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APPLICABILITY OF NAM O WHITE MARINE SAND AS AN ALTERNATIVE FINE AGGREGATE FOR CONCRETE IN QUANG NAM

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Abstract. Nowadays, the making of engineering concrete from appropriate local material becomes a more important concern. This paper aims to use the different methodological systems to evaluate the potential reserves of Nam O white marine sand in Quang Nam province, this sand type is used for mixing with other local materials as concrete fine aggregate which includes fine crushed stone and Thu Bon river sand. This white marine sand is a high potential for replacing partly traditional river sand being run out. Research results indicate that study white sand has a wide distribution area, favorable exploitation conditions, and potential mining reserves reach up to 8017 mil. m^3. The technological properties of white marinesand and mechanical properties of concrete, as well as these design mixing ratios, meet the technical requirements for concrete fine aggregates with compressive strength from 250 - 260 daN/cm^2. This concrete compressive strength (R_c) and flexural strength (R_f), extracted from nondestructive methods, follow a logarithmic correlation like typical concretes. Especially, Rc and R_f rises considerably and rapidly in the first period from 3 to 28 days and drops slowly after 28 days.

Keywords:

1 Introduction

In Vietnam, there are various studies on finding an appropriate material considered as fine aggregate for concrete mixing ratio, such be mentioned early by the Ministry Institute of Transport Science and Technology in the period 1958-1964 for various types of sand in Quang Ninh, Thai Binh, NinhBinh. In the 80s and 90s, various researches and works were referred to the marine sand at locations of Vung Tau, BinhThuan, Quang Ninh [1].Forrepalcingpartlylocal materials in Vietnam, the content of silt and clay is just 1%, with a low fineness modulus by 0.98 - 1.02, that can be used as fine aggregates for both concrete when they do not exceed 50% of the total volume of fine aggregates with constant mixing ratio for water: cement: fine aggregate by 2:1:3 and 1:2:4:6 for engineering concrete. In the cutting-edge paper of [2], they stated a significant statement of rising of concrete strengths such as compressive and tensile strength via applying infield sand as a fine aggregate [2]. In addition, some studies on mixing fine aggregates to make concrete with an increase in the percentage of mixing and replacing

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traditional materials, river sand from 0%, 25%, 50%, 75% to 100%, especially for compressive strength of making of concrete.

In the world, there are many scientific articles and reports for the term of rising concrete strength with different mixing ratios. There is an increase in the mixing ratio that increases the strength but reduces the deformation of the concrete (Osman et al. 2021) [10]. Also in the study of Al-Kheetan (2019) showed the mixing ratio of the mixture consist of water, fine aggregates, and admixtures (by 2 - 4%) are 0.32, 0.37, 0.4, which lead the increase in strength concrete strength up to 42% and water absorption reduced by 65% [11]. The increase of concrete strength and optimization of mortar capacity when using marine sand is also mentioned in the works of Tang et al. (2017) [12] and Couvidat et al. [13]. Dang et al. (2013) [14] and Girish et al. (2015) [15] present a useful using sea dredged sand as a construction material as an alternative to fine aggregates in engineering concrete and mortar. Xiao et al. (2017) [16] using sea sand and seawater to modify concrete, and similar in Sidhardhan et al. (2017) [17] applied sea sand to replace partially fine aggregate, Ravindra et al. (2016) [18] studied the mechanical properties of concrete using sea sand to partially replacing fine aggregate and Gia et al. (2019) [19] studied the properties of marine sand in various Vietnamcoastal areas. Recently, the studies on marines sand and its applications were also mentioned by many other authors: Chau et al. (2018) [3], Duc et al. (2017) [4], Toan et al. (2020) [5]. The previous researches of authors have studied the composition and properties of multi-origin marine sands for different purposes in recent years (Thien et al2014-2020) [6-9, 20, 21, 27]. Refer to the study area in Quang Nam, fine aggregates used to make concrete, mainly comprise river sand and gravel extracted from Thu Bon river system [6-9] [20-21] [27]. But on this river, there are manyscales of hydropowerplants, and most of the soil sediment is accumulated at ponding bed, leading to anobstract of mud and sand flow; that cause shortage of sand material supply day-by-day [27].

However, previous researches did not mention sufficiently about that issue, and for concrete strength variations with study material as white marine sand, also without appropriate statistics possible exploited amount of this sand type. Therefore, this study investigated marine sandy to replace traditional river sand for making concrete within highly applicable for the coastal plain, and a wide plain area with many sandy fields anda large total exploited amount.

2 Research methodology

2.1 Processing and synthesizing documents

Refer to geological and geomorphological maps of 1:50000 scale to delineate geo-stratigraphic units containing marine sand, and orientate to field surveying (**Fig.** 1). In particular, collecting and analyzing hundreds of deep boring logs to study profiles (**Fig.**2) that contain deep-covered marine sand layers.

2.2 Remote sensing image analysis and GIS Methods

The analysis of satellite/aviation images from Landsat 8 OLI data combined with ASTER GDEM data (N15E107- N15E108) are used in the establishment of imaged geological maps with a 1:50000 scale, to delineate the distribution of Nam O marine sand formation to arrange effective survey routes at the studyarea (**Table** 1). The mapping and GIS method is used to establish specialized maps and assessing Nam O marine sand resources based on the distribution map of Nam O marine sand.

