The water-cement ratio is varied till the required flow diameter of 180±5 mm is obtained. This is firstly tested for control mixture without water reducing admixture. Then for a given dosage of water reducing admixture, the quantity of water is varied and the test repeated till the required flow diameter as that of the control mix is obtained.

The water-reducing efficiency (φ') of the admixture is computed from;

$$\varphi' = 1 - \frac{W_a}{W_0} \quad (1)$$

where W_0 and W_a are quantities of water required to produce the required flow diameter of the pastes without and with admixtures, respectively [9].

To investigate the ability of particles dispersion of water reducing admixtures or water reducing efficiency of admixtures, three types of water-reducing admixture were used to conduct the bleeding tests and the results were shown in Fig. 2 and Fig. 3.

From Fig. 2, when comparing at the same dosage, the mixtures with Polycarboxylic based water reducing admixture B produced higher bleeding than the A one. From Fig. 3, the mixtures with Naphthalene based water reducing admixture A produced higher bleeding than those with Lignosulfonate based water reducing admixture. The higher bleeding is caused by the higher ability of particles dispersion of water reducing admixture which leads to more repulsion among particles and then the amount of free water is increased. So, at the same dosage, bleeding increases with increase of water reducing efficiency.

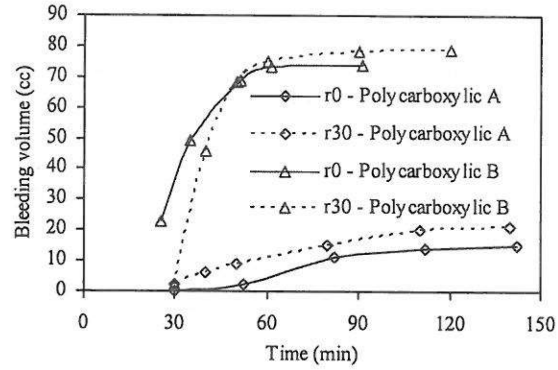

Fig. 2 Bleeding of concretes with 0.5% admixtures and fly ash replacement = 0%, 30% (w/b = 0.4, γ = 1.2)

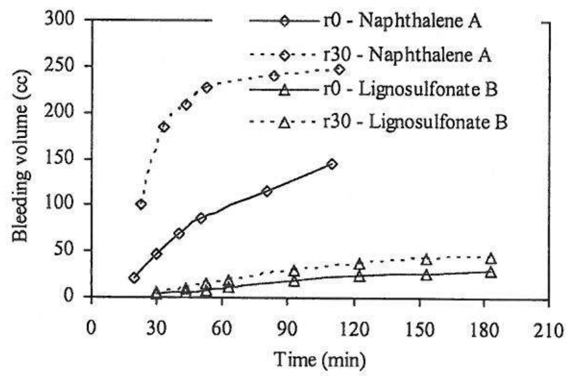

Fig. 3 Bleeding of concretes with 0.5% admixtures and fly ash replacement = 0%, 30% (w/b = 0.5, γ = 1.2)

3.2 Effect of dosage of water reducing admixture

Increasing of dosage of water reducing admixture caused increasing of bleeding as can be observed from Fig. 4 because of higher ability of particle dispersion of water reducing admixture.

It should be noted that the unit water content is generally adjusted to control bleeding when using water reducing admixtures in practice.

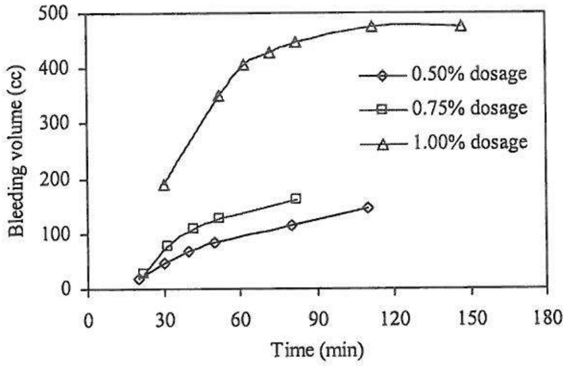

Fig. 4 Bleeding of concretes with Naphthalene A ($w/b = 0.5$, $\gamma = 1.2$, $\%r = 0$)

4. Model for Predicting Bleeding

4.1 Bleeding rate

Bleeding rate has been considered as a parameter to represent bleeding character.

