

EFFECT OF SEA SAND WITH DIFFERENT CHLORIDE ION CONTENTS ON THE PROPERTIES OF CONCRETE

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DOI: 10.56651/lqdtu.jst.v6.n01.671.sce

Abstract

This article presents the results of a study that evaluated the effects of using sea sand with varying contents of chloride ions on the properties of concrete, including physical and mechanical properties as well as durability. The study was carried out on the sea sand samples with different chloride ion contents, including as-received sea sand samples with a chloride ion content of approximately 0.15%, two washed (desalted) sea sand samples with chloride ion content of 0.024% and 0.05%, and sea sand samples added with chloride salt (0.375%), which were then compared with river sand samples. The sand samples had approximately the same fineness modulus ranging from 2.3 - 2.5. The research results indicated that compared with washed sea sand and river sand, concrete mixes using sea sand with high chloride ion content increased the mixing water and reduced the slump retainability of the fresh concrete. Furthermore, early compressive strength (7 days) increased but late age strength (91 and 365 days) decreased in both standard curing and wet-dry circle curing cases. Additionally, the impermeability (water and chloride ion) and the ability to protect the reinforcement from corrosion in concrete were reduced when using sea sand with high chloride ion content compared to washed sea sand and river sand.

Keywords: *Sea sand concrete; sea sand; fine aggregate; mechanical properties; durability.*

1. Introduction

The demand for sand for construction in Vietnam has continuously increased in recent years. According to statistics from the Ministry of Construction, the consumption of construction sand in Vietnam in the period from 2001 to now has increased with a large volume, specifically, it consumed 73 million m³ in 2006, about 131 - 140 million m³ in 2015, and about 182 - 197 million m³ in 2020 and expected about 170 - 190 million m³/year in 2025, about 200 - 220 million m³/year by 2030 [1]. Due to the limited reserves and amount of accretion, the exploitation of sand and gravel has spread and increased continuously in recent years, leading to a serious shortage of sand and gravel resources in rivers. Therefore, there is a problem with studying the use of sand as a source of

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material to replace river sand for construction.

Potential sources of materials to replace river sand that can be exploited include fine sand, saline sand (coastal), sea sand, and artificial sand sources (crushed sand, industrial ash, etc.). Regarding the source of sea sand that can be exploited to make construction sand in our country according to some geological exploration documents and geological atlas of some Vietnamese sea areas and some previous research on the use of sea sand, saline sand is used as construction material [2] shows that many sea areas in Vietnam have sea sand sources qualified as aggregates for concrete (medium to coarse-grained sand, fineness modulus such as sea areas of Quang Ninh, Quang Binh, Quang Ngai, Binh Thuan, Ba Ria - Vung Tau, Soc Trang, Phu Quoc, etc. Therefore, if it is put to exploitation and use, sea sand can replace river sand in domestic construction. However, sea sand often contains a significant amount of chloride salts and other impurities that affect the properties of concrete, especially the risk of causing corrosion of reinforcement in concrete. For example, TCVN 7570:2006 [3] specifies the content of chlorine ions in natural sand for concrete and mortar, not more than 0.01% for prestressed concrete and 0.05% for other concrete and mortar or most international standards of aggregates for concrete and mortar specify limits of the chlorine ion content in sand. Currently, in Vietnam, the use of sea sand in concrete production is not prevalent. However, in many countries around the world, including Europe and Asia, sea sand has been utilized for the production of concrete and mortar for construction purposes for many decades. Countries and territories that use sea sand in construction include the UK, Nordic countries, Japan, Korea, China, Taiwan, and Hong Kong [4].

For concrete using sea sand, in general, some problems of the influence of sea sand on concrete properties have been pointed out by many studies. The first is the effect of salt in the sand on the ability to corrode the reinforced steel in concrete. The chlorine ion content in sea sand depends on the chlorine ion content in the seawater and the moisture content of the sand. The second is the effect of seashell content in sea sand. The seashell content in the sand can adversely affect the properties of concrete as recorded in literature which is often noted to reduce the workability of concrete due to the size and shape of the shell, but the adverse effect on the strength was rarely mentioned [6-9]. The study by Alan Elliott Richardson and Thomas Fuller [10] and Yang [11] used seashells as a partial replacement of aggregate for concrete and concluded that broken and unbroken shell material particles are the main difference between sea sand and river sand; sea sand has a higher density due to the composition containing shell fragments (mainly CaCO_3); Seashell fragments are hard and durable, so they can reduce porosity, density is higher than sand grains, but do not have much effect

on concrete strength when replacing up to 10% of the aggregate, but will have a significant effect when increasing the replacement ratio. The study by Chapman and Roeder [6] evaluated the effect of hollow shell content in sea sand with paste and cement mortar. The porosity of the seashell does not affect the strength and waterproofing of the concrete, whereas the shape of the seashell affects the workability of the concrete. The third is efflorescence. Concrete, mortar, if it contains a significant amount of salt when exposed to a humid environment, often causes efflorescence on the concrete surface. Concrete using sea sand containing a significant amount of salt (when not washed) often causes this phenomenon, especially in structures exposed to wet environments [12]. However, according to the study by Higgins [13], this is in all cases smaller than the similar phenomenon caused by free lime in concrete and mortar. Chandrakeerthy [14] did not detect this phenomenon in concrete containing large chloride ion content, equivalent to 4.44% compared to cement.

