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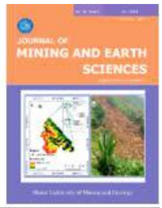

Potential using of marine sand in coastal areas of Vietnam to create concrete for rural roads

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ABSTRACT

In Vietnam, there is not enough sand from the river for the construction operation, and it is necessary to find other resources to replace it. Marine sand was distributed in large areas in the coastal area of Vietnam and was not used for rural roads. This paper presents experimental results on the workability and compressive strength of concrete which was made from Nghe An and Ha Tinh marine sand. The particle size of two marine sands is not fully suitable for use as fine aggregates in concrete according to TCVN 7570:2006. The Ha Tinh sand was more suitable for use as fine aggregates in concrete than Nghe An sand. Three grades of concrete (M20, M25, M30) were designed for testing. Fifty-four samples of concrete were mixed and cured for 3, 7, and 28 days. Results showed that the compressive strength of Ha Tinh concrete achieved the requirements of M20, M25, and M30 grade - concrete. Otherwise, the compressive strength of Nghe An concrete has only achieved the requirements of M10, M15, and M20 grade – concrete. The research results also showed that the concrete made from Ha Tinh sand can be used for the A, B, C, and D grades of rural roads and the concrete made from Nghe An sand can only be used for the C, D grades of rural roads. The workability of all concrete mixtures met the requirements of Vietnamese standards. The sea sand in the coastal area of Vietnam has enormous potential to produce concrete for rural roads.

1. Introduction

Nowadays, Vietnam's total sand volume is about 2.3 million m^3 and only meets 60 to 65% of the demand for sand in construction (MONRE, 2020). The sand volume for the concrete

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production was only 30% of the total demand needed. So, it is necessary to find other replacement resources for sand in construction. Finding other resources to replace aggregate in concrete is a promising avenue (Nguyen et al., 2019; Bui et al., 2020). In Vietnam, there is a lot of sand distributed along the coastal area which can be used as fine aggregate. Therefore, the investigation of the potential use of this material in concrete is necessary in construction practices (MONRE, 2020).

The use of marine sediments has been studied by some authors elsewhere. Sanjaya (2021) indicated that marine sand can be used as fine aggregates in concrete. Dredged marine sand (DMS) can also be used for making concrete and the mechanical and durability properties of this concrete have been studied by Limeira et al. (2010, 2011a, 2011b), Padan (1983), Dias et al. (2008), Huiguang et al. (2011). Limeira et al. (2010) studied three concretes made from DMS and indicated that the compressive strength of those samples met the minimum of 30 MPa. Test results also showed that the fresh and hardened properties of concretes made with DMS approached the results of the control concrete. Limeira et al. (2011a) researched the mechanical and durability properties of concretes fabricated with dredged marine sand (DMS) as a fine granular corrector in partial substitution of raw sand (from 15% to up to 50% by raw sand mass) and showed that those properties achieved the requirement of concrete for harbor pavement. From previous studies, marine sand has the potential to be used as fine aggregates in concrete. In Vietnam, marine sand has been studied to be used for fine aggregates in concrete (Le, 2005, 2006; Tran, 2000; To, 2004; Hoang, 2011; Nguyen, 2011). Le (2006) used marine sand with a small content of salt to make concrete and indicated that the compressive strength and flexural tensile strength equaled 90÷92% of that made with normal fine aggregates. Nguyen (2011) showed that CSSB preparations were used to treat salt in marine sand and after that sand can be used to construct dyke in the Can Gio area. Nevertheless, the use of marine sand for concrete pavement is still limited. So, in this study, marine sand from Ha Tinh and Nghe An province will, therefore, be used to investigate the potential of these materials to make concrete for rural roads. The workability and the compressive strength of concrete were evaluated. In addition, the compressive strengths at 3, 7, and 28 days of curing were investigated.

2. Materials and methods

2.1. Materials

In this study, components of concrete included marine sand (fine aggregates), coarse aggregates, and water. The fine aggregates were collected in the coastal area of Nghe An and Ha Tinh province (Figure 1).

a) b)

Figure 1. Marine sand samples in the coastal area of Ha Tinh (a) and Nghe An (b).

The particle size distribution of marine sand was determined according to the Vietnam Construction Standard TCVN 5772:2006-2. The physical properties of these samples were also performed according to the Vietnam Construction Standard TCVN 5772:2006. The particle size and physical properties of marine sand are shown in Table 1 and Figure 2.

