Influence of different sand types on the properties of self-compacting concrete used for the Dong Nang Ren irrigation project-Bac Lieu province

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Abstract: The scarcity of natural sand for construction in the current circumstance has made researchers and engineers search for another resource to replace it. This paper presents a study on the influence of crushed sand and natural sand on the properties of self-compacting concrete (SCC) implemented for the Dong Nan Ren irrigation project-Bac Lieu province. The experiment pointed out that at fresh state the SCC mixture with natural sand had shown better performance than that with crushed sand. In the meantime, both mixtures with crushed and natural sand have yielded the self-compacting properties (slump flow value and T500) in accordance with the requirement of the concerned project. Compressive and flexural strength at 28 days of the SCC with crushed sand are 10.1% and 21.9% respectively higher than that of the one with natural sand. Besides, both of them achieved the waterproof grade W6, which is suitable for construction of hydraulic structures. This outcome verifies that in case there is a lack of natural sand, the crushed sand can substantially replace it for the SCC production.

Keywords: Self-compacting concrete, crushed sand, natural sand, fresh and hardened concrete properties.

1. Introduction

Self-compacting concrete (SCC) has been developed first in Japan in the late 90-ies (Okamura & Ouchi, 2003). This new concrete technology eliminates the inherent weakness of conventional concrete in the fresh state, which is an easy prone-to-segregation, and can be placed easily without mechanical vibration (Domone, 2007).

The irrigation construction project could have a huge technical advantage, once SCC is implemented (Vu, 2011). However, the shortage of natural sand in some areas of Vietnam raises the question whether the use of another sand type would influence the SCC properties. This is also a goal of the present paper.

1.1. Overview of the Dong Nang Ren irrigation project

The Dong Nang Ren irrigation project - Bac Lieu Province, as illustrated in Figure 1, serves for the rural development in the Mekong Delta. The project is located to the east of National Highway 1A, as shown in Figure 2, it is surrounded by:

– The West and Northwest borders on National Highway IA.

– The Northeast borders Thanh Tri district and My Xuyen district (Soc Trang province).

– The East borders Huong Lo 6 in Vinh Loi district.

– The Southeast borders Bac Lieu canal.

The main objective of the project is to prevent salinity for more than ten thousand hectares of natural land, create for production to boost the economic conditions according to the master plan, and improve the living standards of people in the nearby areas. Once the project is completed, the entire rice cultivation area will ensure 2-3 crops per year, creating favorable conditions for the development of waterway

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traffic, contributing to the redistribution of labor across multiple industries in a scientific and appropriate manner.

Figure 1. Illustration of a sluice-gate in the Dong Nang Ren irrigation system

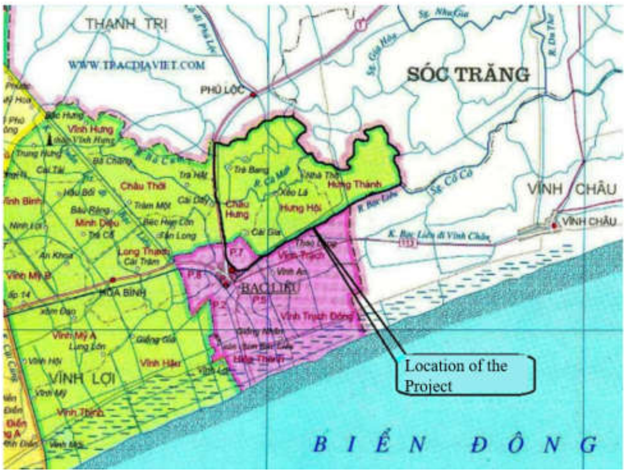

Figure 2. Location of the Project at Vinh Loi District - Bac Lieu Province

Under the Dong Nang Ren project, it is necessary to build three sluice-gates including Hai Hau, Ba Tinh, and Hai Thang in accordance with the floating dam technique. The floating dam, which is composed of various structures such as beam, slab, column, ect., is made of reinforced concrete. To ease the placement, SCC is involved in the project (Nguyen, 2014). The main purpose of this study is to observe how different sand types such as crushed and natural affect on the properties of SCC used for the construction of those sluice-gates in the Dong Nang Ren project.

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, which is conforming to the Vietnamese standard TCVN 2682:2009, is used in this study. In addition, fly ash class F from the coal-fired power plant, which is conforming to the ASTM C 618, is used as supplementary cementitious material in combination with cement in SCC.

Chemical characteristic of cement and fly ash are included in Table 1. Moreover, physical characteristic of cement and fly ash are also provided in Table 2 below.

