

**RESEARCH ON USING ADMIXTURE TO IMPROVE THE DURABILITY
OF CONCRETE OF STRUCTURES USED FOR PROTECTING
SEADIKE SLOPE IN VIETNAM**

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Abstract: *Concrete members used for protecting seadike slope have to be suffered from a severe attack caused by both chemical composition of seawater and mechanical action of wave and current, leading to the decrease in durability and lifetime rapidly. In order to address this problem, this paper presents the method by using a combination of various types of admixtures to improve both corrosion and abrasion resistance for concrete, thus producing the product with higher durability and extending longer lifetime. Based on the obtained results, the paper also provides the suitable rate of fly ash, silica fume and water reducer admixture in concrete used not only for seadike slope protection members but also for all types of concrete and reinforced concrete structures in marine environment. This result may be a reference to the producers for the next coming projects.*

Keywords: Concrete; seadike slope; admixture; durability; lifetime; corrosion; abrasion.

1. INTRODUCTION

Vietnam has about 3260km of coastline and that is seriously affected by climate change and sea level raise. At present, most of the marine structures in general and sea dike, in particular, are made of concrete and reinforced concrete. Due to the serious corrosion and deterioration of the environment, marine concrete structures normally show lower durability and lifetime than similar structures in the river. The losses caused by these deteriorations are considerable and serious.

In order to reduce the loss of life and property, to enhance the marine economic development and to ensure security and national defense, it is essential to have stable seadike systems and coastline protection works with long-term durability and lifetime. These facts lend the foundation for this study is “Research on using

admixture to improve the durability of concrete of structures used for protecting seadike slope in Vietnam”.

2. EXISTENCE, CAUSES OF DAMAGE AND SOLUTION TO IMPROVE THE DURABILITY OF CONCRETE STRUCTURES USED FOR PROTECTING SEADIKE SLOPE IN VIETNAM

2.1. Existence of damage

In Vietnam, due to its geographical location and tropical climate conditions, high humidity, combined with the sea environment, the damage to concrete and reinforced concrete works in general, as well as the structures used for the protection of seadike slope in particular, is very serious. The pictures of the damage and degradation of the concrete structures used for protecting seadike slope in Cat Hai - Hai Phong and Giao Thuy - Nam Dinh can be seen in Figure 1 and 2.

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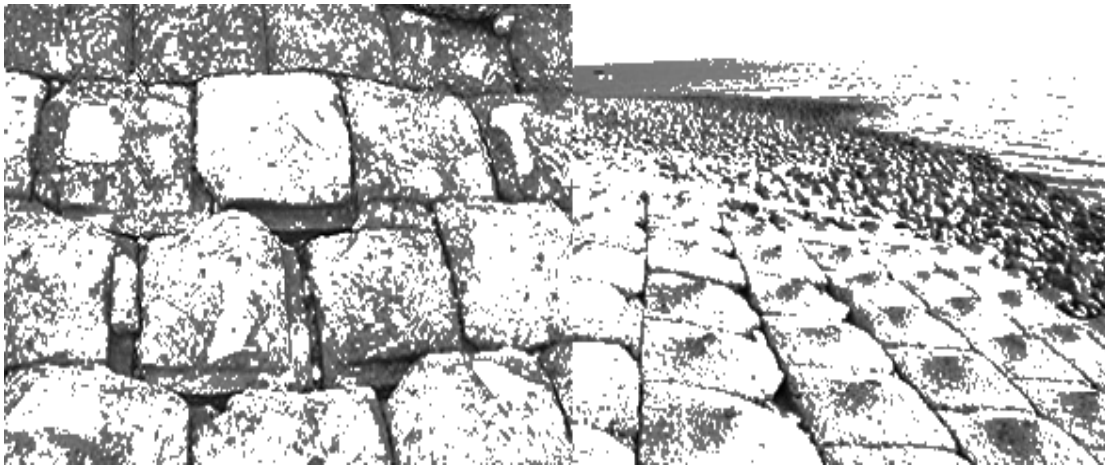


