EFFECT OF ADDITIVE COMPOUNDS ON CONCRETE USED FOR THE CONSTRUCTION OF HYDRAULIC STRUCTURES

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Abstract: *This paper presents the effect of additive compounds on concrete used for the construction of hydraulic structures. The results showed that the use of fly ash replacing 10% of cement content has diminished both slump value and compressive strength of concrete. Yet, the application of superplasticizer with 0.8 liters per 100 kg cement and/or of waterproofing admixture with 0.4 liters per 100 kg have increased essentially both slump value and compressive strength. The binary additive compounds of fly ash and superplasticizer have improved either slump value or compressive strength, even though cement content was 10% less than conventional. In term of waterproof grade, the use of superplasticizer, waterproofing admixture, or fly ash and superplasticizer has resulted in the enhancement of waterproofing grade from W6 to W8. Moreover, the grade W10 has been attained in the concrete mix with superplasticizer and waterproofing admixture usage and in the mix with the trinary compounds of fly ash, superplasticizer and waterproofing admixture.*

Keywords: Concrete, fly ash, superplasticizer, waterproofing admixture, additive compounds.

1. INTRODUCTION

Vietnam still relies much on the agricultural economy, with a monoculture of wet rice. Therefore, the economy depends a lot on nature, if the weather is favorable, it is a favorable environment for agriculture to develop, but when it encounters periods of extreme natural disasters such as drought, floods and tropical storms will seriously affect the lives of the people, especially the development of rice, because rice is one of the important export commodities of the country (World Bank). Hence, the irrigation system in general and a series of hydraulic structures, in particular, have a great impact on the country's economy. Nowadays, one of the key components of the irrigation system includes hydroelectric power dams, especially in the North of Vietnam (EVN, 2015).

Since 1975, Vietnam has entered the era of industrialization and modernity, thus numerous hydroelectric dams have been built throughout the country, most of them were made of concrete (Hoàng Phó Uyên & Nguyễn Tiến Trung, 2001). Accordingly, the concrete dam has become quite popular with increasingly higher and higher scale and form. The hydroelectric concrete dams were within the hydropower plants such as PleiKrong, Se San 3, Se San 4, Ban Ve, Thach Nham, Tan Giang, Long Song, Bac Ha, Ta Thang, Dong Nai 3, Dong Nai 4, ect. And a series of spillways at Hoa Binh and Tuyen Quang power plants. For those purposes, a vast amount of concrete has been used, and normally the dam height varied within the range of 70-138 m (Đoàn Văn Huân, 2012). Up to the present moment, Vietnam has implemented a modernized technology to build the hydroelectric concrete dams. Two types of concrete including conventional vibrated concrete and roller compacted concrete are the most commonly-used in Vietnam for the concerned purposes (Nguyễn Quang Hiệp, 2011).

In recent years, construction projects in general

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have become more and more important in terms of scale and size, requiring high performance concretes for special purposes such as: high impact resistance, waterproofness, anti-corrosion, ect. (Bentur & Mindess, 1990, Aitcin, 1998). These types of concrete need to satisfy the technical requirements of high performance, high early-age strength, flowability, high filling capacity, dimensional stability, good adhesion, no segregation and bleeding, non-cracking, durability, vibration resistance, capability of reinforcement protection (Aitcin, 1998, Okamura & Ouchi, 2003). Construction technology of hydroelectric concrete dams is constantly being improved to increase quality as well as reduce cost of construction. Technology changes along with the construction material development especially the use of additives added to improve the properties of concrete, prolong the service life of the structure, and ensure safety in the management and use of large-scale dams is a scientific matter, economics and immense practice.

As a result of that, in order to perceive the effect of additive compounds on concrete used for the construction of the hydraulic structure, this study attempts to focus on the use of superplasticizer and fly ash, as well as, superplasticizer and waterproofing admixture for the concrete production. Besides, the trinary additive compound of fly ash, superplasticizer and waterproofing admixture is also concerned.

2. MATERIALS AND METHODS

The constituent materials used for this study are presented as follows:

2.1. Cement and fly ash

Portland blended cement PCB40 with commercial band Quang Son, which is conforming to the Vietnamese standard TCVN 6260:2009, is used in this study.

In addition, fly ash used in this study is a treated one conforming to the Vietnamese standard TCVN 10302:2014 from Pha Lai coal-fire power plant. Chemical and physio-mechanical characteristics of cement and fly ash are included in Table 1 and Table 2, respectively.