Table 1. Physical and mechanical characteristic of cement

Compound (wt. %)	Cement	Fly ash
SiO_2	21.22	59.04
Al_2O_3	5.82	22.10
Fe_2O_3	6.54	6.28
CaO	62.92	1.60
MgO	1.62	0.90
SO_3	-	0.17
K_2O	0.19	4.58
Na_2O	0.28	0.34
TiO_2	0.06	0.40
LOI	1.25	4.75

Table 2. Physical characteristic of cement and fly ash

Parameters	Units	Cement	Fly ash
Specific density	g/cm^3	3.11	2.2
Bulk density	g/cm^3	1.31	-
Blaine fineness	cm^2/g	3320	3840
Consistency	%	27.5	-
Initial setting time	min.	133	-
Final setting time	min.	251	-
Soundness of cement	mm	2.4	-
3 days Compressive strength	N/mm^2	24.2	-
28 days Compressive Strength	N/mm^2	44.5	-

2.2. Coarse and fine aggregates

This study proposes the use of crushed and natural sand as fine aggregates and crushed stone as coarse aggregate from the adjacent provinces close to Bac Lieu, where there is an abundant amount of suppliers, such as Vinh Long or Kien Giang.

The characteristic of sand and crushed stone, conforming TCVN 7572:2006, is given in Table 3. Besides, in order to obtain grading of aggregates, sieve analysis is also carried out, and the results are provided in Table 4.

2.3. Water and admixtures

Superplasticizer used in this study is a high-range water reducer admixture, which is a third generation polycarboxylate superplasticizer. Water used for mix proportion is tap water at Bac Lieu area. Characteristic of superplasticizer and water is shown in Table 5.

2.4. Mix proportion of SCM

In this study, SCC mixture corresponding to the strength class of 25MPa (M25) at the age of 28 days is designed. The criteria for self-compacting properties are that the slump flow value needs to be greater than 600mm and the T_{500} is not longer than 8 seconds (EFNARC, 2006). There are two SCC mixes, one involves the use of crushed sand and the other with natural sand.

Table 3. Characteristic of sand and crushed stone

Parameters	Sand		Crushed
	Crushed	Natural	Stone
Specific density, g/cm^3	2.86	2.65	2.88
Bulk density, g/cm^3	1.57	1.47	1.46
Porosity, %	38.2	38.2	47.13
Moisture content, %	1.03	1.03	0.62
Clay, silt and dust content, %	18.1	1.78	0.99
Fineness modulus	2.77	2.52	-

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

Sieve size,	Sand, %		Crushed stone,
mm	Crushed	Natural	%
100	-	-	0.0
70	-	-	0.0
40	-	-	0.0
20	-	-	7.76
10	-	-	94.51
5	1.1	-	99.11
2.5	21.9	10.6	-
1.25	43.3	20.7	-
0.63	59.2	42.5	-
0.315	70.7	75.2	-
0.14	81.9	98.2	-
Pan	100	100	100

Table 5. Characteristic of water and superplasticizer

Parameters	Water	Super-plasticizer
Specific density, g/cm^3	1	1.20÷1.24
pH value	7	5÷7

The mix proportion has been carried out in accordance with the SCC mix design recommendation originally developed by Professor Okamura, who was considered as the first person to introduce SCC to the scientific society (Okamura & Ouchi, 2003). Besides, several guidelines on SCC from EFNARC have been taken into consideration (EFNARC, 2002, 2006). Some "trial-and-error" were involved into mix proportion of SCC. The final proportion of two SCC mixes is presented in Table 6 below. It is noted that the only difference between them is sand type.

Table 6. Mix proportion of SCCs

	Cement PCB40	Fly ash	Crushed stone	Crushed sand	Natural Sand	Water	Superplasticizer
	kg	kg	kg	kg	kg	L	L
M1	200	300	925	900	-	175	5.6
M2	200	300	925	-	900	175	5.6

2.5. Specimen preparation and experimental programme

After a relevant mixing procedure, SCC mixtures (M1 and M2) were tested at a fresh state in order to define the slump-flow value, as well as the T_{500}, in accordance with the standard TCVN 12209:2018, as it is illustrated in Figure 3. Afterward, a series of cubic specimens (150x150x150 mm^3), Figure 4, prismatic specimens (100x100x400 mm^3), Figure 5, and three cylindrical specimens (150 mm diameter and 150 height), Figure 6, were prepared in order to determine compressive strength, flexural strength and waterproof grade respectively.