Figure 1. Corrosion and mechanical abrasion of 2D structures without cap

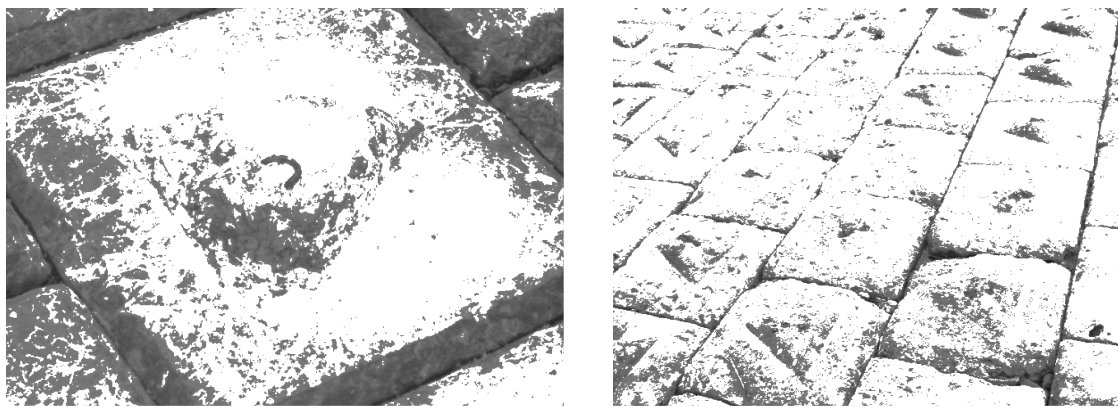


Figure 2. Corrosion and mechanical abrasion of 2D structure with cap

2.2. Causes of damage

The works built in the coastal area are under the direct influence of the composition of the marine environment and climate, including chemical composition of seawater; Temperature; Hydrostatic pressure; Tide; Wave; Mist and droplets; Floating ice and marine life. With these factors, the marine environment is highly inhospitable for commonly used materials of construction, including concrete and reinforced concrete.

The concrete and reinforced concrete structures in the marine environment can be damaged in the following ways: Concrete damaged by mechanical and physical actions; Concrete damaged by chemical and biological actions; Reinforcing steel damaged by chemical actions.

Protective structures of seadike slope - the

main research object are located in the tide area, which is under the most dangerous impact of the marine environment due to enormous destructive power as the simultaneous influence of reinforcing steel corrosion, mechanical abrasion, chemical and microbial corrosion of concrete.

2.3. Solutions to improve the durability of concrete and reinforced concrete in marine environment

2.3.1. Improve the corrosion durability

To ensure long-term durability for concrete and reinforced concrete impacted of corrosion of the marine environment, the following solutions can be considered: (1) Change the mineral composition of cement; (2) Transform hydration product of cement; (3) Increase the density of concrete; (4) Separate concrete from corrosion environment; (5) Protect concrete

from the penetration of Cl⁻.

2.3.2. Improve the abrasion durability

Solutions for improving the abrasion resistance is actually enhanced strength and hardness to the concrete. The following solutions can be considered: (1) Increase the strength of hardened cement; (2) Increase the strength of transition area between aggregate and hardened cement.

2.4. Analysis to select appropriate solutions for concrete and reinforced concrete structures used for protecting seadike slope in Vietnam

After reviewing the solutions mentioned above, it can be seen that the effective solution

is to use several types of admixture available in the market to meet following demands: (1) Transform hydration product to disable the harmful components of concrete; (2) Produce hydration products with high degree of crystallinity and close arrangements; (3) Limit the chloride ion diffusion; (4) Improve the density of concrete, especially in the transition zone of aggregate and harden cement.

After analyzing, the final admixture combination used in the study includes: Fly ash + Silica fume + Plasticizer (Water reducer). Summary of the effects of additive components is in Figure 3.