The aforementioned issues are making the utilization of sea sand as an aggregate for concrete difficult. The objective of this study is to assess the impact of utilizing untreated and treated sea sand (sea sand with different chloride contents) as a substitute for river sand in concrete mixes on various properties, including the strength and durability of concrete. The study was conducted on conventional concrete with a compressive strength grade of 30 MPa (grade 30) and grade of 40 MPa (grade 40) and a concrete mix slump of 15 ± 1 cm.

2. Materials and test methods

2.1. Materials

2.1.1. Cement

Nghi Son PC40 cement was used in this study. This cement has met the requirements of TCVN 2682:2020. Tables 1 and 2 present the physical and chemical properties, respectively, of the Nghi Son PC40 cement utilized in this study.

Table 1. Physical properties of the cement

No.	Properties	Unit	Result
1	Fineness (Blaine method)	cm ² /g	3.800
2	Setting time (initial-final)	min	120 - 180
3	Compressive strength		
	3 days	MPa	31.9
	28 days	MPa	52.3
4	Soundness (Le Chatelier method)	mm	0.0

Table 2. Chemical properties of the cement used in the study

Material	L.O.I	SiO ₂	Fe ₂ O ₃	Al ₂ O ₃	CaO	MgO	SO ₃	K ₂ O	Na ₂ O	TiO ₂	CaO _f
Cement	1.23	19.4	3.4	5.2	63.5	1.6	2.3	0.91	0.00	0.45	0.20

2.1.2. Fine aggregate

Sea sand for making concrete samples used in the study includes sea sand in the Van Don-Quang Ninh Sea area and Lo River sand (as a control sample). Sea sand consists of 4 sand samples with different contents of chloride ions 0.15%, 0.375%, 0.05%, and 0.024%, respectively, as-received sand (SS0.15), sand with added NaCl salt (SS0.375), and two types of washed sand, SS0.05, and SS0.024. The physical properties and particle size of the sands are presented in Tables 3 and 4.

Table 3. Physical properties of the sands

Properties	Unit	Result				
		River sand RS	Sea sand SS0.15 (nk)	Sea sand SS0.375	Sea sand SS0.05	Sea sand SS0.024
Specific gravity	g/cm ³	2.63	2.63	2.63	2.62	2.62
Bulk density	kg/m ³	1430	1412	1396	1422	1426
Water absorption	%	1.25	1.28	1.24	1.2	1.2
Silt, mud, and clay content	%	1.1	0.66	0.69	0.12	0.06
Organic matter	color	Not darker than the reference color				
Shell content	%	0	8.2	8.4	6.5	5.6
Ion chloride content	%	0	0.150	0.375	0.05	0.024
SO ₃ content	%	0.005	0.064	0.082	0.046	0.032

Table 4. Particle size of the sands

Sieve hole (mm)	Unit	The cumulative amount of retained on sieve (%wt)				
		River sand RS	Sea sand SS0.15 (nk)	Sea sand SS0.375	Sea sand SS0.05	Sea sand SS0.024
2.5 mm	%	8.3	2.82	1.93	3.1	3.6
1.25 mm	%	21.9	12.74	13.1	14.2	18.7
630 mm	%	42.9	46.20	47.3	49.3	52.1

Sieve hole (mm)	Unit	The cumulative amount of retained on sieve (%wt)				
		River sand RS	Sea sand SS0.15 (nk)	Sea sand SS0.375	Sea sand SS0.05	Sea sand SS0.024
315 mm	%	81.9	80.10	78.6	82.4	82.6
140 mm	%	96.4	91.20	90.3	93.9	94.8
< 140 mm	%	3.6	8.80	9.70	6.1	5.2
Modulus		2.51	2.33	2.31	2.46	2.52

2.1.3. Coarse aggregate

The coarse aggregate used consists of 5 - 20 mm crushed limestone. The mechanical and physical properties of the coarse aggregate met the requirements specified in TCVN 7570:2006.

2.1.4. Chemical admixture

The chemical admixture used in the study is a superplasticizer branched MG 8735 from BASF. This is a polycarboxylate ether (PCE)-based plasticizer, with a water reduction capacity of about 25%.

2.1.5. Mixing water

The water used for mixing samples in this study is tap water in Hanoi city. The properties of the water conform to TCVN 4506:2012 *Mixing water for concrete and mortar - Technical requirements*.