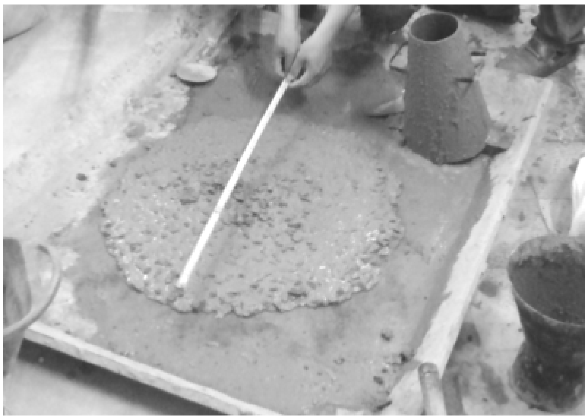

Figure 3. Determination of slump flow value

Compressive and flexural strength are defined at 3, 7, 14 and 28 days. At each age, three identical specimens are requisite. Thus, for every SCC mix (M1 or M2) there are twelve identical specimens each used for compressive and flexural tests at different ages. Waterproof grade is defined by using the specimen at 28 days.

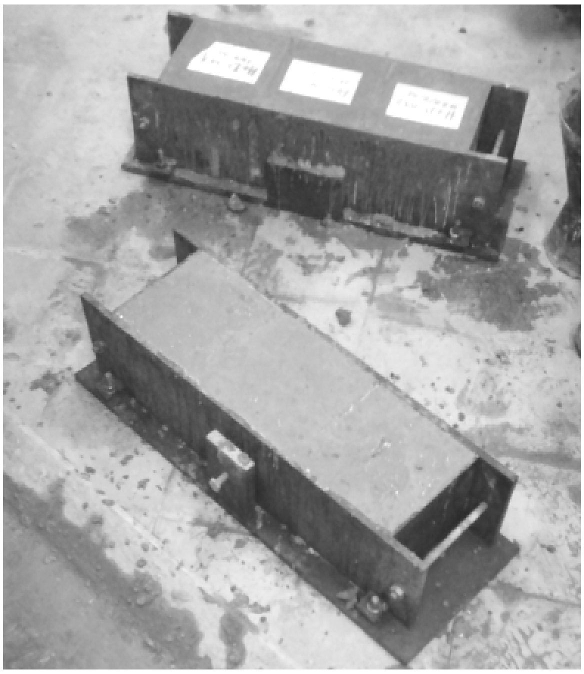

Figure 4. Cubic specimens for the compressive test

After casting SCC mixtures into the corresponding moulds, the specimens were kept in the laboratory for 24 hours, then they were removed from the moulds and cured under the standard condition (T=25±2^{o}C; W>95%) up to the testing date.

Figure 5. Prismatic specimens for the flexural test

Regarding the tests on the specimens at hardened state, the compressive strength was defined in accordance with TCVN 3118:1993, while the flexural strength was with TCVN 3119:1993, as shown in Figure 7, and waterproof grade was with TCVN 3105:1993.

Figure 6. Cylindrical specimens for the waterproof test

Figure 7. Central-loading flexural test

3. Results and discussion

3.1. Self-compacting properties

Slump flow value and T_{500} of SCC mixtures M1 and M2 are included in Table 7. It can be observed that the slump flow value of M1 mixture with crushed sand is lower than that of the M2 with natural sand. While the T_{500} of the former is greater than that of the later. Thank to the round shape and smooth surface of natural sand, in which the particle can easily slide one over another, the flowability of the mix M2 is slightly better than that of the mix M1 (Nguyen, 2019).

Table 7. Flowability of SCC mixes

Mix	Slump flow value	T_{500}
	mm	s
M1	665	6
M2	690	5

Theoretically, to design SCC mixes in general, in comparison with conventional concrete it needs to increase the fine content (Okamura & Ouchi, 2003). Since the amount of cement and fly ash of the M1 and M2 is similar, despite the fact that the fine content of crushed sand in the M1 is much higher than that of natural sand in the M2, as shown in Table 4, self-compacting properties of the former is worse than the later. This phenomenon can be explained that due to the similar dosage of superplasticizer in the M1 and M2, the fine content in aggregate in the M1 cannot play a role as “motor” to improve the flow speed and diameter of the halo (Domone, 2007).

3.2. Compressive and flexural strength

Once three identical specimens were tested, the average result of those specimens was obtained to assess and make an evaluation. The average results at different ages of compressive and flexural strength are represented in Figure 8 and Figure 9 respectively.