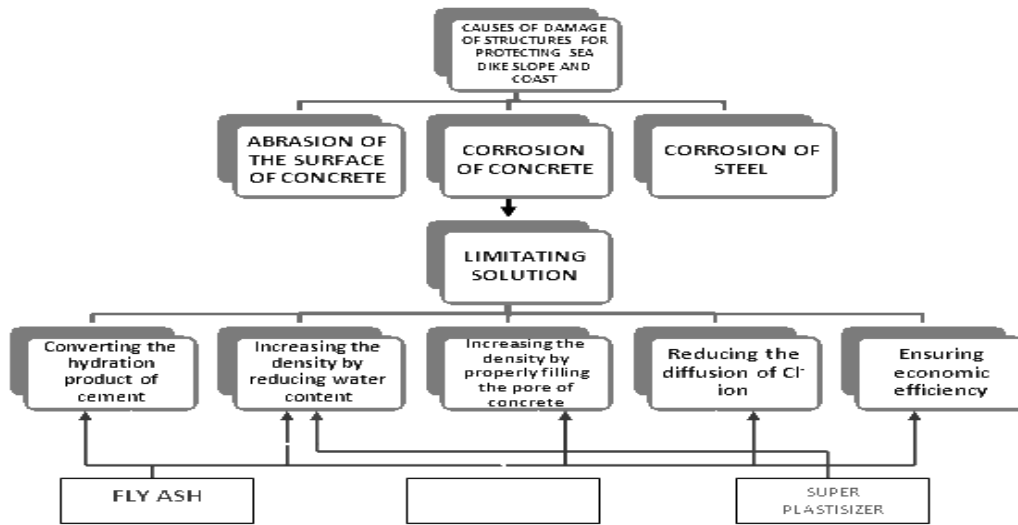


Figure 3. Diagram summarizing the role of admixtures used in the study

3. RESEARCHED RESULTS AND DISCUSSION

3.1. Materials and concrete mix proportion

3.1.1. Materials

The main kinds of materials are used in this research contain: Butson cement PC40 (TCVN 2682); Phalai Fly ash (TCVN 10302); Silica fume of Castech (TCVN 8827); Songlo Sand (TCVN 7570); Standard-sand of VIBM (TCVN 6227); Kienkhe crushed stone (TCVN

7570); High water reducer HWR100 of Castech; Water (TCVN 4506).

3.1.2. Concrete mix proportion

Determine the concrete proportion based on the guideline of Ministry of Construction “Technical instruction to determine the concrete mix proportion” with additional consideration of the typical characteristic for concrete containing admixture to obtain more accurate results for the experimental stage. The result of concrete mix is in Table 1.

Table 1. Concrete proportion based on theoretical calculation

No	Code of sample	Mix proportions of concrete (kg/m ³)							W/C M
		CM	C	F	S	Sand	CA	W	
1	F ₀ S ₀ P ₀	339	339	0	0	706	1224	185	0,545
2	F ₃₀ S ₀ P ₀	374	262	112	0	661	1203	185	0,495
3	F ₂₅ S ₅ P ₀	388	272	97	19	650	1199	185	0,477
4	F ₂₀ S ₁₀ P ₀	361	253	72	36	666	1206	185	0,512
5	F ₁₅ S ₁₅ P ₀	388	272	58	58	647	1198	185	0,477

Remark: CM-Cementitious Material; C-Cement; F-Fly Ash; S-Silica Fume; CA-Coarse Aggregate; P-Plasticizer; W-Water.

Carry out slump test to determine actual required water content. The results of concrete mix proportion after determining actual water content are in Table 2.

Table 2. Concrete proportion after conducting the test to determine required water