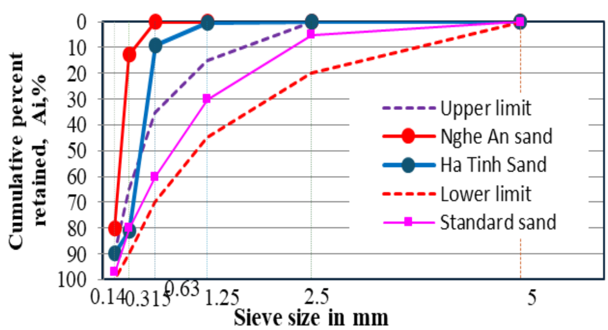

Figure 2. Particle size distribution of marine sand in the coastal area of Nghe An and Ha Tinh provinces.

Table 1. Physical properties of Ha Tinh sand and Nghe An sand.

No	Physical properties	Ha Tinh sand	Standard sand	Nghe An sand
1	Specific gravity, kg/m^3	2650	2630	2560
2	Fineness modulus of sand (M_k)	1.80	2.72	0.93
3	Silt, clay, and dust content (%)	0.4	0	0.7
4	Salt content (%)	0.31	0	0.50
5	Organic impurities	MS (Brighter than standard color)	MS (Brighter than standard color)	MS (Brighter than standard color)
6	Mica content, (%)	0.03	0	0.02
7	Bulk density, kg/m^3	1450		1320

Table 2. Chemical components and physical properties of PCB cement (Nguyen et al., 2020).

No	Chemical components and Physical properties		PCB But Son Cement
1	Chemical component, %	SiO_2	19.74
2		Al_2O_3	5.18
3		Fe_2O_3	3.11
4		CaO	63.14
5		MgO	1.61
6		Na_2O	0.15
7		K_2O	0.70
8		SO_3	1.85
9		TiO_2	0.12
10		LOI	2.58
11	Bulk density, kg/m^3		1300
12	Specific gravity, kg/m^3		3100
13	Compressive strength at 28 days curing (MPa)		40

As shown in Figure 2 and Table 1, the particle size of two marine sands is not fully suitable for use as fine aggregates in concrete according to TCVN 7570:2006. In this study, these sands are also used to make concrete for rural roads because of their benefits such as large volumes, and on-site mining. The Fineness modulus of Ha Tinh sand and Nghe An sand was 1.80 and 0.93 respectively. The Fineness modulus of Ha Tinh sand was higher than that of Nghe An sand. It can be seen that the Ha Tinh sand was more suitable for use as fine aggregates in concrete than Nghe An sand. As compared with the study of Wu et al. (2020), the bulk density and fineness modulus of these sands are smaller than those of sea sand in Tianjin China.

In this study, PCB cement from the But Son factory was used. The chemical components and physico-mechanical properties of cement (Nguyen et al., 2020) are shown in Table 2.

Fresh water is used for mixing concrete and meets the requirements of Vietnam standards. Coarse aggregates have a specific gravity of 2,700 kg/m^3 and a bulk density of 1,370 kg/m^3. The particle size of coarse aggregates is shown in Figures 3, 4. It can be seen that the coarse aggregates are suitable for use to create concrete.

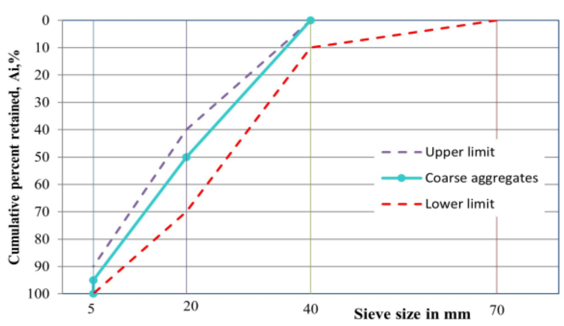

Figure 3. Particle size distribution of coarse aggregates.

Figure 4. Coarse aggregates.

