EVALUATION OF THE UTILIZATION OF MARINE SAND AS FINE AGGREGATE FOR CONCRETE IN QUANG NAM

Do Quang Thien[1*], La Duong Hai[2*], Tran Huu Tuyen[1], Avirut Chinkulkijniwat[3]

Abstract: *This paper uses a system of different research methods to evaluate the reserves of marine sand formations in Quang Nam region, and at the same time determine the reasonable mixing ratio between marine sand and other local materials to create a suitable fine aggregate for concrete for concrete used for coastal roads of coastal roads. Research results have identified 3 marine sand formations: dark-yellow sand of Da Nang formation (mQ_1^3dn), white sand of Nam O formation (mQ_2^2no) and light-yellow sand (m, mvQ_2^3), with total resource reserves is 25696 million m^3. In which, Nam O fine sand has a wide distribution area, large reserves, favorable exploitation conditions and has the greatest potential (mining resources up to 8017 million m^3). That can be exploited and used as fine aggregate for concrete producing. In addition, this study has also determined 3 mixing ratios among fine sand, river sand and fine crushed stone as 50:20:30; 30:30:40; 40:20:40; to create a suitable mix of fine aggregate for manufacturing concrete.*

Keywords: Marine sand, fine aggregate, fine sand, concrete.

1. INTRODUCTION

In recent years, many countries around the world have been exploiting marine sand for replacing part or all river sand in various aspects of construction. Especially in Vietnam, along with the strong and rapid development of social infrastructure and series of hydropower constructions etc, river sand resources have been increasingly run out. Currently, the national demand for construction sand is about 130 million m^3/year, and these demands will increase significantly by 200 million m^3/year. That will lead to a consequence for after 10-15 years of exploitation, the amount of river sand will be a shortage, the main supply of river sand is not able to meet 40-50% of construction sand demands. As a result, there has been a shortage of construction sands, sandy material prices rising and illegal exploitation of sand and gravel at the riverbed in recent years. Therefore, the Vietnamese government has been encouraging precise researches to favorable using of different types of replaced materials to supplement the increasing construction sand demands. They also enact regulations for sand exploitation management and protection of riverbeds and riverbanks. The protection of riverbeds, riverbanks are limited legal privacy, even authorities banned sandy material exploitation of riverbed. Stand on the above problems, There are many encouragements and suggestions of research as well as finding of relevant fine aggregate materials to replace river sand is not only meaningful in terms of science but a sustainable long-term base to solve the problem of natural construction sand shortages.

In Vietnam, there are various studies on fine aggregates for replacing river sand in making of engineering concrete and mortar, 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, Ninh Binh. In the 80s and 90s, some researches and works were

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referring to the marine sand at locations of Vung Tau, Binh Thuan (Kiem, 1979-1985), Quang Ninh (Hiep et al, 1987). Recently, the studies of using natural fine sand for different construction purposes have also become concerned interest in many pieces of research, Gia et al (2019) study the properties of marine sand in various Vietnamcoastal areas. In recent years, in the workshop on research on the application of materials and concrete for sea and island projects, author Sang (2021) researched the manufacture of durable fine-grained concrete from salted sand, fly-ash and fine-granulated blast furnace slag for replaced local materials in Vietnam provinces. In addition, the studies on marines sand and its applications were also mentioned by many other authors: Chau et al (2018), Duc et al (2017), Toan et al (2020). The previous research of authors have study the composition and properties of multi-origin marine sands for different purposes in recent years (Thien et al, 2014 - 2021). In Quang Nam, fine aggregates used to make concrete - mortar, mainly comprises river sand extracted from Thu Bon river system. But nowadays on this river system, there are over 50 small and medium hydropower plants, 11 large hydropower plants, most of the soil sediment is accumulated at lake bed, leading to a shortage of mud and sand flow; and erosion-accumulation activities happen unpredictably and complicated, that cause strong alternations to the environment, residential living. Furthermore, due to typical topographical - geological conditions for the coastal plain, this study area has a wide plain with many sandy areas and sand fields, which come from marine origin, with a large total amount. Therefore, the study to investigate this marine sandy resource to replace traditional river sand in making engineering concrete is an urgent and highly applicable issue.