2.2. Test method

Properties of cement, fly ash, natural sand, crushed stone, chemical admixture, and mixing water are determined according to Vietnamese standards test methods specified in TCVN 2682:2009, TCVN 10302:2014, TCVN 7570:2006, TCVN 8826:2012, TCVN 4506:2012, respectively. The properties of fresh concrete include slump, the slump retainability as per TCVN 3105:2022, TCVN 3106:2022; the compressive strength and elastic modulus were tested as per TCVN 3118:2022 and ASTM C469, respectively; The durability of concrete including water permeability, and chloride ion penetrability was determined according to TCVN 3116:2022, TCVN 9337:2012, respectively. The ability to protect reinforcement steel from corrosion: method of accelerated corrosion by forced current according to NT Build 356 standard.

2.3. Mix proportions

The studied concrete mix consists of two groups grade 30 (> 30 MPa) and grade 40 using the different sand types. The cement contents were 355 kg/m³ and 414 kg/m³ and the superplasticizer dosages were 0.7% and 1% of the cement content for the mixes of grade 30 and grade 40, respectively. The ratio of sand to aggregate (S/A ratio) was kept constant at 0.42 - 0.43 for all mixes. The slump of fresh concrete after mixing was controlled at 14 - 16 cm by adjusting the amount of mixing water. Details of the concrete mix are shown in Table 5.

Table 5. Concrete mix proportions

Mix group	Mix ID	W/C ratio	S/A ratio	Mix proportions for one cubic meter					
				Cement (kg)	River sand (kg)	Sea sand (kg)	Gravel (kg)	Chem. Ad. (L)	Water (L)
River sand (RS)	30RS	0.54	0.42	355	799	0	1091	2.48	182
	40RS	0.45	0.42	414	778	0	1066	4.14	176
Sea sand SS0.15 (nk)	30SS0.15	0.54	0.42	354	0	801	1090	2.48	183
	40SS0.15	0.45	0.43	414	0	788	1059	4.14	179
Sea sand SS0.375	30SS0.375	0.54	0.42	355	0	802	1091	2.48	187
	40SS0.375	0.44	0.43	415	0	790	1061	4.15	183
Sea sand SS0.05	30SS0.05	0.56	0.42	354	0	795	1078	2.47	183
	40SS0.05	0.46	0.43	414	0	783	1053	4.14	177
Sea sand SS0.024	30SS0.024	0.61	0.43	353	0	789	1067	2.47	183
	40SS0.024	0.50	0.42	412	0	768	1043	4.12	176

NOTE: 30, and 40 are symbols for concrete grade 300 and 400 respectively; RS, SS0.15, SS0.375, SS0.05, SS0.024 are symbols for river sand, sea sand with chlorine ion content 0.15% (original-nk), 0.375%, 0.05% and 0.024% respectively (by mass).

3. Test results and discussion

3.1. Properties of the fresh concrete

3.1.1. Effect of type of sea sand on workability and slump retainability of fresh concrete

Concrete mixtures were adjusted with the amount of mixing water and using the same type of superplasticizers to control the slump in the range of 14 - 16 cm as required. Visual observation shows that the concrete mixes using sea sand have the same plasticity as river sand. The results of the experiment to determine the mixing

water content so that the concrete mix using different types of sand achieves a slump in the range of 14 - 16 cm as shown in Figure 1a shows the amount of mixing water required to achieve the same workability of concrete mixtures tends to increase with increasing chlorine ion content in sand. Specifically, compared with the mix using washed sea sand (SS0.024), the amount of mixing water increased by about 5 - 6 liters/m³ for the mixtures containing the sea sand with 0.375% chlorine ions, and compared to the river sand mix, higher mixing water amount of the as-received sea sand mixes (SS0.15) and SS0.375 also required. The increased sea salt content in the sand reduces the workability of the concrete mix, which can be explained by the Cl⁻ and Ca⁺² ions present in the sea salt, which reduces the effect of superplasticizers, and at the same time promotes the cement hydration in the concrete. The high degree of hydration of the cement thus reduces the mobility of the concrete mix.