2.2. Methods

First of all, the mixing proportions of concrete were designed to meet the compressive strength of 20 MPa, 25 MPa and 30 MPa, workability of 3÷5 cm. The methods were used to design components of concrete based on Bolomey - Scramtaev methods (Nguyen et al., 2019). After that, the concrete mixture was tested for slump, and if it met the requirements, the strength compression test specimen was performed. In case the concrete mixture did not achieve a slump, the N/X ratio must be increased. According to Table 3, the standard concrete of C20, C25, and C30 needs less cement content, so the N/X ratio is larger than concrete using marine sand.

Table 3. The mix proportions of the concrete.

No	1	2	3
Ha Tinh concrete			
Samples	M20	M25	M30
Coarse aggregates, kg	1089	1074	1063
Fine aggregates (marine sand), kg	813	783	752
Cement, C, kg	323	378	433
Water, W, lit	190	190	190
W/C	0.57	0.50	0.43
Nghe An concrete			
Samples	B20	B25	B30
Coarse aggregates, kg	1089	1074	1063
Fine aggregates (marine sand), kg	813	782	751
Cement, C, kg	323	377	433
Water, W, lit	190	190	190
W/C	0.57	0.50	0.43
Control concrete			
Samples	C20	C25	C30
Coarse aggregates, kg	1085	1074	1063
Fine aggregates (standard sand), kg	813	782	751
Cement, C, kg	293	343	393
Water, W, lit	190	190	190
W/C	0.65	0.55	0.48

The mix proportion of concrete was prepared in accordance with TCVN 3105:1993 (Figure 5) and the slump tests were subsequently performed according to TCVN 3016:1993.

Figure 5. Specimen of concretes.

The cube samples of concretes with sizes of 150 x 150 x 150 mm were prepared for compression tests. Fifty-four samples of concrete were mixed and cured for 3, 7, and 28 days. Compressive strength tests were then conducted in Digimax III Control tester (Figure 6) according to TCVN 3118:1993. The samples were compressed at a pressure of 6 ± 4 daN/cm^2 until failure. After that, the compressive strength is calculated as the ratio of the load at failure to the specimen surface area.

Figure 6. Compressive strength test in CONTROL DIGIMAX 3.

3. Results and discussions

3.1. Workability

The workability of all mixed concretes is shown in Figure 7. It can be seen that the workability varied from 3.7 cm to 4.3 cm and reached the requirement of Vietnamese standards. The workability of Ha Tinh sand (M20, M25, M30) was smaller than that of Nghe An sand (B20, B25, B30).

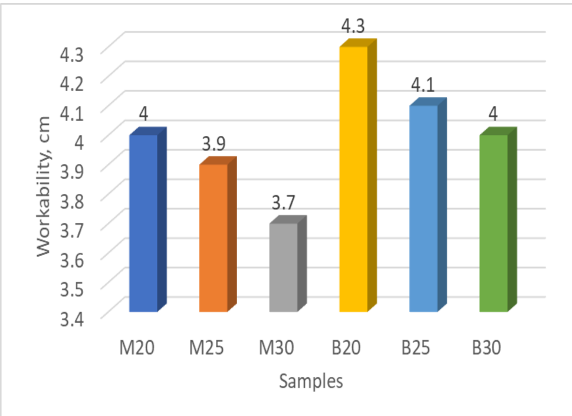

Figure 7. Workability of the concrete.

3.2. Compressive strength

Results of compressive strength of all concrete samples at 3, 7, and 28 days of curing are shown in Figures 8÷15. It could be observed that the compressive strength of Nghe An concrete (B20, B25, and B30) at 3, 7, and 28 days of curing were 75.8÷85.5%, 69.6÷78.2%, and 66 .6÷74.9% of compressive strength of the Ha Tinh concrete (M20, M25, and M30).

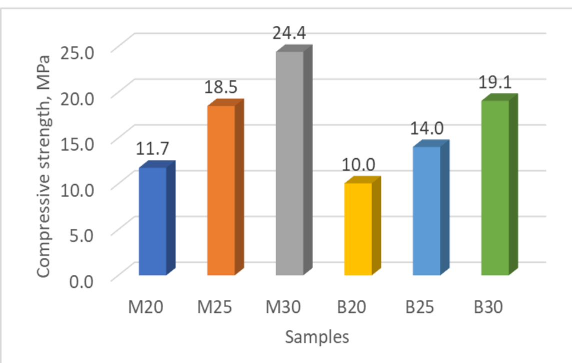

Figure 8. Compressive strength at 3 days of curing.