Table 1. Chemical characteristic of cement and fly ash

Compound (wt. %)	Cement	Fly ash
SiO_2	22.32	58.97
Al_2O_3	4.95	24.37
Fe_2O_3	4.84	5.43
CaO	64.22	4.43
MgO	1.62	2.82
SO_3	-	0.06
K_2O	0.11	0.55
Na_2O	0.26	0.09
TiO_2	0.05	0.40
LOI	1.24	3.24

Table 2. Physio-mechanical characteristic of cement and fly ash

Parameters	Units	Cement	Fly ash
Specific density	g/cm^3	3.12	2.2
Bulk density	g/cm^3	1.32	-
Blaine fineness	cm^2/g	3340	3818
Consistency	%	26.5	-
Initial setting time	min.	135	-
Final setting time	min.	254	-
Soundness of cement	mm	2.4	-
3 days Compressive strength	N/mm^2	25.5	-
28 days Compressive strength	N/mm^2	45.7	-

2.2. Coarse and fine aggregates

In this study, crushed stone coarse aggregate with the maximum size of 40 mm is used, while fine aggregate is natural sand from Bac River, Ha Giang Province. The characteristic of coarse and fine aggregates conforming TCVN 7570:2006 is given in Table 3. Besides, in order to obtain grading of aggregates, sieve analysis was also carried out, and the results can be seen in Table 4 below.

Table 3. Characteristic of sand and crushed stone

Parameters	Units	Sand	Crushed stone
Specific density	g/cm^3	2.63	2.72
Bulk density	g/cm^3	1.42	1.43
Porosity	%	38.2	47.6
Moisture content	%	1.03	0.62
Clay, silt and dust content	%	0.78	0.86
Fineness modulus	-	2.72	-

Table 4. Gradation of sand and crushed stone by sieve analysis

Sieve size, mm	Sand, %	Crushed stone, %
100	-	0.0
70	-	0.0
40	-	3.5
20	-	47.6
10	-	72.5
5	-	97.1
2.5	9.0	-
1.25	23.5	-
0.63	46.3	-
0.315	84.0	-
0.14	94.5	-
Pan	100	100

2.3. Water and admixtures

Two types of chemical admixture are implemented; one is a high-range water reducer admixture, which is a third generation polycarboxylate superplasticizer, and the other is waterproofing admixture. Meanwhile, water used for the concrete mix proportion is tap water at Hanoi area. The characteristic of tap water and chemical admixtures is shown in Table 5.

2.4. Concrete mix proportion

In this study, a concrete mixture corresponding to the slump of 6 cm at the fresh state and strength class of 30 MPa at the age of 28 days is designed. This reference mix designated as M1 is conventional concrete without any additives. The second mix or M2 includes the addition of fly ash replacing 10% of cement content in comparison with the mix M1. The next two mixes or M3 and M4 are the ones similar to the M1 except for the use of superplasticizer and waterproofing admixture, respectively. The admixture content is applied in compliance with the suggestion from the manufacturer, the former is 0.8 liter per 100 kg cement and the latter is 0.4 liter per 100 kg cement.

Table 5. Characteristic of water and admixtures

Parameters	Water	Super-plasticizer	Water-proofing admixture
Specific density, g/cm^3	1	1.20÷1.24	1.17÷1.19
pH value	7	7÷11	7÷9

The additive compounds are studied in the next three mixes or M5, M6 and M7. The M5 is a binary compound of fly ash and superplasticizer, while the M6 is of superplasticizer and waterproofing admixture. The last one M7 is the trinary compound of fly ash, superplasticizer and waterproofing admixture.

Some "trial-and-error" were involved in concrete mix proportion. The final detailed proportion used in this study can be observed in Table 6.

2.5. Specimen preparation

After a relevant mixing procedure, as shown in Figure 1, all of the mixtures (M1-M7) were tested at the fresh state in order to define slump value in accordance with the standard TCVN 3106:1993, as is illustrated in Figure 2.

Afterward, six cubic specimens (150x150x150 mm^3) and three cylindrical specimens (150 mm diameter and 150 height) were prepared in order to determine compressive strength and waterproofing grade respectively at hardened state.

Table 6. Concrete mix proportion

	PCB40	Crushed stone	Sand	Water	Fly ash	Superplasticizer	Waterproofing admixture
	kg	kg	kg	L	kg	L	L
M1	315	1255	650	175	-	-	-
M2	284	1255	650	175	31	-	-
M3	315	1255	650	165	-	2.5	-
M4	315	1255	650	168	-	-	1.3
M5	284	1255	650	169	31	2.5	-
M6	315	1255	650	166	-	2.5	1.3
M7	284	1255	650	170	31	2.5	1.3

Figure 1. Manual concrete mixing

After casting concrete mixture into the corresponding moulds along with a proper vibration by a manual poker, the specimens were kept in the laboratory for 24 hours, then they were removed from the moulds and cured under the standard condition (T=20±2°C; W>95%) up to the testing date, as shown in Figure 3 and Figure 4.