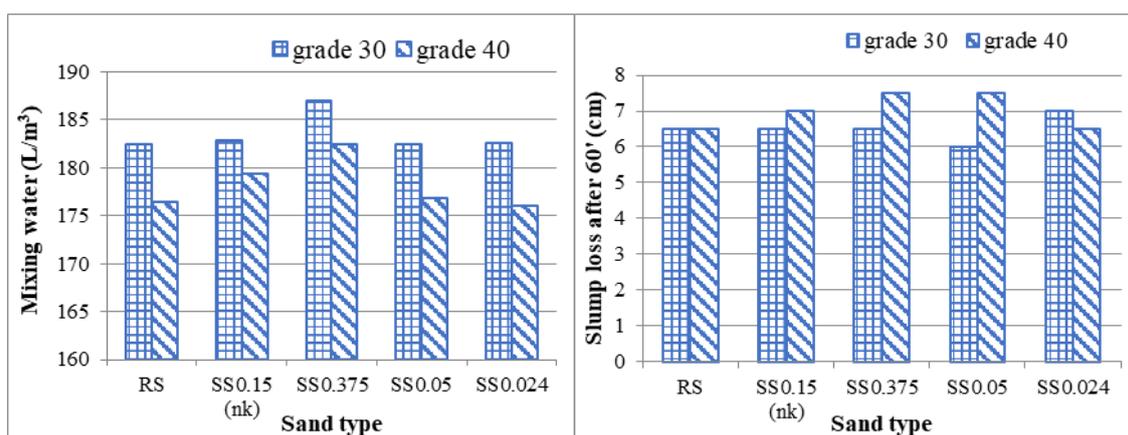


Figure 1. Effect of sea sand with different chloride content on
a) workability b) slump retainability.

The ability to maintain the workability of the fresh concrete was assessed by the loss of slump after mixing and 60 min after mixing. The river sand and sea sand concrete mixes lose their slump after 60 minutes in the range of 6 - 7.5 cm (Figure 1b). Experimental results show that in general there is no clear difference in the ability to maintain the slump of the fresh concrete with different types of saline sands at different levels. However, the highest slump loss of fresh concrete was the sample with the highest chloride ion content (SS0.375).

3.1.2. Bleeding of the fresh sea sand concrete

The bleeding test results of fresh concrete showed that there was no significant change in the sea sand compared with river sand, as well as the change in the chlorine

ion content in the sand. All concrete grades have a water separation that meets the requirements of TCVN 9340:2012 on the water separation of a concrete mixture with a slump from 9.5 to 20 cm, not more than 0.8%.

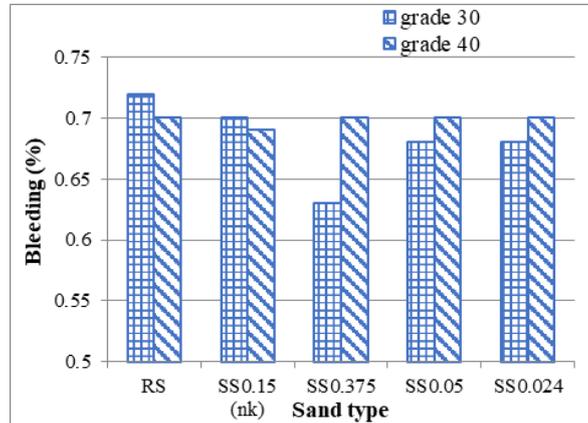


Figure 2. Effect of sand type on bleeding of fresh concrete.

3.2. Mechanical properties of sea sand concrete

3.2.1. Compressive strength

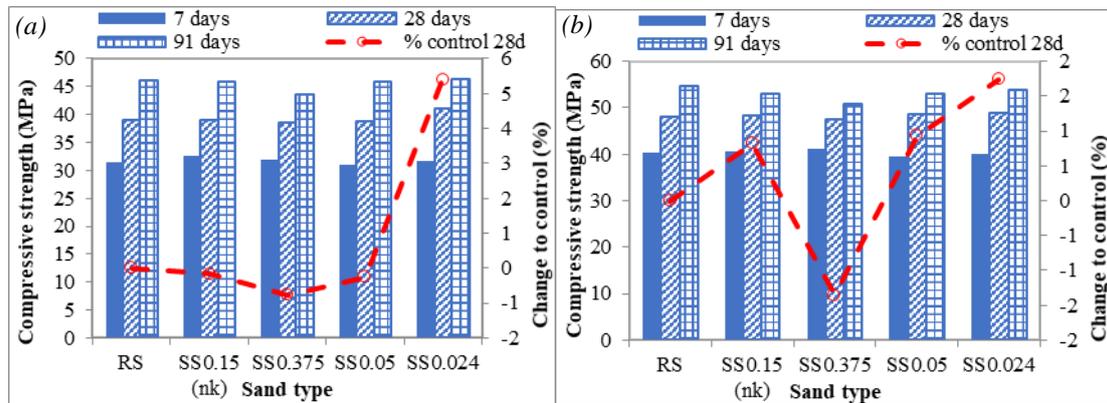


Figure 3. Compressive strength of concrete with different types of sand
 a) grade 30 mixes; b) grade 40 mixes.