Table 1. Landsat 8 OLI data and ASTER GDEM data in establishing of imaged geological – geomorphological map (1:50000)

Time of collecting	Coll	Row	Spartial resolution	Cloud coverage percentage (%)	Image quality
Sept 2nd,2020	125	049	30 m × 30 m	24,08	9 (Good)
Feb 25th,2021	125	049	30 m × 30 m	0,41	9 (Good)

Sources: *http://earthexplorer.usgs.gov; https://gdemdl.aster.jspacesystems.or.jp/index_en.html*

2.3 Concrete compressive strength experiment installation

This research article utilized nondestructive instead of destructive analysis for concrete compressive strength determination with relevant parameters as R_c. The main reason for this applies comes from many previous relevant reports. The nondestructive method is the only way to predict and accurately determine thedeeply internal crack, and exposes cracks, and investigate whether any structural damage has occurred. Structural health monitoring by nondestructive like rebound hammer and UPV becomes very useful for the prediction of the service life of the structure (Hannachi and Nacer, 2012). Ultrasonic pulse velocity (UPV): A complex system of stress waves develops, which includes both longitudinal and shear waves and propagates through the concrete. Electronics timing circuits enable the transit time *t* of the pulse to be measured (Jedidiet. al. 2014 and 2017) [22, 23]. Lopez et al (2016) [25] studied the concrete compressive strength estimation by UPV test in Parana, Brazil with a similar concept for this research. Hong (2020) [24] proposes a compressive strength estimation equation from the correlation between the ultrasonic pulse velocity and the compressive strength according to the age of the concrete.

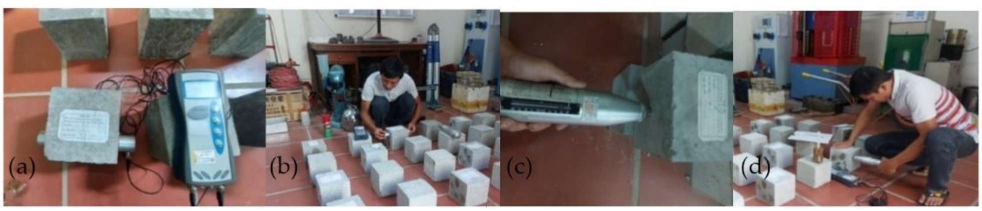

Fig. 1. Experiment to determine concrete compressive strength by an ultrasonic pulse machine Matest - C369N (a, b) and rebound hammer Matest - C380 (c, d) of Italy

Rebound hammer (RH): This nondestructive method is following Vietnam Engineering Standard (TCVN 9335:2012) [31] for engineering concrete material. Main 4 studied series of concrete compressive strength (R) was conducted rebound hammer for studied concrete blocks in considerable detail and these results are good adapted to other previous reports. International scientific reports used this rebound hammer test to measure the surface hardness of concrete and there is an empirical relationship between the compressive strength of concrete and the rebound index [26].

2.4 Field survey method with sampling and sample analysis

This research was conducted from January to June 2021 and was arranged along a survey route perpendicular to the elongation of Nam O marine sand formation. The point sampling location has a depth of 0.3-1.5m, distributed throughout the plain, and focuses on in-field sand mines being exploited. Sand samples from Thu Bon River were taken at Giao Thuy mine (Dai Loc), and samples of Fine crushed stone were taken at the Que Son district. Samples of particle size, technological properties, and salt content in sand, fine aggregate samples...were analyzed at Danang Construction Quality Accreditation Center following current Vietnam standards (**Table** 2 and **Fig.** 5).

Table 2. Sampling location and salt content of Nam O white sand (mQ_2^2no)

Symbol	Depth (m)	Cl-		SO42-		Coordianry		Location	Date of sampling
		g/m3	%	g/m3	%	X	Y		
MS7-1	0,5	1.02	0.040	1.18	0.046				
MS7-2	1,5	1.17	0.046	1.23	0.048	212306	174699	Huong An mine	9/3/2021 9/6/2021
MS7-3	2,5	1.33	0.052	1.35	0.053				
MS9	0,5	1.15	0.045	1.32	0.052	214309	174588	Lieu Trinh	9/3/2021
MS11	0,4	<1	0.039	<1	0.039	223430	173630	Binh Tu	9/3/2021
MS13	0,4	1.22	0.048	1.17	0.046	216191	174433	Que Thanh	9/3/2021 9/6/2021
MS15	0,3	<1	0.039	<1	0.039	231761	172900	Tan An	24/1/2021
MS21	0,5	1.25	0.049	1.31	0.051	234455	172723	Tam Phu	24/1/2021 9/6/2021
MS29	0,3	<1	0.039	<1	0.039	243538	170952	Ky Khương	25/1/2021
MS31	0,5	1.34	0.053	1.14	0.045	239086	171773	Tam Anh	25/1/2021
MS33	0,4	1.15	0.045	1.16	0.045	240901	171216	Tam Anh	25/1/2021
MS35	0,4	<1	0.039	<1	0.039	238178	171758	Tam Anh Bac	25/1/2021
MS37	0,4	1.78	0.070	1.21	0.047	242559	171492	Tam Hoa	25/1/2021

Note: *Testing samples of salt content, test methods SMEWW-4500 Cl^- - B, SMEWW-4500 SO_4^{2-}E*[34, 35]

3 Results and discussion

3.1 Characteristics of Nam O white sand in Quang Nam

Marine sand of the Nam O Formation (mQ_2^2no) has formed in the marine environment about 6000 - 2500 years ago when maximum Flandrian marine transgression with sea-level changed in the range of +5 m - +3m. And with an optimal climate (wet and heavy rain), so that this marine sand was characterized by gray-white color and then slowly reduce until the end of the middle Holocene (**Fig.** 2).