2. METHODOLOGIES

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. In particular, collecting and analyzing hundreds of deep boring logs to study profiles that contain deep-covered marine sand layers for the Quang Nam region (Thien DQ et al, 2014)

Remote sensing image analysis: 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 and geomorphological maps with a 1:50000 scale.

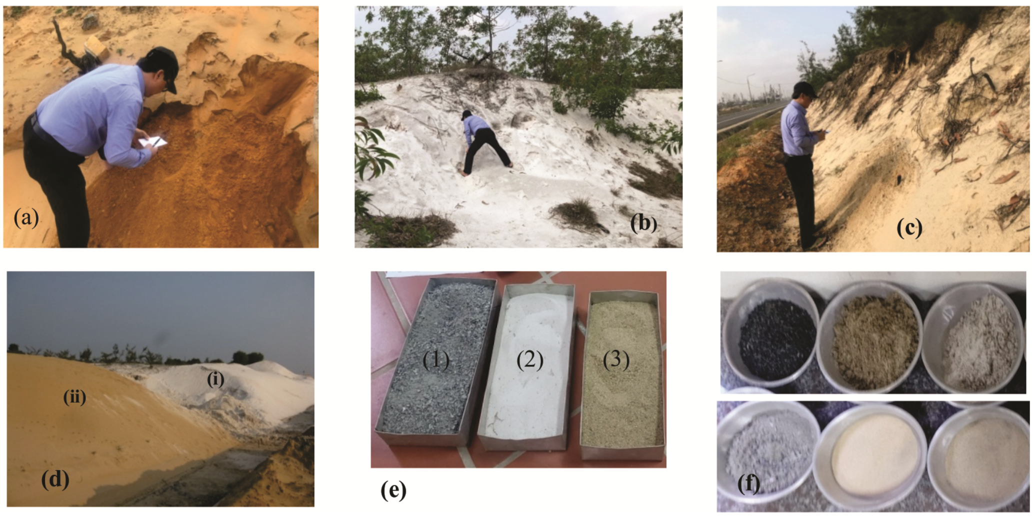

Figure 1. (a) Dark-yellow sand (mQ_1^3dn) at Tam Phu, Tam ky; (b) White sand (mQ_2^2no) at Binh Sa, Thang Binh; (c) Light-yellow sand bar (m, mvQ_2^3)at Tam Thanh, Tam Ky; (d) Covered white sand (i) upon the dark - yellow sand (ii) at Tam Thang, Tam Ky; (e) samples of (1) fine crushed stone, (2) study white sand, (3) river sand; (f) physical - technological test preparation with mentiond materials from (e)

Mapping and GIS method: This method is used to establish specialized maps and cross-sections, and evaluate assessing marine sand resources based on distribution maps with 06 Quaternary formation map with 1:50000 scale.Through marine sand formations in the study area, that used ArcGIS software to convert DEM model and TIN model.

Field survey method with sampling: This research work was conducted from January to March 2021 and was arranged along a survey route perpendicular to the elongation of marine sand formations. 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 Que My quarry (Que Son) (Figures 1a-1d).

Sampling analysis method: Samples of particle size, physical-technological properties, and salt content in sand, fine aggregate samples...were analyzed at Danang Construction Quality Accreditation Center and Geotechnical Laboratory of Hue University of Sciences following current Vietnam standards (Figures 1e and 1f).