No	Code of sample	Mix proportions of concrete (kg/m ³)								W/ CM
		CM	C	F	S	Sand	CA	P	W	
1	F ₀ S ₀ P ₀	339	339	0	0	706	1224	0	184	0,54
2	F ₀ S ₀ P _{0,3}	339	339	0	0	706	1224	1,02	156	0,46
3	F ₃₀ S ₀ P _{0,3}	374	262	112	0	661	1203	1,12	161	0,43
4	F ₂₅ S ₅ P _{0,3}	388	272	97	19	650	1199	1,16	175	0,45
5	F ₂₀ S ₁₀ P _{0,3}	361	253	72	36	666	1206	1,08	173	0,48
6	F ₁₅ S ₁₅ P _{0,3}	388	272	58	58	647	1198	1,16	186	0,48
7	F ₀ S ₀ P _{0,35}	339	339	0	0	706	1224	1,19	149	0,44
8	F ₃₀ S ₀ P _{0,35}	374	262	112	0	661	1203	1,31	157	0,42
9	F ₂₅ S ₅ P _{0,35}	388	272	97	19	650	1199	1,36	171	0,44
10	F ₂₀ S ₁₀ P _{0,35}	361	253	72	36	666	1206	1,26	166	0,46
11	F ₁₅ S ₁₅ P _{0,35}	388	272	58	58	647	1198	1,36	182	0,47
12	F ₀ S ₀ P _{0,4}	339	339	0	0	706	1224	1,36	146	0,43
13	F ₃₀ S ₀ P _{0,4}	374	262	112	0	661	1203	1,50	150	0,40
14	F ₂₅ S ₅ P _{0,4}	388	272	97	19	650	1199	1,55	163	0,42
15	F ₂₀ S ₁₀ P _{0,4}	361	253	72	36	666	1206	1,45	155	0,43
16	F ₁₅ S ₁₅ P _{0,4}	388	272	58	58	647	1198	1,55	171	0,44
17	F ₀ S ₀ P _{0,45}	339	339	0	0	706	1224	1,53	153	0,45
18	F ₃₀ S ₀ P _{0,45}	374	262	112	0	661	1203	1,68	157	0,42
19	F ₂₅ S ₅ P _{0,45}	388	272	97	19	650	1199	1,75	167	0,43
20	F ₂₀ S ₁₀ P _{0,45}	361	253	72	36	666	1206	1,62	159	0,44
21	F ₁₅ S ₁₅ P _{0,45}	388	272	58	58	647	1198	1,75	175	0,45

3.2. Results and discussions

3.2.1. Compressive strength, absorption, and density

Experimental results of compressive strength, absorption, and density of harden concrete of 21 mixtures at different ages as in Table 3.

Table 3. Results of compressive strength, absorption, density of harden concrete

No	Code of sample	Compressive strength at (MPa)			Properties at 28-day age			Properties at 60-day age		
		3 days	7 days	14 days	ρ kg/dm ³	Abs %	f'c MPa	ρ kg/dm ³	Abs %	f'c MPa
1	F ₀ S ₀ P ₀	20,3	25,8	30,4	2,46	6,97	33,8	2,47	7,29	35,4
2	F ₀ S ₀ P _{0,3}	18,7	27,5	35,1	2,50	6,30	38,6	2,51	6,28	40,5
3	F ₃₀ S ₀ P _{0,3}	18,5	29,0	35,6	2,46	6,26	39,9	2,46	6,25	43,2
4	F ₂₅ S ₅ P _{0,3}	19,1	28,4	36,1	2,44	6,20	40,2	2,45	6,18	43,3
5	F ₂₀ S ₁₀ P _{0,3}	21,0	30,2	39,1	2,44	6,16	44,6	2,44	6,17	46,8
6	F ₁₅ S ₁₅ P _{0,3}	19,7	29,0	36,5	2,42	6,18	41,6	2,42	6,18	44,8
7	F ₀ S ₀ P _{0,35}	22,2	29,0	36,2	2,51	5,94	40,5	2,52	5,95	42,4
8	F ₃₀ S ₀ P _{0,35}	21,0	30,5	37,2	2,46	5,92	42,0	2,46	5,94	45,2
9	F ₂₅ S ₅ P _{0,35}	20,6	30,2	36,9	2,44	5,76	41,8	2,45	5,76	44,6
10	F ₂₀ S ₁₀ P _{0,35}	22,8	32,2	40,5	2,45	5,73	45,7	2,45	5,72	49,1
11	F ₁₅ S ₁₅ P _{0,35}	21,4	30,8	38,0	2,42	5,80	43,6	2,43	5,81	47,4
12	F ₀ S ₀ P _{0,4}	24,3	32,5	40,2	2,51	5,50	44,0	2,51	5,51	45,4
13	F ₃₀ S ₀ P _{0,4}	23,9	33,7	40,1	2,47	5,45	45,9	2,47	5,43	49,0
14	F ₂₅ S ₅ P _{0,4}	23,7	32,9	39,7	2,45	5,26	45,0	2,46	5,30	48,5
15	F ₂₀ S ₁₀ P _{0,4}	25,8	34,7	43,2	2,46	5,23	49,9	2,47	5,27	52,3
16	F ₁₅ S ₁₅ P _{0,4}	24,5	33,4	40,5	2,44	5,30	46,9	2,44	5,31	50,1
17	F ₀ S ₀ P _{0,45}	23,5	32,0	39,2	2,50	5,55	43,0	2,51	5,56	44,4
18	F ₃₀ S ₀ P _{0,45}	23,0	32,7	39,3	2,46	5,54	44,1	2,46	5,53	46,0
19	F ₂₅ S ₅ P _{0,45}	22,7	32,3	39,6	2,46	5,35	44,8	2,47	5,40	46,8
20	F ₂₀ S ₁₀ P _{0,45}	24,9	33,7	42,6	2,50	5,31	48,5	2,51	5,36	50,8
21	F ₁₅ S ₁₅ P _{0,45}	23,8	33,5	40,5	2,46	5,41	45,8	2,47	5,42	49,4