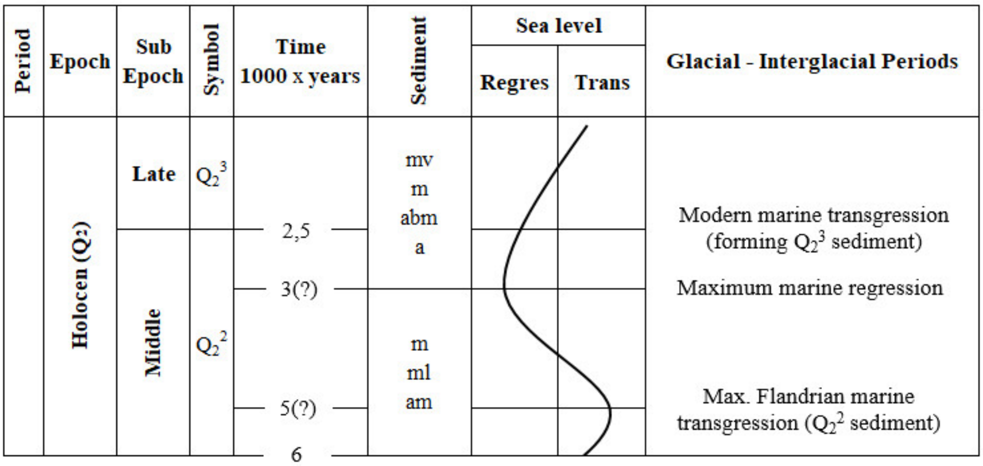

Fig. 2. Geological circle of glacial and interglacial in corresponding to Nam O sand formation establishing in Quang Nam coastal plain [20]

Notes:*m - marine; mv - marine and wind; abm - aluvial, marine, and orgainc; a - alluvial , ml - marine and lake; am - aluvial and marine*

Table 3. Sand bar profiles of Nam O white sand in thestudy area [20]

Boreholes symbol	Number of layers	Depth (m)	Thickness (m)	Detail description
BS37 (Hoi An)	-	0-18	18	Profile of sand bar include quartz sand, gray, gray-white color, weak cohesion
TK10	1	0-1.5	1.5	Quartz small sand, white color
(Binh Duong)	2	1.5 - 6.8	5.3	Quartz small sand, white color
	3	6.8-18	11.2	Quartz small-medium sand, white color
BS31 (Ky Khuong)	1	0 - 9.8	9.8	Quartz small medium sand, gray color, weak cohesion, well sorted
	2	9.8-12	2.2	Quartz medium-coarse sand, gray white color, contain Mollusca crust fossil, weak cohesion
Nui Thanh	1	0 - 15.5	15.5	Loose sand, gray-white color
	2	15.5-16.3	0.8	Fine sand, gray-gray white - black gray color, contain Mollusca crust fossil, weak cohesion

Figs 3 and 4 shown that white sand sediment is usually distributed in the form of the dune, infield sand bars from 5 m - 10m in height, and similar to the western edge of the studied plain, there is various sand bars with 0.23km - 4.7km (Figs 5a and 5b). These sand sediments continuously stretchwith a surface exposure area is about 253.5 km^2. White marine sands cover unconformably upon the top of river sand sediments at lower Holocene swamps, with thickness from 5 m to 10m with overlapped with dark-yellow sand (Fig. 5c). From Table 3, it can be seen that the Nam O Formation consists of white medium-small grained quartz sand containing Mollusca shells under the shape of sand bars and gult type with thickness varies from 5.6 m to 45.9 m, with an average thickness of 12.3 m.