3. RESULTS AND DISCUSSION

3.1. Marine sand potential for fine aggregate in making of concrete

Research results have identified 3 marine sand formations: Late Pleistocene dark-yellow sand of Danang formation (mQ_1^3dn); middle Holocene white sand of Nam O Formation (mQ_2^2no); and late Holocene light-yellow sand (m, mvQ_2^3) from Thien DQ. et al, 2014.

a) Characteristics of marine sand

Late upper Pleistocene dark-yellow marine sand of Danang formation ($mQ_1^{3(2)}$đn): From Figures 2 and 3, it can be seen that dark-yellow sand is often distributed with a narrow area (112.5 km^2) as shape as high infield mounds or a marine accumulation shelf from 5-7m to 12- 15m high in North Tam Anh, South Tam Anh, Tam Hiep, Tam Quang in the study area. The dark-yellow marine sand is covered by younger marine sand sediments, distributed in Binh Duong, Binh Giang, Huong An, Que Phu, Que Xuan 1 (Que Son); and from Tam Thang, Tam Phu to Tam Quang (Nui Thanh) with total area by 385.5 km^2. Formation thickness by 6.2 - 32.5m, average 16m (Figure 3).

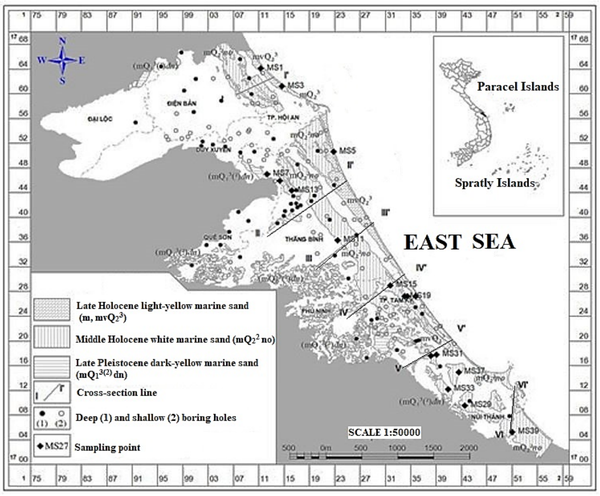

Figure 2. Distributed map of marine sand sediments in Quang Nam coastal plain

Middle Holocene white sand of Nam O formation (mQ_2^2no): This marine sand is usually distributed in the form of the dune, infield sand bars from 5 m to 8-10m in height, and similar to the western edge of the study plain, there is much sand bar with a width of 0.23-4.7km. These sand sediments continuously stretch with a surface exposure area is about 253.5 km^2, with thickness from 2-5 m to 10-15m. In many places, white sand formations overlapped with dark-yellow sand (Figure 1d). Thickness varies from 5.6m to 45.9m, This is a highly potential formation for exploitation and uses as a fine aggregate to replace traditional river sand in Quang Nam (Figures 1b and 1d).

Late Holocene light-yellow marine sand formation (m, mvQ_2^3): This marine sand sediment is a product of re-sedimentary from previous ones and it is the youngest formation being formed by sea waves and tides. The sand dyke systems of the shallow coastal line are 5-7m to 25-28m high, extending from Duy Hai (Dai Cua) to Tam Hai (An Hoa), along with the appearance of the original Truong Giang lagoon in the Late Holocene period. Currently, the surface of the dunes is covered with casuarina forests, thus limiting the movement of the sandy wind (Thien et al, 2014). This marine sand is unconformably covered on dark-yellow sand of the Da Nang formation and comfortably covered on the white sand of the Nam O Formation with a thickness of about 1.1-25.8m and an average of 10.5m (Figure 1e).