The development of concrete compressive strength with time of the tested sample is shown in Figure 4 and Figure 5.

The experimental results show that: Compressive strength follows the logarithm rule but compressive strength of sample with the use of admixture is higher than the one without admixture especially after 14 days. When the content of plasticizer change in 0,3; 0,35; 0,4 or 0,45%, sample F₂₀S₁₀ (with 20% fly ash and 10%

silica fume) has the highest compressive strength among samples with different mineral admixture content, then the samples with lower compressive strength are F₁₅S₁₅, F₂₅S₅, and F₃₀S₀. When the content of mineral admixture change, the sample with a plasticizer of 0,4% (P_{0,4}) has the highest compressive strength among all samples with the same mineral admixture content. Among 21 samples, the sample F₂₀S₁₀P_{0,4} obtain the highest compressive strength of 52,3MPa.

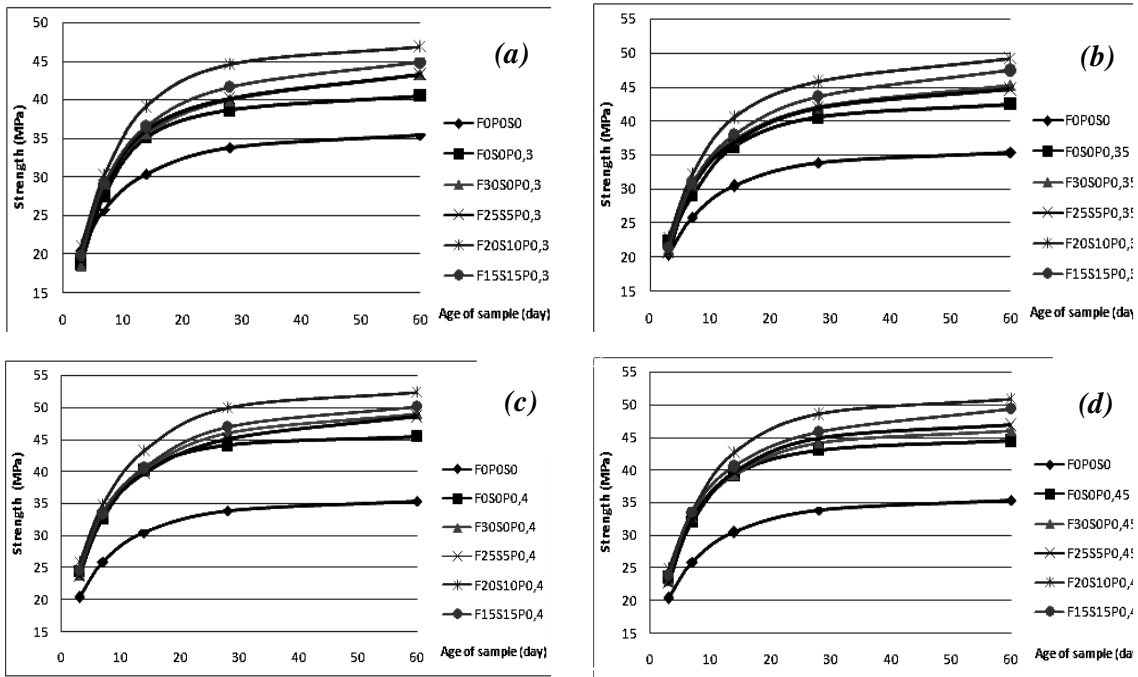


Figure 4. Concrete compressive strength with time when using different amount of mineral admixture; with a) $P=0,3\%$; b) $P=0,35\%$; c) $P=0,4\%$; d) $P=0,45\%$

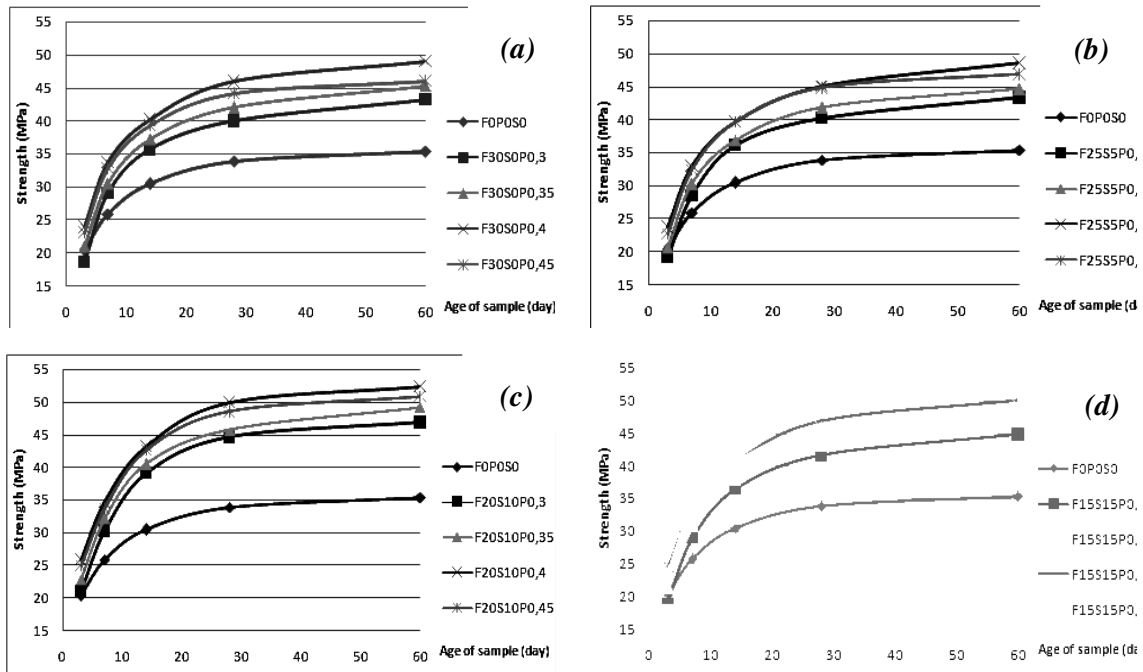


Figure 5. Concrete compressive strength with time when using different amount of plasticizer with a) $F_{30}S_0$; b) $F_{25}S_5$; c) $F_{20}S_{10}$; d) $F_{15}S_{15}$

3.2.2. Permeability

Determine the permeability coefficient at 60-days age for 9 samples of which there are

one control sample and 8 samples containing admixture. The results are in Table 4 and Figure 6.