Looking into Figure 8, it is seen that compressive strength of the M1 with crushed sand is always higher than that of the M2 with natural sand at 3, 7, 14, and 28 days. Compressive strength of the M1 at 3, 7, and 14 days are 37%, 56.7%, and 79.6% respectively that at 28 days. For the M2, the corresponding relations are 33.3%, 50.8% and 62.8%. It is noted that the evolution of compressive strength at the early ages (3 and 7 days) was quite slow in comparison with the conventional concrete. This might be due to the use of high amount of fly ash in the mixes, which results in low compressive strength at the early age, but it is enhanced essentially in the long term (Neville, 2002).

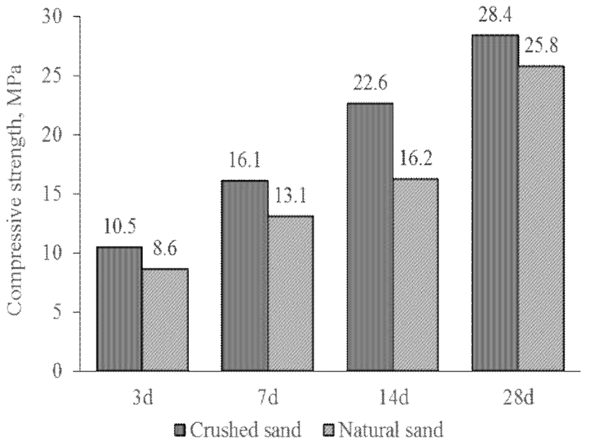

Figure 8. Results from the compressive test

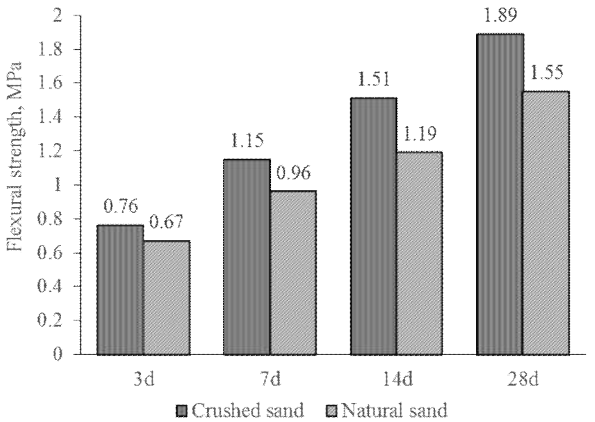

Figure 9. Results from the flexural test

A similar observation can be drawn in terms of flexural strength, looking into Figure 9, that the crushed sand yields better results than the natural sand at 3, 7, 14, and 28 days. Flexural strength of the M1 at 3, 7, and 14 days are 40.2%, 60.8%, and 79.9% respectively that at 28 days. For the M2, the corresponding relations are 43.2%, 61.9% and 76.8%.

It is important to note that both mixes M1 and M2 have complied with the designed strength class of M25. Compressive and flexural strength at 28 days of the M1 with crushed sand are 10.1% and 21.9% respectively higher than that of the M2 with natural sand. This outcome verifies that in case there is a lack of natural sand, the crushed sand can substantially replace it for the SCC production.

3.3. Waterproof grade

Waterproof grade is presented in Table 8. The similar grade W6 is achieved by both of the M1 and M2. This proves that these SCCs can be used effectively for the construction of hydraulic structures in accordance with TCVN 9139:2012 “Hydraulic Structures - Concrete and reinforced concrete Structures in coastal areas - Technical Specifications”.

Table 8. Results from the waterproof test

Mix	Waterproof grade
M1	W6
M2	W6

4. Conclusion

The influence of different sand types on the properties of SCC implemented for the Dong Nang Ren irrigation project-Bac Lieu province was studied in this paper. Two types of sand were involved such as crushed sand and natural sand. These sands were used for the SCC production of strength class 25MPa or M25. Several conclusions can be withdrawn:

- At fresh state, the SCC mixture with natural sand had better performance than that with crushed sand. This result was due mainly to the round shape and smooth surface of the natural sand that has made the particles able to slide easily one over another. However, both sands have yielded the self-compacting properties (slump flow value and T_{500}) in accordance with the requirement of the concerned project;
- Compressive and flexural strength at 28

days of the SCC with crushed sand are 10.1% and 21.9% higher than that of the one with natural sand. This outcome verifies that in case there is a lack of natural sand, the crushed sand can substantially replace it for the SCC production.

- Both of SCCs using crushed and natural sand achieved the waterproof grade W6, which is suitable for construction of hydraulic structures.

Last but not least, the outcomes of this study are useful for not only the construction of the Dong Nang Ren irrigation project-Bac Lieu province, but also the other projects in the Mekong Delta.

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