Samples of concrete mixes made with both sea sand and river sand were taken and cured under standard conditions. Compressive strength was then measured at the ages of 7, 28, and 91 days. The experimental findings reveal that at 7 days of age, concrete containing sea sand with a high concentration of chlorine ions displays slightly greater strength compared to concrete made with washed river sand and washed sea sand (as illustrated in Figure 3). Specifically, the aggregates made with original sea sand samples SS0.15 and SS0.375 showed a strength that was 1 - 3.4% higher than the river sand samples, even though the mixing water volume of these aggregates was higher than that

of the river sand samples. It is worth noting that the sand samples had approximately equal magnitude modulus. However, at 28 days, the strength of the sea sand samples was equivalent to that of the river sand samples. And, at 91 days, the strength of these grades decreased compared to the control river sand mix, with the SS0.375 sand mix exhibiting the highest reduction level of 5.1 - 7.3% compared to the river sand sample. Meanwhile, the SS0.024 washed sea sand sample showed similar strength at 28 and 91 days to the river sand sample (as shown in Figure 3).

The phenomenon of early age enhancement of concrete when the sea salt content in the sand is higher can be explained by the presence of dissolved salts in the seawater that exist in the form of ions, including Ca^{2+} ions and especially Cl^- ions. When these ions are present in concrete from the beginning, they promote the hydration of cement. According to Ramachandran's research results presented in [15], the degree of promotion of cement hydration by cations is as follows: $Ca^{2+} > Mg^{2+} > Ba^{+2} > Li^+ > Na^+ > K^+$; and for anions in the order of $SO_4^{-2} > OH^- > Cl^- > Br^- > I^- > NO_3^- > CH_3COO^-$. Some research results also suggest that the Cl^- ion in cement systems promotes the hydration of cement even faster than SO_4^{-2} .

3.2.2. Elastic modulus

The results of the elastic modulus test for concrete mixes using different types of sand at the age of 7, 28, and 91 days are shown in Figure 4. The figure indicates an increasing and decreasing trend in the elastic modulus due to the use of different types of sand. The differences in concrete mixes with the same slump, as observed have a similar trend of compressive strength. Specifically, the elastic modulus at the age of 7 days for SS0.15 and SS0.375 sea sand concrete mixes is equivalent to that of washed river sand and sea sand. However, after 28 days and especially 91 days, the elastic modulus of the sea sand samples is lower than that of river sand, with a reduced level of 2.5 - 6.2%.

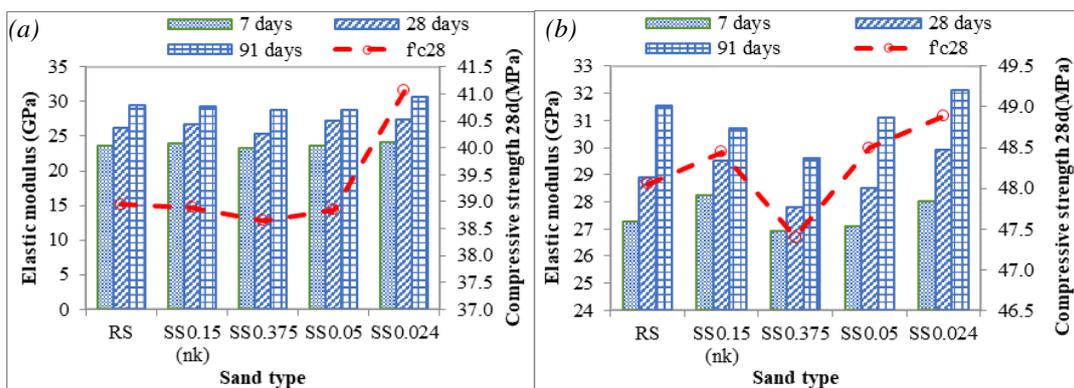


Figure 4. Elastic modulus of concrete with different types of sand
 a) grade 30 mixes; b) grade 40 mixes.

3.3. Water and chloride ions penetrability, steel corrosion protection of concrete using sea sand

3.3.1. Water and chlorine ion penetrability

The test results of water and chloride ion penetrability tests on concrete using different types of sea sand and river sand are presented in Figure 5. The test results of chloride ion penetrability in terms of the coulometric parameter passed the concrete sample showed that the chlorine ion penetrability of concrete tends to increase as the chlorine ion content in the sand increases (when the sand contains a larger amount of salt). This indicates an increase in the chloride ion penetrability of concrete with increasing salt content in the sand. The concrete mix grade 30 using SS0.375 sand showed higher ion permeability results compared to the average level of other mixes. Similarly, the mixes using sand with higher salt content also showed higher water penetrability (Figure 5).