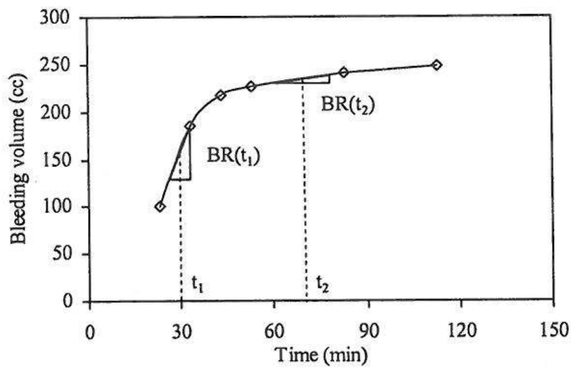

Fig. 5 Characteristic of bleeding with time

Bleeding rate at a certain time (BR(t)) can be obtained by differentiating the relationship of bleeding volume versus time (see Fig. 5).

$$BR(t)=\frac{d}{dt}(BV(t)) \quad (2)$$

where BV(t) is the bleeding volume versus time relationship.

In this paper, bleeding rate BR(t) is considered as an important parameter that represents the whole bleeding behavior.

In this study, free water, effective surface area of solid particles, and average degree of reaction have been considered as analytical parameters affecting the bleeding rate.

4.2 Analytical parameters affecting bleeding

(i) Free water

Free water at any time has been defined as the amount of water that is free, by any means, from being restricted by all solid particles in the fresh concrete. Moreover, it has been found that very fine powder particles could fill in the voids among cement particles and drive out water entrapped in these voids. This driven out water becomes available as additional free water. So, free water can be determined as follow;

$$W_{fr}(t)=W_u(t)-W_{rp}(t)-W_{ra'}(t)+W_{aa}(t) \quad (3)$$

where $W_u(t)$ is unit water content of the mix (kg/m^3 of concrete), $W_{rp}(t)$ is water restricted by powder materials (kg/m^3 of concrete), $W_{ra'}(t)$ is restricted water at the surface of aggregates (kg/m^3 of concrete), and $W_{aa}(t)$ is additional free water due to filling effect of fine powders. The determination of $W_{rp}(t)$, $W_{ra'}(t)$, and $W_{aa}(t)$ can be found from the publication of Tangtermsirikul S. et al. [11].

Increasing the amount of free water increased bleeding rate. The effect of free water on bleeding rate is shown in Fig. 6.

(ii) Effective surface area of solid particles

The effective surface area of solid particles at any time has been defined as the surface area of solid particles that have the possibility to be in contacts. It has been derived as;

$$S_{eff}(t)=\eta_a \cdot S_{ta}(t)+\eta_p \cdot S_{tp}(t) \quad (4)$$

$$S_{tp}(t)=1000\cdot\sum_{i=1}^{n} S_{pi}\cdot w_{pi} \quad (5)$$

$$S_{ta}(t)=1000\cdot(S_s\cdot w_{s'}+S_g\cdot w_{g'}) \quad (6)$$

where $S_{ta}(t)$ and $S_{tp}(t)$ are surface area of total aggregates and total powder materials in mix, respectively (cm^2/m^3 of mix); $w_{s'}$, $w_{g'}$, and w_{pi} are the saturated surface dry weight of fine aggregate, coarse aggregate and the absolutely dry weight of powder material type i, respectively (kg/m^3 of mix); S_s, S_g, and S_{pi} are the specific surface area of fine aggregate, coarse aggregate and powder material type i, respectively (cm^2/g); n is the total number of kind of powder materials used in the mix; η_a and η_p are the effective contact area ratio of aggregate and powder, respectively [11].

Increasing effective surface area of solid particles reduced bleeding rate, and free water due to the increased water retainability. The effects of effective surface area of solid particles on bleeding rate and free water are shown in Fig. 6.