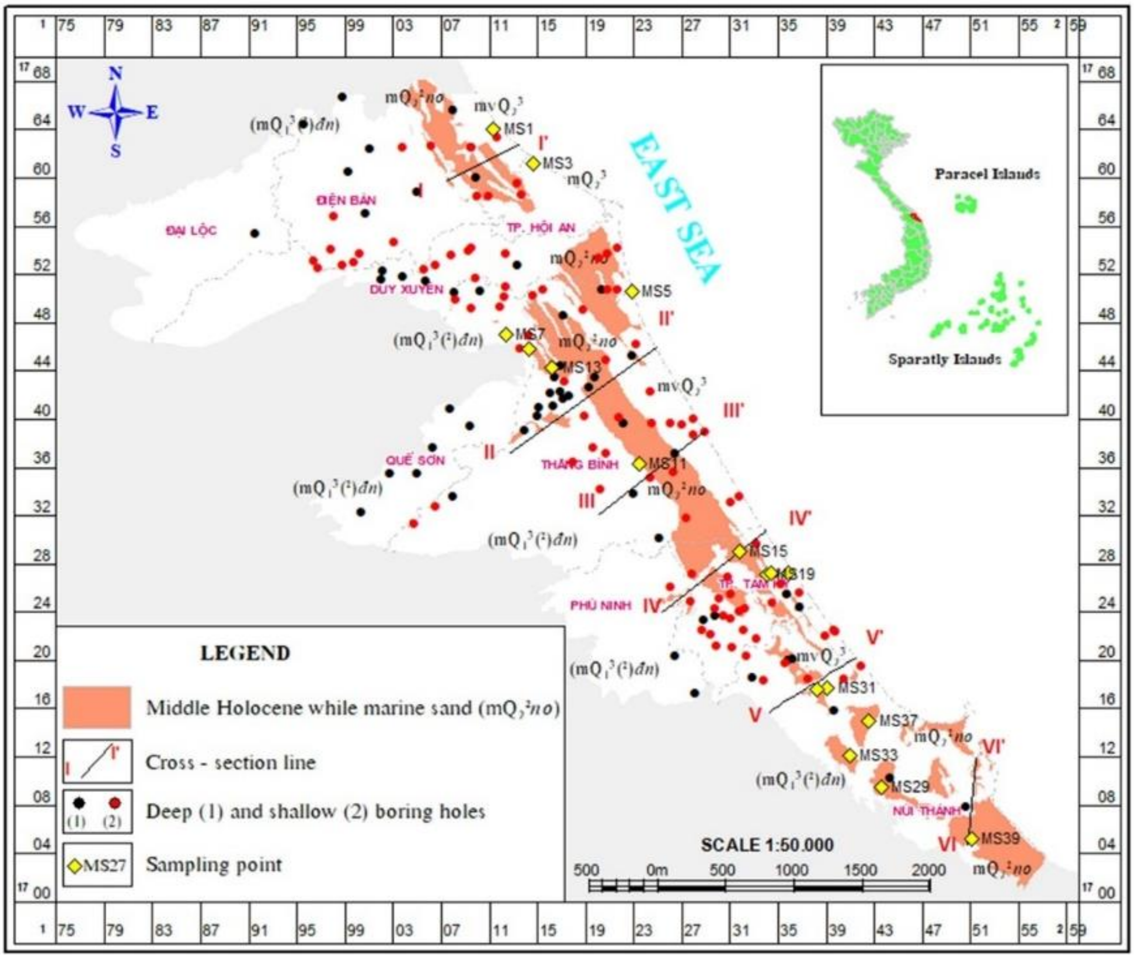

Fig. 3. Distributed map of Nam O marine sand sediments (mQ_2^2no) in Quang Nam area

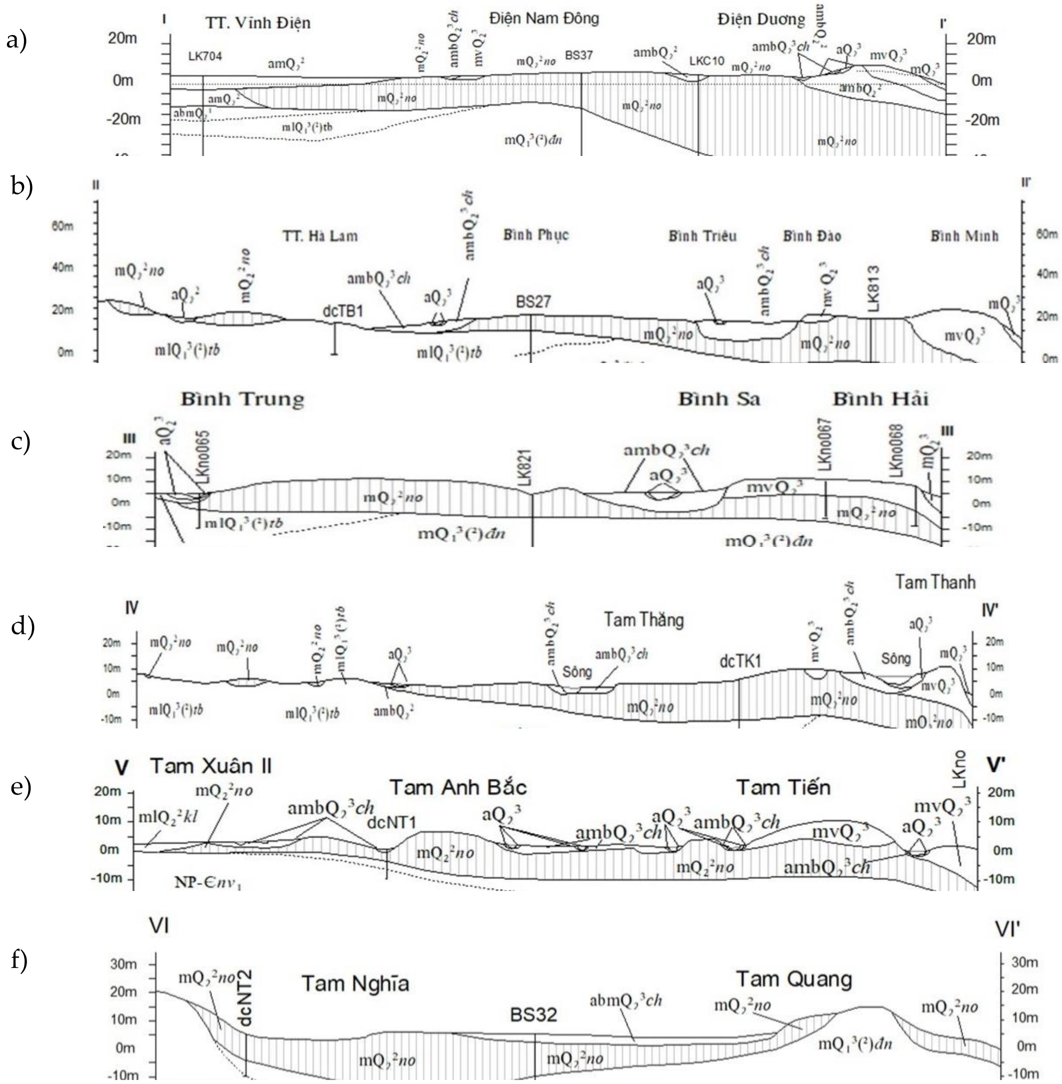

Fig. 4. Profile of Nam O marine sand along with routes: (a) I-I′, (b) II-II′, (c) III-III′, (d) IV-IV′, (e) V-V′, (f) VI-VI′