Figure 2. Slump determination

Figure 3. Cubic specimen after mould removal

Figure 4. Cylindrical specimen used for the waterproofing test

Compression test on cubic specimens was carried out at 7 and 28 days, as shown in Figure 5, while the waterproofing test on cylindrical specimens, as shown in Figure 6, was performed at 28 days of curing. All of tests were conducted in compliance with the corresponding standards.

Figure 5. Compression test

Figure 6. Waterproofing test

3. RESULTS AND DISCUSSION:

3.1. Fresh properties

Slump value of concrete mixtures (M1-M7) is shown in Figure 7. It can be seen that slump value of M1 is 6 cm as designed. The addition of fly ash in M2 results in the reduction of slump value. This might be due to the grain size of fly ash is smaller than that of cement, as it can be observed in Table 2, thus it requires more water to yield the slump value as same as the M1.

Meanwhile, by using superplasticizer in the M3, the slump value increases significantly almost twice as high as that of the M1, yet the implementation of waterproofing admixture in the M4 also enhances the slump value. Although the use of chemical admixtures is with a small amount, 0.8 liters and 0.4 liters per 100 kg cement for superplasticizer and waterproofing admixture respectively, their impact on fresh properties of concrete is quite vital.

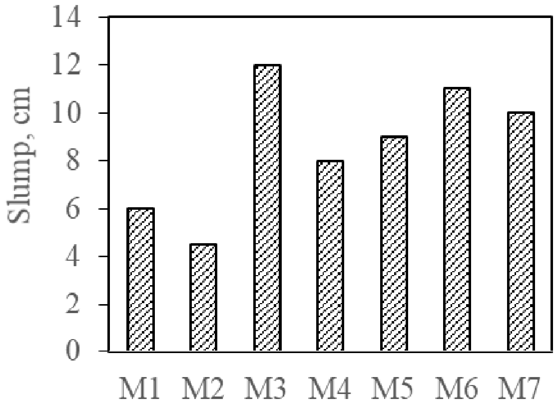

Figure 7. Slump value of concrete mixtures

Despite partial cement replacement with fly ash in the M5, the slump value is improved in comparison with that of the M2, thanks to the use of superplasticizer. This points out that the superplasticizer usage is truly recommended in case of the mineral additive implementation. The slump value of the M6 is even higher than that of the M5, the combination of superplasticizer and waterproofing admixture makes the concrete mixture more workable. Finally, the trinary compound of fly ash, superplasticizer and waterproofing admixture enhances the slump value notably in comparison with that of the M1 and M2.

3.2. Hardened properties

Compressive strength of concretes (M1-M7) at 7 and 28 days is presented in Figure 8. Firstly, the M1 strength complies with concrete grade design of 30MPa and the 7-days-strength is about 58% that of 28 days. The fly ash replacement of 10% cement content in the M2 has caused the strength reduction at both 7 and 28 days about 10%. However, according to various research sources [Malhotra & Mehta, 2008], strength increase would occur in the long term thanks to the abundantly pozzolanic reaction caused by fly ash.

On the other hand, looking into Figure 8, compressive strength of the M3 at 7 and 28 days is higher than that of the M1 about 64% and 20% respectively. This indicates that the use of superplasticizer not only increases 28-days-strength, but also the early age strength or 7 days vastly. This is a positive outcome to accelerate the construction process of hydraulic structures. Yet, the use of waterproofing admixture yields compressive strength of the M4 at 7 and 28 days is greater than that of the M1 about 34% and 11% respectively.

Regarding the binary additive compound effect, it can be observed that compressive strength of the M5 at 28 days is similar to that of the M1, even though cement content of the former is 10% less than that of the latter. This result is owing essentially to the use of superplasticizer. Besides, compressive strength of the M6 at 7 and 28 days enhances about 53% and 18% respectively in comparison with that of the M1. Eventually, the trinary additive compound effect of fly ash, superplasticizer and waterproofing admixture on compressive strength in the M7 has proved with the improvement of 37% and 8% at 7 and 28 days respectively in comparison with that of the M1, considering that the cement content of the former is 10% less than that of the latter.