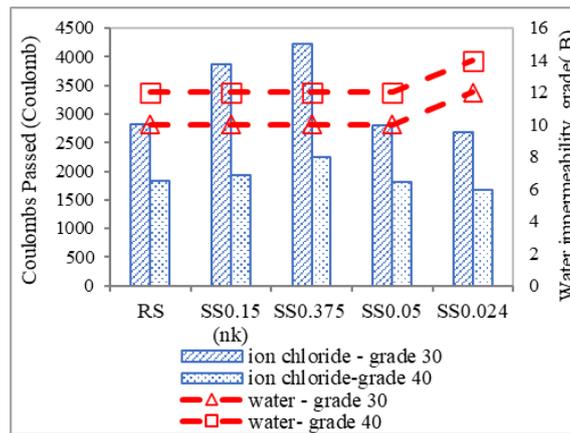


Figure 5. Effect of sand type on the resistance to chloride ion penetration and water permeability of concrete.

This result can be explained by the fact that as-received sea sand contains a significant amount of salt and clay dust content that is significantly higher than that of washed sea sand and river sand, which increases the conductivity of the tested concrete sample by facilitating the movement of ionized ions such as Cl^- , Ca^{2+} , Mg^{2+} , etc. However, the impermeability test showed no difference between the mixes using sea sand and river sand, except for the sample using washed sea sand which showed better impermeability (improved by 2 levels in both grades 30 and 40). Furthermore, the experimental results indicate that the resistance to chlorine ions and water repellency depend on the W/C ratio, and the cement content, and a decrease in the W/C ratio and an increase in the cement content reduce the ability of chlorine ion permeability and increase the impermeability.

3.3.2. Deterioration in strength and surface quality of concrete specimens when curing under the dry-wet cycle

The concrete samples were cured in alternate wet-dry cycles, with 2 weeks of water immersion followed by 2 weeks of drying. The results of the compressive strength test of concrete samples at 91 and 365 days of age are presented in Figure 6.

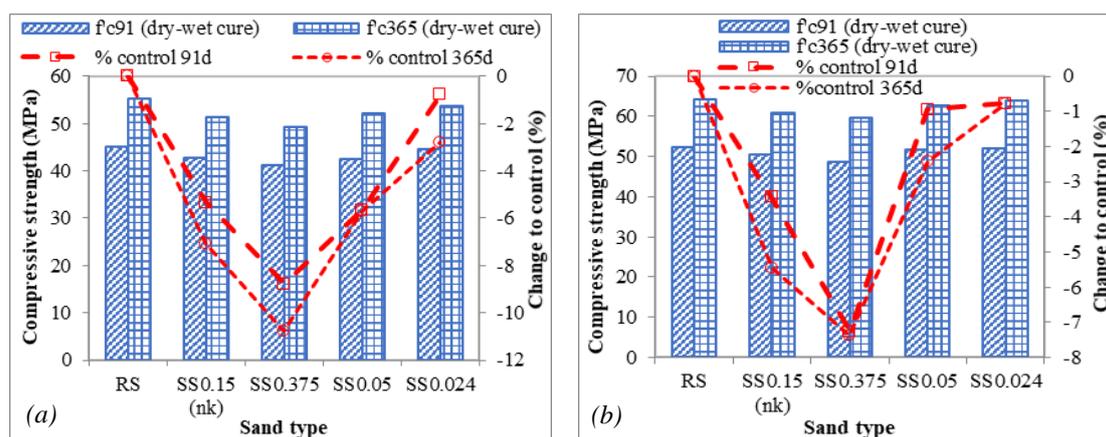


Figure 6. Strength and compressive strength loss of concrete samples cured in wet-dry cycle
a) grade 30 mixes; b) grade 40 mixes.

The experimental findings reveal that as the chlorine ion content of the sea sand increases, the reduction degree of compressive strength decreases. At the age of 91 and 365 days, the concrete mixes using the as-received sea sand SS0.15 and SS0.375 showed strength reductions of 5.4 - 7.1% and 7.4 - 10.8% for concrete grades 300 and 400, respectively. Although the strength of the sea sand concrete samples SS0.05 and 0.024 at 91 and 365 days decreased compared to the river sand samples, the decrease was quite small, with the highest being up to 5.7%. The order of strength reduction of sea sand and river sand concrete when cured in the dry-wet cycle is SS0.375 > SS0.15 > SS0.05 > SS0.024 > RS. The degree of strength reduction of concrete cured by dry-wet cycles at a late age is greater than that of concrete cured under standard conditions. Previous studies have shown that the phenomenon of strength reduction in concrete containing high contents of chlorine ions over time is due to the early activation of cement hydration, followed by a gradual decrease in the degree of cement hydration with age. Consequently, the degree of cement hydration at a late age is generally lower than usual. Moreover, in dry-wet cured concrete, the amount of salt in the concrete leads to recrystallization which causes volume expansion and forms stress. This often leads to microstructural cracks that decrease the strength of concrete and increase its susceptibility to penetration by external liquids, thereby increasing the degree of strength deterioration. In dry-wet cycle curing samples, this process is repeated several times, leading to the gradual degradation of concrete strength.