Fig. 5. Marine sand of Nam O formationin study area ($mQ_2{}^2no$) (a) Tam Phu; (b) Binh Sa; (c) Covered white sand (i) upon the dark-yellow sand (ii) at Tam Thang

Table 4. Gradation and technological properties of Nam O white sand (mQ_2^2 no)

Engineering requirement	Number of samples	Accumation index, A_i(%) with particle diameter (mm)						Technological properties								Clay conten (%)	Silt, mud, clay content (%)	Organic
		2.5	1.25	0.63	0.315	0.14	<0.14	W	Δ_s	γ_x	n	γ_d	γ_w	H_p	M_s			
	13	0.00	0.01	0.45	30.54	94.18	100	3.25	2.65	1.45	54.34	2.55	2.59	1.82	1.23	0.02	0.39	Light color
A_i (%)		0	0 - 15	0 - 35	5 - 65	65 - 90	-	-	-	-	-	-	-	-	-	-	-	Light color
≤ B30		-	-	-	-	-	a_i≤ 35%	-	-	≥ 1.25	-	-	-	-	≥ 0.7	≤ 0.25	≤ 3.0	

Notes: *W: natural water content (%), Δ_s: unit weight (g/cm³); n: porosity (%); γ_x: porous density (g/cm³); γ_d: dry density (g/cm³); γ_w: wet density (g/cm³); H_p: water absorption (%); A_i: accumulation index (%); Ms: fineness modulus; B: Concrete durability.*

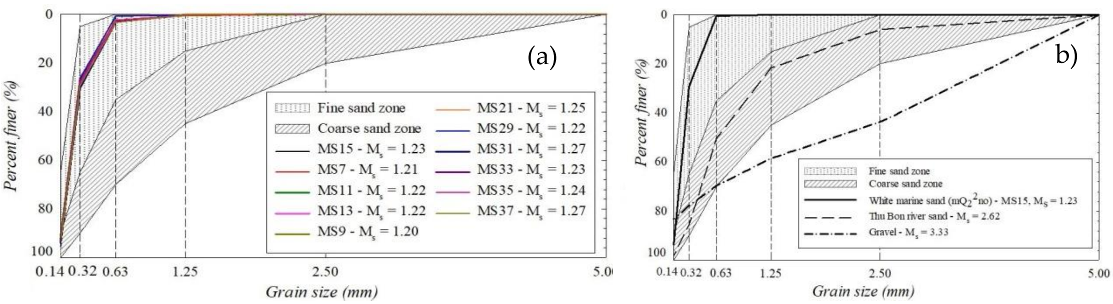

Fig. 6. Grain size distribution curve and fineness modulus (M_s) of Nam O white marine sand (a); white sand, river sand, and fine crushed stone (b)

Table 4 and **Fig.** 6a show that the earlier marine sand formations are formed and distributed at high depths, the composition and technological properties are satisfactory as a natural building material except for silty sand. The criteria for$M_s$by 1.20-1.27, averaging 1.23 and in the fine sand area of the chart, particle diameter < 0.14 mm, porous volume, silt and clay content, and organic of fine marine sand meet the technical requirements of fine aggregates for concrete with durability grade B15 - B25 as TCVN. According to Table 2, the results of determining the salt content of 13 samples in the study area showed that Nam O white sand had low salt content and met the requirements as aggregates for concrete according to regulations (<0,05 %), Cl^- from 0.039 to 0.070% (averaging 0.046 %), SO_4^{2-} from 0.039 to 0.053 % (averaging 0.045 %) [29]. Some sand samples were taken near the beach (Tam Hoa, Tam Anh) or deep (Huong An) contain inconsiderable salt content than others.

3.2 White sand potential for fine aggregate

The main input documents used for numerical calculation include results of field survey and samplings on January 24th to June 10th, 2021, Map of distribution of marine sand formations in the study area is with the scale of 1:50000; 144 survey boreholes (19 boreholes for Nam O white sand) with depths by 10-15m to over 100m and the results of additional analysis of 13 samples for determining technological properties as mentioned above. In which, there are 10 boreholes drilled by the authors themselves in 2014, with a depth of 13.5-33 m [20]. The results of the assessment of white sand reserves are shown in Tables 5 and 6.

Table 5. Calculation results for Nam O white sand resources in Quang Nam

Min. thickness (m)	Max. thickness (m)	Unit weight (g/cm³)	Area (km²)	Avg. thickness (m)	Predicted resource level 334a (mil. m³)	Thickness (m)	Exploited Reserves (mil. m³)
5.6	45.9	2.66	253.48	12.3	12920.71	5.0	8017.13

Table 6. Reserves of white sand mines in Quang Nam
(Quang Nam Department of Natural Resources and Environment, http://tnmtquangnam.gov.vn)

No	Mine name	Area (km²)	White sand reserves		Notes
			mil. tons	mil. m³	
1	Huong An	5.76	22.5	15	Exploiting/mining
2	Lieu Trinh	5	22.7	25	At zoning area of East Que Son industrial and service complex
3	Binh Tu	5	60	40	Belong to Pasca forestry project
4	Que Thanh	2	55	36.7	-
5	Ky Khuong	-	47	31.3	Exploitation planning in 2010: 10 mil. tons, in 2011-2015: 18 mil. tons, in 2016-2020: 7.2mil. tons
6	Tam Anh	2	Good quality	-	
7	South Tam Anh	0.35	Good quality	-	At zoning area of Chu Lai open-economy complex
8	North Tam Anh	0.53	Good quality	-	
9	Tam Hoa	0.23	Good quality	-	Belong to Pasca forestry project

Tables 5 and 6 indicated that the assessedreserves ofwhite marine sandy resources in the study area are quite high with 12.921 million m³with total exploited reserves is 8017 mil. m³. According to previous reports [6-9], this study area has up to 09 white sand mines with a total exploration area of 21km² and reserves of about 200 million [27].