Table 4. Results of permeability coefficient

No	Code of sample	W/CM	K (cm/s)	No	Code of sample	W/CM	K (cm/s)
1	F ₀ S ₀ P ₀	0,54	5,3*10 ⁻¹⁰				
2	F ₃₀ S ₀ P _{0,35}	0,42	4,5*10 ⁻¹¹	6	F ₃₀ S ₀ P _{0,4}	0,40	2,8*10 ⁻¹¹
3	F ₂₅ S ₅ P _{0,35}	0,44	3,8*10 ⁻¹¹	7	F ₂₅ S ₅ P _{0,4}	0,42	2,5*10 ⁻¹¹
4	F ₂₀ S ₁₀ P _{0,35}	0,46	3,0*10 ⁻¹¹	8	F ₂₀ S ₁₀ P _{0,4}	0,43	2,1*10 ⁻¹¹
5	F ₁₅ S ₁₅ P _{0,35}	0,47	3,7*10 ⁻¹¹	9	F ₁₅ S ₁₅ P _{0,4}	0,44	2,3*10 ⁻¹¹

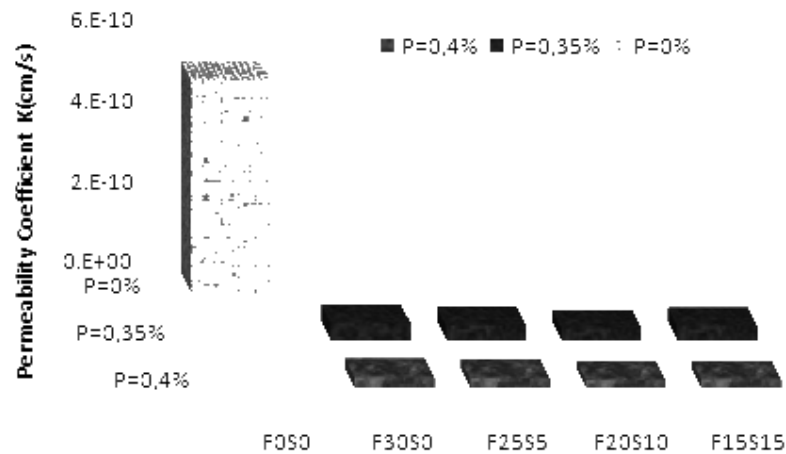


Figure 6. Results of permeability coefficient

Results show that permeability coefficient of the sample groups with and without additives consistent with the theoretical rules of the change of this indicator with the ratio W/CM and the particle size of the material component changes. Eight samples using water reducer decrease permeability coefficient than that of the control samples without additives. The samples with 0,4% plasticizer have a smaller value of permeability coefficient than the sample with 0,3% plasticizer. This result fully justified because samples using more plasticizer result in a lower ratio of W/CM, excess water evaporates leaving voids will cause less

absorbent.

The sample use only fly ash for cement replacement (sample 2,6), although the ratio W/CM smaller than the other additives sample still permeability coefficient slightly larger than the sample used both fly ash and silica fume (sample 3,4,5,7,8,9). This result can be explained that the sample group using silica fume promote insert fully into the small voids between cement particles, thus increasing the denseness in microstructure thereby improving permeability resistance ability, reduces permeability coefficient. The samples with admixture obtain the values of permeability

coefficient in the range of $2 \cdot 10^{-11}$ cm/s -:- $4,5 \cdot 10^{-11}$ cm/s, so is lower than the normal concrete permeability coefficient within $1,5 \cdot 10^{-9}$ cm/s (concrete M30)-:- $7,1 \cdot 10^{-11}$ cm/s (concrete M40).

3.2.3. Abrasion

Determine the abrasion degree at 60-days age for 9 sample groups, using the same method as in the permeability test. The results are shown in Table 5 and Figure 7.

Table 5. Results of abrasion

No	Code of sample	Abrasion (%)	No	Code of sample	Abrasion(%)
1	F ₀ S ₀ P ₀	6,08			
2	F ₃₀ S ₀ P _{0,35}	5,25	6	F ₃₀ S ₀ P _{0,4}	4,80
3	F ₂₅ S ₅ P _{0,35}	5,28	7	F ₂₅ S ₅ P _{0,4}	4,82
4	F ₂₀ S ₁₀ P _{0,35}	5,18	8	F ₂₀ S ₁₀ P _{0,4}	4,75
5	F ₁₅ S ₁₅ P _{0,35}	5,25	9	F ₁₅ S ₁₅ P _{0,4}	4,79