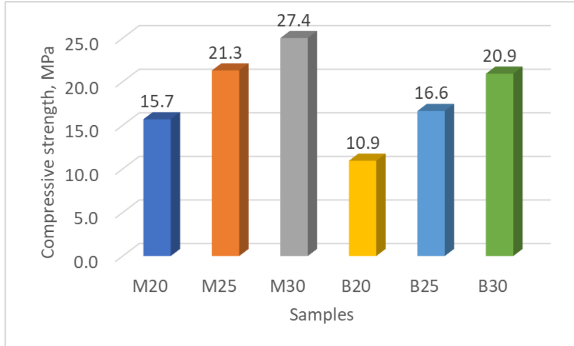

Figure 9. Compressive strength at 7 days of curing.

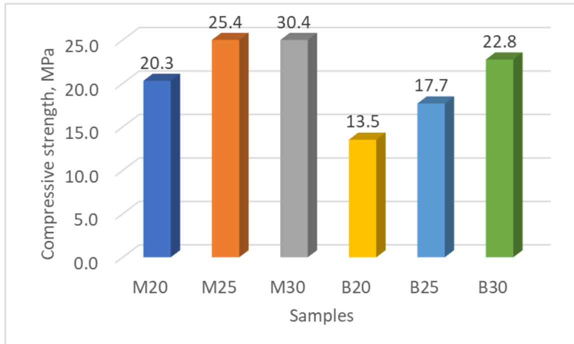

Figure 10. Compressive strength at 28 days of curing.

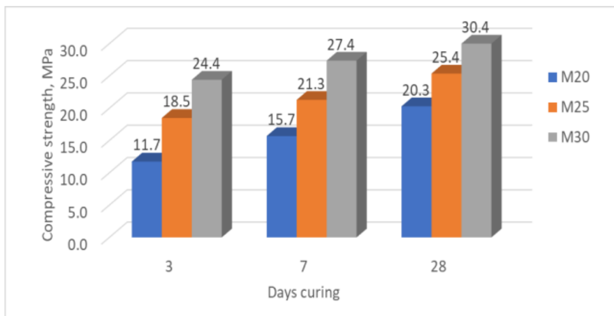

Figure 11. Compressive strength of concretes using Ha Tinh sand.

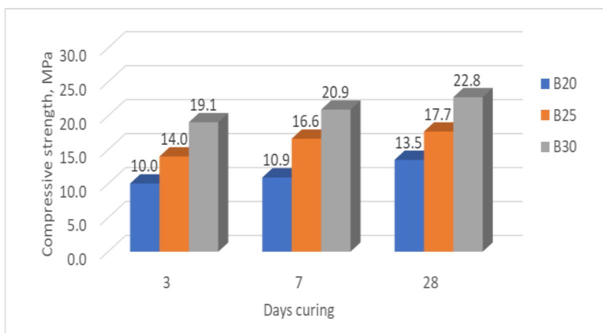

Figure 12. Compressive strength of concretes using Ha Tinh sand.

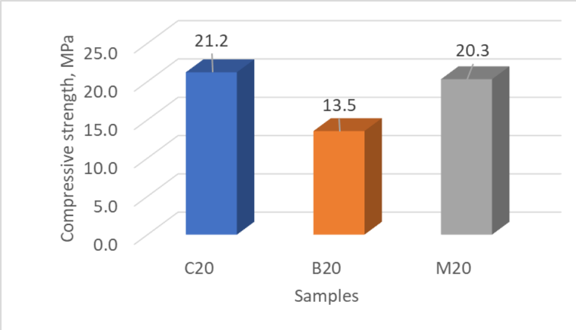

Figure 13. Compressive strength of 20-grade concretes at 28 days.

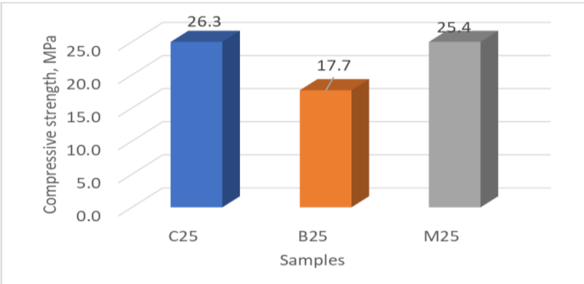

Figure 14. Compressive strength of 25-grade concretes at 28 days.