3.3 Mixing ratio between marine sand and local materials

Grain size distribution curves and technological properties of materials are summarized in Fig. 6b and Table 7, respectively. The river sand sample completely met the echnical requirements of coarse sand for concrete production, while the fine crushed stone and white sand samples unsatisfied the requirements in both gradation and technological properties when compared with the Vietnamese standard of Aggregate for concrete and mortar (TCVN 7570-2006) [29]. Indeed, the gradation curves of white sand and fine crushed stone are outside the allowable zone, Nam O sand (1.23) and fine crushed stone (3.33), clay content (4.208 > 3%), and particle size < 14 mm (16.73 > 10 %) also exceeded the requirements. When mixing white sand and river sand, the percentage of river sand in the mixture tends to be high (50%-70%) due to the low fineness modulus of white sand. Therefore, to control the river sand content used within the desired proportion (20-30%), the selected river sand (coarse) with Ms>2 was mixed with white sand and fine crushed stone to create a mixture of high-quality materials.

Table 7. Gradation and technological properties of materials mixed as fine aggregates for concrete

No	Fine aggregate	Accumulation index, A_i(%) with particle diameter (mm)						Technological properties								Clay content (%)	Silt, mud, clay (%)	Organic
		2.5	1.25	0.63	0.315	0.14	<0.14	W	Δ_s	γ_x	n	γ_d	γ_w	H_p	M_s			
1	White sand	0.00	0.01	0.45	30.54	94.18	100	3.25	2.649	1.452	54.82	2.544	2.584	1.551	1.23	0,002	0.395	Light
2	Fine crushed stone	43.70	58.50	69.57	77.69	83.27	100	3.12	2.714	1.492	54.98	2.588	2.635	1.785	3.33	-	4.208	Light
3	River sand	5.98	21.6	50.38	85.53	98.05	100	3.86	2.665	1.498	56.21	2.534	2.583	1.934	2.62	0	0.515	Light
Engineering requirement	A_i (%)	0-20	15-45	35-70	65-90	90-100	ai≤ 10%	-	-	-	-	-	-	-	-	-	-	Light color
	≤ B30	-	-	-	-	-	a_i≤ 10%	-	-	≥ 1.25	-	-	-	-	2.0-3.3	≤ 0.25	≤ 3.0	

The relevant technological properties can be seen that most mixing ratios have acceptable fineness modulus (Ms = 2-2.59, equivalent to coarse sand) and satisfactory by percentage of grain <14 mm ≤ 35 %). Only 3 mixing ratios with high fineness modulus (2.41-2.51) have the grain size distribution curve within allowable limit. Therefore, it is recommended to use these 3 mixing by (PT523, PT334, PT424) to produce concrete in the study territory.

Table 8. Relevant technological properties of fine aggregate for concrete after mixing

No	Symbols	Mixing ratio %			Accumulation index, A_i(%) with particle diameter (mm)						Technological properties								Clay content (%)
		White sand	River sand	Fine crushed stone	2.5	1.25	0.63	0.315	0.14	<0.14	W	Δ_s	γ_x	n	γ_d	γ_w	H_p	M_s	
1	PT433	40	30	30	27.13	34.38	38.30	54.58	91.63	100	2.88	2.684	1.476	54.98	2.571	2.613	1.649	2.45	2.016
2	PT523	50	20	30	16.58	25.28	37.92	68.83	95.12	100	3.36	2.678	1.475	55.07	2.554	2.600	1.810	2.44	2.830

No	Symbols	Mixing ratio %			Accumulation index, A_i(%) with particle diameter (mm)						Technological properties								Clay content (%)
		White sand	River sand	Fine crushed stone	2.5	1.25	0.63	0.315	0.14	<0.14	W	Δ_s	γ_x	n	γ_d	γ_w	H_p	M_s	
3	PT613	60	10	30	15.00	22.78	30.79	60.64	95.16	100	3.06	2.670	1.464	54.83	2.567	2.606	1.506	2.24	2.640
4	PT415	40	10	50	18.74	26.27	35.19	58.14	91.08	100	3.47	2.682	1.487	55,46	2.585	2.612	1.399	2.29	3.821
5	PT514	50	10	40	17.89	24.85	33.28	57.11	91.87	100	3.33	2.677	1.478	55.22	2.564	2.606	1.639	2.25	2.844
6	PT334	30	30	40	19.77	27.84	41.29	67.41	95.02	100	3.14	2.681	1.474	54.96	2.564	2.608	1.697	2.51	2.387
7	PT424	40	20	40	18.88	25.55	38.50	64.76	93.08	100	3.34	2.678	1.456	54.36	2.557	2.602	1.759	2.41	2.691
8	PT604	60	0	40	16.83	25.97	32.07	57.49	95.28	100	2.91	2.667	1.461	54.77	2.553	2.596	1.681	2.28	2.245
9	PT505	50	0	50	16.39	22.56	32.38	61.65	94.13	100	3.04	2.669	1.480	55.44	2.549	2.594	1.759	2.27	3.131
10	PT406	40	0	60	22.05	31.45	39.60	57.04	89.79	100	3.18	2.670	1.469	55.02	2.551	2.595	1.746	2.40	4.407
11	PT307	30	0	70	26.43	36.63	46.35	60.53	88.78	100	3.60	2.672	1.466	54.85	2.551	2.597	1.774	2.59	5.012
Engineering requirement		Ai (%)			0	0 - 15	0 - 35	5 - 65	65 - 90	-	-	-	-	-	-	-	-	-	-
		≤B30			-	-	-	-	-	ai≤ 35%	-	-	≥ 1.25	-	-	-	-	≥ 0.7	≤ 3.0

3.4 Fine aggregate analysis for Nam O white marine sand

Currently, many methods have been used in concrete mix design. In which, the most popular methods are the look-up table, experiment, and calculation. Selection of concrete mixed ratiosmeets technical and economic requirements as following factors:

Required concrete strength (concrete grade): Compressive strength of concrete after 28 persevered days (R28).