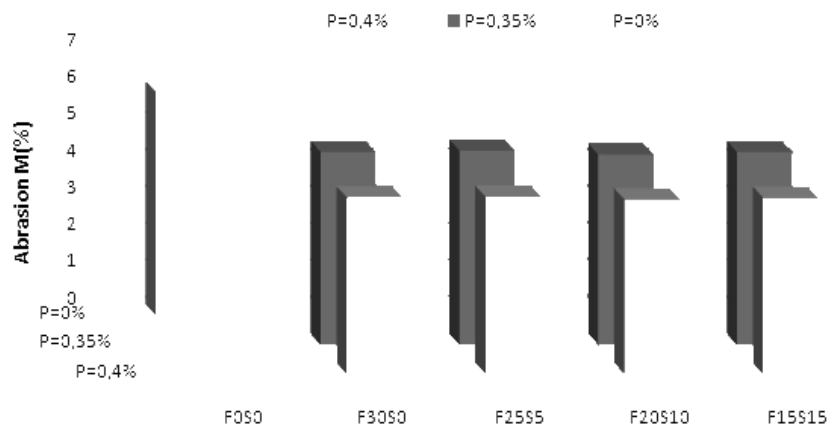


Figure 7. Results of abrasion

The experimental results showed that, compared to the sample without admixture, the degree of abrasion in the sample with admixture decreased, but abrasion of all samples did not differ much. In theory, the sample using silica fume tend to improve abrasion resistance better, but the real measurements show that this difference is not clearly shown. The degree of abrasion of the sample group using silica (sample 3,4,5,7,8,9) is close to samples without silica fume (sample 2,6). The tendency of changing abrasion degree is similar to changing compressive strength, consistent with the

theory; that is the higher compressive strength, the higher the abrasion resistance as possible. Sample F₂₀S₁₀P_{0,4} is least abrasive.

4. CONCLUSION

The research has clarified the causes, mechanisms for destruction of structures used for protecting seadike slope, which results from the impact of multiple factors on the marine environment, with two key factors of chemical and mechanical actions.

In the range of the research with the replacement of Portland cement by 10-:-30% fly ash, 5-:-15% silica fume and with the use of 0,3-

:-0,45% of plasticizer. The laboratory test results show that blending admixture in any proportion will improve the properties of concrete compared with the samples without admixture and with the replacement of Portland

cement by 20% fly ash, 10% silica fume and use 0,4% plasticizer concrete obtain the optimum characteristics, meeting the requirements of structure used for protecting seadike slope and it is strongly proposed to use.

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Tóm tắt:

NGHIÊN CỨU SỬ DỤNG PHỤ GIA ĐỂ NÂNG CAO ĐỘ BỀN CHO BÊ TÔNG CÁC CẤU KIỆN BẢO VỆ MÁI ĐÊ BIỂN VIỆT NAM

Các cấu kiện bê tông dùng để bảo vệ mái đê biển thường phải chịu tác động phá hoại mãnh liệt của các thành phần ăn mòn trong nước biển cũng như tác động cơ học của sóng và dòng chảy dẫn đến giảm độ bền và tuổi thọ một cách nhanh chóng. Để giải quyết sự hạn chế này, bài báo đề cập đến hướng nghiên cứu sử dụng kết hợp một số loại phụ gia nhằm nâng cao khả năng chống ăn mòn do tác động hóa học, cũng như mài mòn do tác động cơ học cho bê tông từ đó có thể nâng cao độ bền và kéo dài tuổi thọ cho công trình. Từ các kết quả nghiên cứu, bài báo cũng đưa ra khuyến cáo về tỷ lệ pha trộn phụ gia thích hợp gồm tro bay, muội silic và phụ gia hóa dẻo giảm nước trong thành phần bê tông không những dùng cho các cấu kiện bảo vệ mái đê biển bằng mà còn có thể dùng cho các loại kết cấu bê tông và bê tông cốt thép làm việc trong môi trường biển. Kết quả này giúp các nhà sản xuất có thể tham khảo cho các công trình có cùng ứng dụng trong thời gian tới.

Từ khóa: Bê tông; mái đê; phụ gia; độ bền; tuổi thọ; ăn mòn; mài mòn.

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