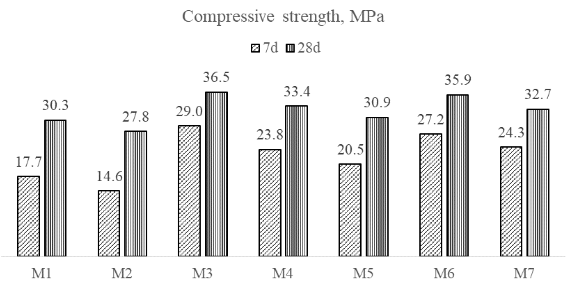

Figure 8. Compressive strength of concretes at 7 and 28 days

Take a look at the results in Table 7, there is an actual difference in terms of waterproofing grade among the concretes (M1-M7). The use of superplasticizer in M3, of waterproofing admixture in M4, of fly ash and superplasticizer in M5 has resulted in the enhancement of waterproofing grade from W6 of the M1 and M2 to W8. Moreover, the grade W10 was achieved in the M6 with superplasticizer and waterproofing admixture usage and in the M7 with the trinary compounds of fly ash, superplasticizer and waterproofing admixture. This result clarifies the role of chemical admixtures, such as superplasticizer and waterproofing admixture, in the mix that makes concrete used for the construction of hydraulic structures not only more sound and robust, but also more durable thanks to the higher waterproof grade achievement.

Table 7. Waterproofing grade of concretes

M1	M2	M3	M4	M5	M6	M7
W6	W6	W8	W8	W8	W10	W10

4. CONCLUSION

The effect of additive compounds on concrete at fresh and hardened state was studied in this paper. The following conclusions can be withdrawn:

- The use of fly ash replacing 10% of cement content has reduced both slump value at fresh state and compressive strength of concrete at hardened state. While, the use of superplasticizer with 0.8 liter per 100 kg cement and of waterproofing admixture with 0.4 liter per 100 kg have increased essentially both slump value and compressive strength.
- The binary additive compounds of fly ash and superplasticizer have improved either slump value or compressive strength, even though cement content was 10% less than conventional. The binary additive compounds of superplasticizer and waterproofing admixture did present the same trend of improvement.
- In term of the waterproof grade, the use of superplasticizer, or waterproofing admixture, or fly ash and superplasticizer has resulted in the enhancement of the waterproofing grade from W6 to W8. Moreover, the grade W10 has been attained in the concrete mix with superplasticizer and waterproofing admixture usage and in the mix with the trinary compounds of fly ash, superplasticizer and waterproofing admixture.

Last but not least, the outcomes of this study are useful for the implementation for the construction of hydraulic structures that would make them more durable thanks to the qualified waterproof grade.

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Hoàng Phó Uyên & Nguyễn Tiến Trung. (2001) *Nghiên cứu sử dụng tro bay từ phế thải nhà máy nhiệt điện Phả Lại I làm phụ gia khoáng hoạt tính nhằm tăng tuổi thọ, chống lại hiện tượng nứt do nhiệt thủy hóa trong bê tông khối lớn.* Tuyển tập kết quả Khoa Học Công Nghệ, Viện Khoa Học Thủy Lợi.

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Tóm tắt:

ẢNH HƯỞNG CỦA MỘT SỐ LOẠI PHỤ GIA ĐẾN BÊ TÔNG SỬ DỤNG CHO XÂY DỰNG CÁC CÔNG TRÌNH THỦY LỢI

Bài báo này nghiên cứu ảnh hưởng của hợp chất phụ gia đến bê tông phục vụ cho xây dựng các công trình thủy lợi. Kết quả chỉ ra rằng sử dụng tro bay thay thế 10% xi măng trong bê tông đã làm giảm độ sụt và cường độ nén. Trong khi đó, sử dụng phụ gia siêu dẻo với hàm lượng 0,8 lít và/hoặc phụ gia chống thấm với hàm lượng 0,4 lít cho 100 kg xi măng đã làm gia tăng đáng kể độ sụt và cường độ nén. Hợp chất đôi của tro bay và phụ gia siêu dẻo cũng đã làm tăng độ sụt và cường độ nén, mặc dù lượng xi măng sử dụng ít hơn bình thường 10%. Sử dụng phụ gia siêu dẻo, hoặc chống thấm, hoặc kết hợp của tro bay và phụ gia siêu dẻo đã làm tăng mác chống thấm từ W6 lên W8. Ngoài ra, mác W10 đã đạt được ở bê tông có sử dụng kết hợp của phụ gia siêu dẻo và chống thấm, cũng như ở bê tông có sử dụng hợp chất ba của tro bay, phụ gia siêu dẻo và chống thấm.

Từ khóa: Bê tông, tro bay, phụ gia siêu dẻo, phụ gia chống thấm, hỗn hợp phụ gia.

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