Engineering properties: Properties of construction in various environmental conditions of drying and wetting, and weathering.

Engineering structural features: usually used for choosing the plasticity of the concrete mix and reasonable fine aggregate. Therefore, it is necessary to consider reinforced or non-reinforced structures, thick or thin reinforcements, wide or narrow structural areas, etc.

Table 9. Material for 1m^{3}of concrete (a) and 1 mixed sample (b)

Symb	Cement		Water		Coarse aggregate		White sand		River sand		Fine crushed stone		Water/Cement
	Kg(a)	Kg(b)	Liter(a)	Liter(b)	m3(a)	kg(b)	m3(a)	kg(b)	m3(a)	kg(b)	m3(a)	kg(b)	
PT100	341	23.87	195	13.65	0.838	82.46	0	0.00	0.447	46.88	0	0.00	0.57
PT523	341	23.87	195	13.65	0.838	82.46	0.224	22.72	0.089	9.38	0.134	14.00	0.57
PT334	341	23.87	195	13.65	0.838	82.46	0.134	13.63	0.134	14.06	0.179	18.67	0.57
PT424	341	23.87	195	13.65	0.838	82.46	0.179	18.17	0.089	9.38	0.179	18.67	0.57

In this study, the look-up table method was applied [28] to determine the material composition for the standard mix concrete with high density and durability grade B20. The normal concrete was made from 100% Thu Bon river sand (taken at Giao Thuy - Dai Loc mine), coarse aggregate with Dmax = 20 (taken at Que My Granite quarry, Que Son), and clean water [6-9]. The remaining concrete mix grades corresponding to 1m^3 of concrete mortar and 1 typical samples of mixing are shown in **Table 9**.

After concrete slump testing (testing that the PT100 standard grade meets the slump requirement of 6-8cm), the concrete mixes were homogeneously mixed and molded into sample groups by the instructions of TCVN 3105:1993. The test samples were preserved in the controlled room temperature condition for 3days, 7days, 14days, 28days, 60days, and 90days samplesand then tested in conformity with current standards to determine relevant mechanical properties of concrete with the results presented in **Table 10** [32].

Table 10. Mechanical properties of the studied concrete [33]

Parameter	Sample size (cm)	Number of samples	TCVN	Mixing ratios			
				PT100	PT523	PT334	PT424
Density (g/cm^3)	15×15×15	3	3115:1993	2.30	2.31	2.34	2.32
Water absorption (%)	15×15×15	4	3113:1993	3.21	2.48	2.10	2.61
Shrinkage (mm/m)	10×10×40	1	3117:1993	0.371	0.315	0.367	0.321
Abrasion resistance (g/cm2)	5×5×5	3	3114:1993	0.26	0.34	0.28	0.32
Water tightness (kG/cm2)	ϕ15	3	3116:1993	9.7	11.1	10.3	10.7
Flexural strength for 28 days (daN/cm2)	15×15×60	2	3119-1993	27.81	29.87	28.21	26.95
Compressive strength for 28 days (daN/cm2)	15×15×15	3	3119-1993	271.7	260.2	257.6	251.8

Fig. 7a and 7b indicate the slump of concrete mixes PT523, PT334 and PT424 meets the requirements of regulations [30] and be higher than standard concrete mix PT100. Because study fine white sand has a low M_s=1.23 and a large surface area, its particle surface is easily wet and lubricated. In addition, the good roundness particles of white sand contributed to increasing the flexibility and kneading ability of the concrete mixture, resulting in a high slump. The density of concrete PT523, PT334 and PT424, and PT100 are almost the same (2.30-2.34g/cm^3). Due to the higher fine particle content of studied concretes (PT523, PT334, and PT424) compared to the standard concrete (PT100), the water absorption (2.10-2.61%) and the shrinkageof the studied concretes are lower while the abrasion resistance (0.28-0,34 g/cm^2) and water tightness properties are higher than PT100 concrete.