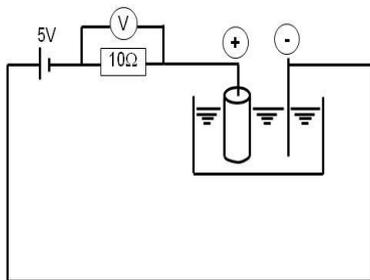
Regarding the surface quality of concrete samples cured under the dry-wet cycle: Observations on the surface of concrete samples cured in the dry-wet cycle up to 1-year-old (Figure 7) showed no phenomenon occurred. The appearance of efflorescence on the surface of the specimen can be seen on many concrete structures or masonry walls using saline sand working in a humid environment. With the concrete samples tested, on the surface of these samples, there is only a white powder coating when the samples are allowed to dry. This may be due to the amount of lime released when soaking the sample. Note, however, that with the wet-dry cycle curing method, each sample cycle is immersed in water for 14 days so during this time some salt in the sample can be washed out and 14 days left to dry. There is also not enough time for the dissolved salts to be released onto the surface of the sample to form regions of recrystallized salt. Therefore, this method may not reflect the ability to cause salt bloom with concrete when using saline sand as in actual conditions.



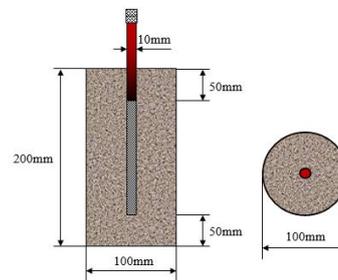
Figure 7. Concrete samples using sea sand cured in alternate wet-dry cycles.

3.3.3. Ability protection reinforcement steel from corrosion

The ability to protect the reinforcement from corrosion of concrete using samples of sea sand and river sand (control) performed according to the corrosion acceleration method according to NT Build 356 standard is described as shown in Figure 8. Reinforced concrete samples are cured under standard conditions for 28 days before being tested for rebar corrosion.

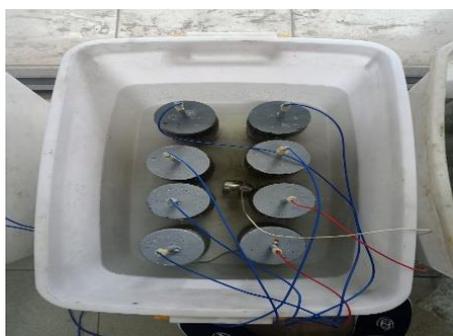


(a) Experimental diagram



(b) Reinforced concrete sample

Figure 8. Experimental diagram and reinforced concrete samples for testing according to NT Build 356.



(a) Concrete samples in the test



(b) Cracks on the concrete sample

Figure 9. Reinforced concrete samples during and after steel bars corrosion test.

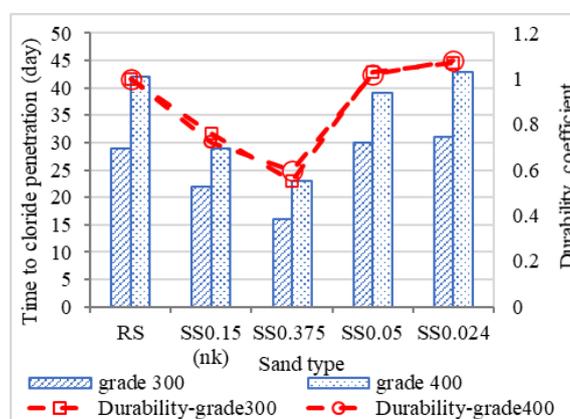


Figure 10. Ability to protect steel bars of concrete using different types of sand tested according to NT Build 356.

The test results in Figure 10 shows the number of days when the chlorine ion flow started to penetrate the rebar (current started to increase) and the number of days of sample cracking (cracking was observed) since the beginning of the sample immersion. The results show that the time to start corrosion of reinforcement bars in concrete and the time the samples cracked for the mixes using the as-received sea sand (SS0.15) and SS0.375 sand are the shortest, while the mixes using washed sea sand (SS0.024) and SS0.05 and river sand samples are equivalent. The durability coefficient (calculated as the ratio of time in days when chlorine ions penetrate to the steel bar of the test sample compared with the control sample of the test concrete samples) showed that the samples used the as-received sea sand (SS0.15) is quite low 0.76 and 0.72, whereas that of sample SS0.375 is the lowest 0.55 and 0.60 for grade 30 and 40 respectively. The results of this experiment show that the content of chlorine ions affects the ability to protect the reinforcement from corrosion, when increasing the concentration of chlorine ions will make the corrosion process take place faster, and the ability to protect the

reinforcement of concrete will decrease rapidly. According to the test results, the durability coefficient of the high chlorine ion sea sand samples (SS0.15, SS0.375) reduces the long-term durability of the reinforcement steel by about 28 - 45%. The effect of chlorine ions in the sand on the ability of concrete to protect reinforcement can be explained by the fact that chlorine ions present in concrete will contribute to shortening the time when aggressive agents such as chlorine ions migrate in concrete to the steel bars surface (through shortening the time when the current through the sample begins to increase rapidly) when the amount of chlorine ions accumulates large enough, it will cause corrosion of the steel bar, which is the cause of concrete cracking.