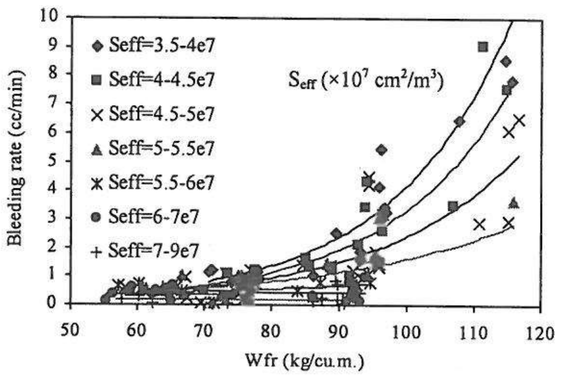

Fig. 6 Relationship between bleeding rate and free water classified by the range of effective surface area of solid particles

(iii) Average degree of reaction

The average degree of hydration reaction of paste at any time has been defined as the weight fraction of hydrated cement per total cement in the paste mixture and can be computed using the following equation.

$$\alpha_{hy}(t) = \frac{\sum_{k=1}^{4} m_k \cdot \alpha_k(t)}{\sum_{k=1}^{4} m_k} \qquad (7)$$

where k is the mineral compound of cement (C_3A, C_4AF, C_3S, C_2S), m_k is the mass of each compound per cubic meter of concrete at any water to binder ratio (kg/m^3), and $\alpha_k(t)$ is the degree of hydration of each compound in cement (%) [12].

The degree of pozzolanic reaction of paste has been defined as the weight fraction of already reacted fly ash per total fly ash in the paste mixture and can be computed using the following equation [12].

$$\alpha_{poz}(t) = \frac{\tan^{-1}[(0.049 \cdot T_c^{0.496} - 0.186 \cdot \frac{w}{b} - 0.135) \cdot t]}{\tan^{-1}[(0.049 \cdot T_c^{0.496} - 0.186 \cdot \frac{w}{b} - 0.135) \cdot 365]} \cdot \alpha_{poz}(365) \qquad (8)$$

where T_c is curing temperature (°C), $\frac{w}{b}$ is water to binder ratio, t is the age of concrete (day), and $\alpha_{poz}(365)$ is degree of pozzolanic reaction of paste at 365 days (%).

The average degree of reaction can be computed using the equation (9) [12].

$$\alpha_{react}(t) = \left(1 - \frac{\%rFA}{100}\right) \cdot \alpha_{hy}(t) + \left(\frac{\%rFA}{100}\right) \cdot \alpha_{poz}(t) \qquad (9)$$

where %rFA is the replacement percentage of fly ash in the total binder (% by weight of the total binder).

Fig. 7 shows that an increase in average degree of reaction decreases the bleeding rate. This is because water is utilized during the hydration and pozzolanic reaction.

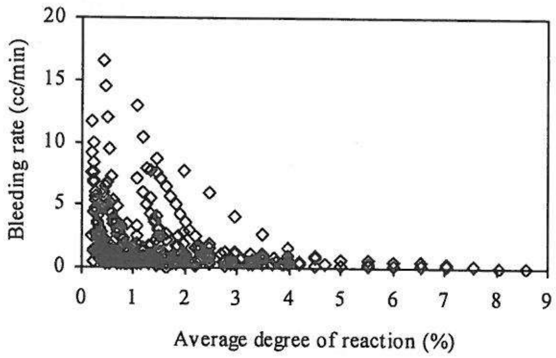

Fig. 7 Relationship between bleeding rate and average degree of reaction

All analytical parameters will be useful for creating a prediction model for bleeding in the future.

5. Conclusions

Based on the test results, the following conclusions can be made.

1. The mixtures with fly ash which have lower water retainability produced higher bleeding than those with cement only.
2. When paste volume and water to binder ratio are kept constants, the higher bleeding is caused by the higher ability of particles dispersion which depends on type and dosage of water reducing admixture.
3. Bleeding rate increases with the increase of free water content but reduces with the increase of effective surface area of solid particles and average degree of reaction.

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