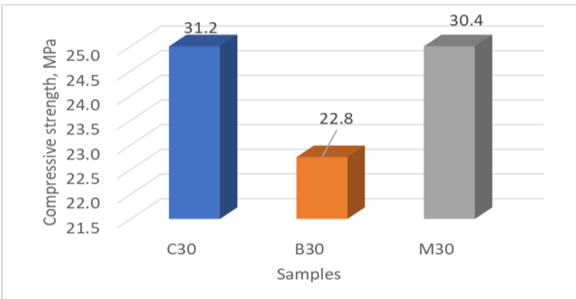

Figure 15. Compressive strength of 30-grade concretes at 28 days.

The compressive strength of all days of curing of concrete made from Ha Tinh sand (M20, M25, and M30) was higher than those of concrete made from Nghe An sand (B20, B25, and B30). This phenomenon can be explained based on the particle size characteristics of each type of sand. The Fineness modulus of Nghe An sand was smaller than that of Ha Tinh sand. Consequently, the Nghe An sand needs more cement to achieve the requirement of compressive strength of M20, M25, and M30 - grades concrete.

It was also found that the compressive strength of Nghe An concrete (B20, B25, and B30) at 3, 7 days of curing equals 57.8÷80.3%, 77.3%÷90.0% of compressive strength at 28 days of curing. The compressive strength of Nghe An concrete at 3, and 7 days of curing equals 74.2÷83.8%, 80.8÷94.0% of compressive strength at 28 days of curing.

From these Figures, the compressive strength of concretes with Ha Tinh sand was that of controlled concretes while the W/C of them was different. The reason for these results is that the concretes with Ha Tinh sand used more cement content than that in controlled concretes. The research results showed that in order to achieve the grade concretes, the concretes with Ha Tinh sand used less water. As shown in Table 1, marine sand has a low salt content, less than 1%. Therefore, salt content in sand does not affect concrete strength for ages up to 28 days. Salt contents only affected compress strength at more than 28 days and up to 90 days. Chloride ions can penetrate the concrete and cause accelerated corrosion of the reinforcement (Wegian, 2010). Qasim et al. (2020) indicated that increasing the salt content causes a decrease in the compressive strength of concrete.

From Figures 11÷15, the compressive strength of Ha Tinh sand was equal to that of control concrete. However, the compressive strength of Nghe An sand only equaled 63.7% to 72.9% of the compressive strength of control concrete. The components of M20, M25, and M30 of concrete using Nghe An sand only met the compressive strength of M10, M15, and M20. Otherwise, the concretes using the Ha Tinh sand already met the requirement of M20, M25, and M30 grade concrete. These concretes can be used for D, C, B, and A grades of rural roads respectively. The reason for these results is the Fineness modulus of Ha Tinh sand (M_K = 1.80) is higher than that of Nghe An sand (M_K = 0.93). The Ha Tinh (sand) fine aggregate was more suitable for making concrete. As compared with the results of Limeira's study (Limerra, 2012), the compressive strength of Ha Tinh concrete can be similar to that of the control concrete. Ngugi et al. (2014) indicated that sand found in Nairobi County and its environs contain silt and clay content and organic impurities that exceed the allowable limits, and these impurities result in a significant reduction in concrete's compressive strength. Ginting (2021) showed that increasing the proportion of sand in aggregate increases the compressive strength.

4. Conclusions

Based on the results, some conclusions are made as follows:

Ha Tinh sand can be used to create M20, M25, and M30 - grades of concrete which correspond to D, C, B, and A grades of rural roads, respectively. Whereas Nghe An sand can be only used for M20 grade concrete in C and D grades of rural roads. The use of Ha Tinh sand was more effective than Nghe An sand in concrete production.

The workability of all concrete mixtures met the requirements of Vietnamese standards. The sea sand in the coastal area of Vietnam has enormous potential to produce concrete for rural roads. For further studies, the properties of concrete using marine sand should be investigated.

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Contribute of authors

Nu Thi Nguyen - proposes ideas and contributes to the manuscript; Son Truong Bui, Dung Ngoc Nguyen - construct the manuscript and contribute to the material analyses; Hieu Xuan Do, Tuan Dinh Vu, Anh Tuan Bui, Nghia Van Chu, Phuong Lam Thi Nguyen, and Thai Van Le - tested the experiment in the laboratory. The authors declare no conflict of interest.

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