4. Conclusion

In the scope of this study, the effects of sea sand with different contents of chlorine ions on the properties of the fresh concrete, physical and mechanical properties, and the durability of the concrete, can be drawn as follows:

- Sea sand with increased chloride ion content reduces workability (or increases mixing water) and reduces the slump retainability of fresh concrete using sea sand. The concrete mixes using sea sand with a chlorine ion content of 0.375% give the greatest reduction in workability and slump retainability compared to the as-received sea sand and other samples. This is the basis for selecting washing technology to ensure the quality of sea sand used for concrete and mortar as required.

- The strength development of concrete using sea sand at the age of 7 and 28 days is higher than that of river sand and washed sea sand, but the late strength (after 28 days) tends to decrease. The strength after 365 days of sea sand containing 0.15% chlorine ion content (original sand) and 0.375% decreased by about 5.4 - 7.1% and 7.4 - 10.8% for the concrete mixes with grades 30 and 40, respectively. The results are the basis for selecting concrete mix design using sea sand according to each sea area and locality.

- Chlorine ion and water impermeability of concrete using sea sand also decrease when chloride salt content in sea sand increases. Mixing using sea sand with chlorine ions at 0.375% has low chlorine ion permeability compared to the average waterproofing in the control sand samples. Therefore, the lower the chlorine content of the sea sand, the better the waterproofing properties.

- The ability to protect the reinforcement of marine concrete is also significantly reduced when increasing the concentration of chlorine ions in the sand. Mixing sea sand with chlorine ion content of 0.15% (original sand sample) and 0.375% has a long durability coefficient (time to protect the reinforcement from corrosion) and is only 24 - 28% and 40 - 45% compared to the control sample (river sand).

- The phenomenon of precipitation of white salt on the concrete surface was not observed with the concrete samples using sea sand in this study. However, the dry-wet curing regime used in this study may not accurately reflect the dry-wet conditions of the actual climate in our country, so it is necessary to limit the use of saline sand with a high concentration of salt chlorine ions greater than 0.15% as specified in some standards (JGJ 206, GOST 8736-2014, BS EN 13139).

- From the research results, the scientific basis for the design and construction of concrete using sea sand is drawn according to the chlorine content of each sea sand area. At the same time, proposing technological measures to use sea-sand, technical requirements to ensure the effective use of sea sand, meeting technical criteria, economic efficiency, improving the durability of concrete structures, and steel reinforcement.

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ĐÁNH GIÁ ẢNH HƯỞNG CỦA CÁT BIỂN VỚI HÀM LƯỢNG ION CLO KHÁC NHAU ĐẾN TÍNH CHẤT CỦA BÊ TÔNG

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Tóm tắt: Bài báo trình bày kết quả nghiên cứu đánh giá ảnh hưởng của việc sử dụng cát biển với hàm lượng ion clo trong cát khác nhau đến tính chất của hỗn hợp bê tông, cơ lý và độ bền lâu của bê tông. Nghiên cứu đã thực hiện đánh giá trên mẫu cát biển có hàm lượng ion clo khác nhau bao gồm mẫu cát biển nguyên khai (hàm lượng ion clo ~ 0,15%), hai mẫu cát biển qua rửa (khử muối) (0,024%, 0,05%) và mẫu cát biển bổ sung muối clorua (0,375%) và so sánh với mẫu cát sông. Các mẫu cát có mô đun độ lớn xấp xỉ nhau trong khoảng 2,3 - 2,5. Kết quả nghiên cứu cho thấy, so với cát biển qua rửa và cát sông, các cấp phối bê tông sử dụng cát biển có hàm lượng ion clo cao làm tăng cường nước trộn và giảm khả năng duy trì độ sụt của hỗn hợp bê tông; cường độ nén tuổi sớm (7 ngày) tăng nhưng cường độ tuổi muộn (91 và 365 ngày) giảm trong cả hai trường hợp bảo dưỡng tiêu chuẩn và bảo dưỡng khô-ướt. Ngoài ra, khả năng chống thấm (nước, ion clo), khả năng bảo vệ cốt thép khỏi ăn mòn của bê tông sử dụng cát biển có hàm lượng ion clo cao cũng giảm hơn so với cát biển qua rửa và cát sông.

Từ khóa: Bê tông cát biển; cát biển; cốt liệu nhỏ; tính chất cơ học; độ bền lâu.

Received: 16/04/2023; Revised: 26/05/2023; Accepted: 23/06/2023; Published: 30/06/2023