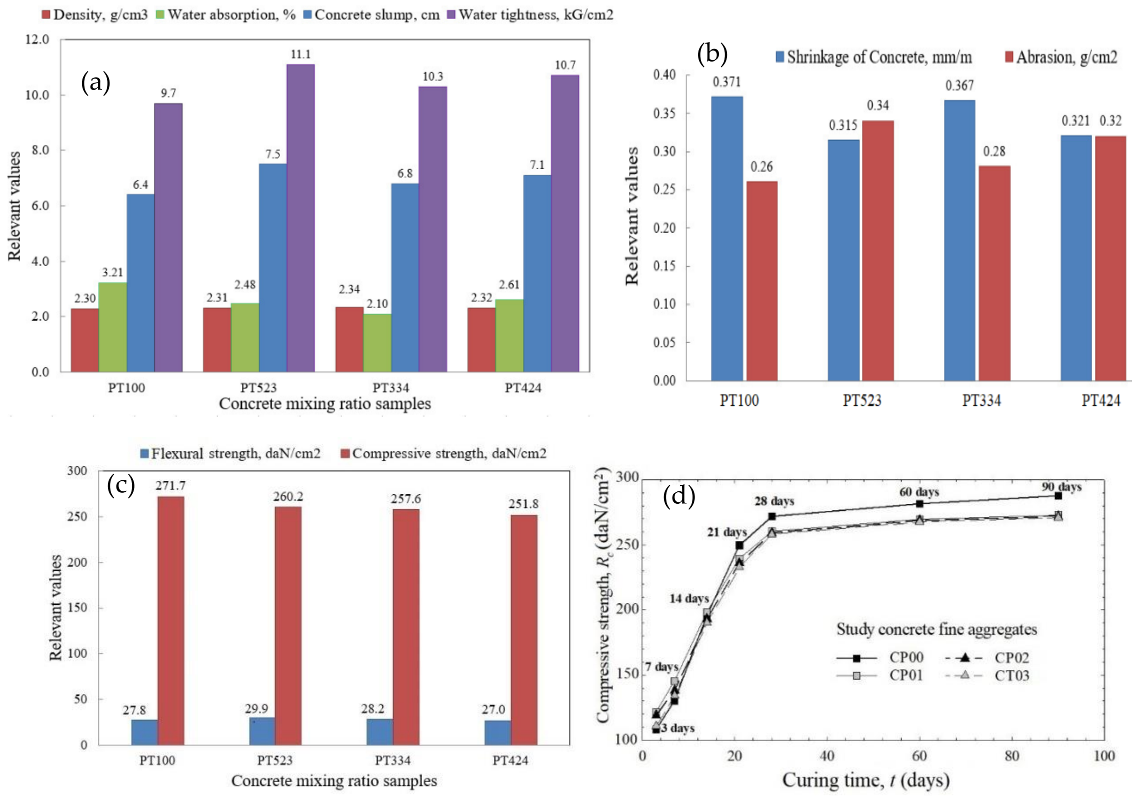

Fig. 7. Mechanical properties (a, b, c) and strength development of studied concretes (d)

From Fig. 7c indicates that R28 of PT523, PT334, PT424 is lower than and reaches compared to the R28 of PT100 concrete. The flexural strength is the same due to the high M_s = 3.33 of crushed stone content for a relatively large volume (30-40%) in the studied mix. In other words, the mix of river sand and white sand creates a high fineness modulus, almost equivalent to river sand by 2.62.

The compressive strength for concrete types is illustrated in Fig. 7d and Table 11. The concrete compressive strength (R) using a fine aggregate mix still follows the logarithmic. *R* of the studied concrete mixes developed quickly in the first 14 days due to the influences of salt content in marine sand (acting as a catalyst) that has accelerated the hydrationof concrete in early stages.

Table 11. Mean compressive strength of the studied concrete types [31]

Symbol	Compressive strength Rc(daN/cm²)						
	3 days	7 days	14 days	21 days	28 days	60 days	90 days
PT100	108.1	130.4	195.7	249.6	271.7	281.4	287.7
PT523	121.7	145.6	198.4	239.2	260.2	269.6	272.9
PT334	119.1	138.1	193.2	235.9	257.6	264.0	267.9
PT424	111.0	134.1	190.2	232.8	251.8	257.5	261.7

Due to the rapid hydration process in the first 7 days, the R_c of concrete mixes PT523, PT334, PT424 is higher than that of PT100 concrete. However, after 7 days, PT100 concrete compressive strength is higher because the fine grain content of Nam O white sand participates early in solidification of concrete. In addition, the white sand is of marine origin, quite uniform, its hydration process requires more water and cement while the amount of water and cement are the same in the design of the grades for concrete studied. After 14 days, the compressive strength development of concrete PT523, PT334, PT424 tend to gradually slow. At 21 days, concrete strength(R21) reached 92-92.5%compared to that of concrete R28, and lower than the compressive strength of concrete PT100 about 3.6-7.5%.

In period from 28 - 90 days, the compressive strength of concrete mixes rised very slow, and the increase of compressive strength of PT523, PT334, PT424 reached 102-104% at 60 days and at 90 days compared to R28. At different curing times, compressive strength of studied concrete and PT100 have a negligible difference, specifically PT523, PT334, PT424 concretes has R28 reaching 93-96%, and after 28 days, the variations of R are same as R of PT100. The compressive strength of concrete PT523 has the most suitable ratio for the concrete due to the high coarse grain content, rough and angular particle at surface, strong bonding ability with cement paste.

4 Conclusions

From the above research results, the following conclusions can be drawn:

Nam O white marine sand (mQ_2^2 no) was formed during the Middle Holocene marine transgression. They have a wide distribution and large amount, hence, they yieldpotential in exploitation and application to be appropriate fine aggregates for replacing local river sand in concrete. The gradation and technological properties of Nam O white sand all meet Vietnam standard of a fine aggregate for low-grade concrete with strength B15-B25. Highly recommend 3 mixing ratios as PT523, PT334, and PT424 tofessiblly produce concrete in the study area.

The mechanical and physical properties of the study concrete show gradually different from sample PT100, specifically: Water absorption and shrinkage are lower, but the abrasion and water tightness are higher. The R_{28} reached 92.5-96.6 % compared to PT100, and the flexural strength is almost the same. In addition, concrete compressive strength (R) follows a logarithmic rise as typical. This rises considerably and rapidly in the first 3 to 28 days and slowly after.

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