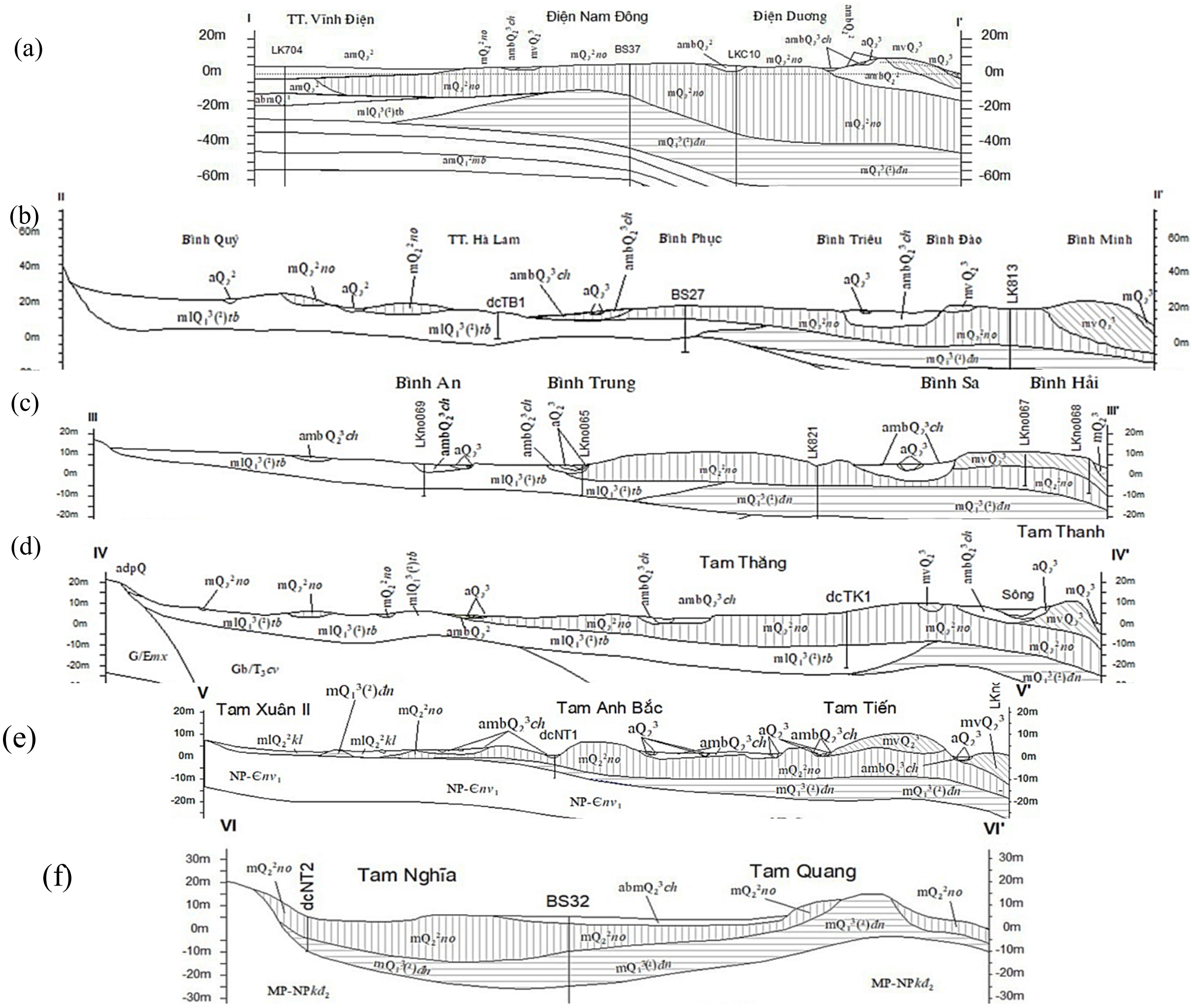

Figure 3. Profile of marine sand along with routes: I-I', (b) II-II', (c) III-III', (d) IV-IV', (e) V-V', (f) VI-VI'

b) Physical and technological properties

The content of chloride ions (Cl^-) and sulfate ions (SO_4^{2-}) can affect the quality of concrete and mortar. The results of determining the salt content of 05 samples in the study area showed that marine sands had low salt content following Vietnam engineering standard with ion Cl^- and ion SO_4^{2-} percentage <0.05%. It is shown in Table 1 that the earlier marine sand formations are formed and distributed at high depths, the composition and properties are satisfactory as a natural building material except for sand and dust. The criteria of fineness modulus, particle diameter <0.14mm, porous volume, silt-clay content, and organic and fineness modulus of fine sand (M_s=1.04-1.25) meets the technical requirements of fine aggregates for concrete with durability grade B15 - B25 (Figures 4a, 4b and 4c).

Table 1. Physical - techonological properties and gradation of study marine sand

Marine sand formation	Number of samples	Accumulation index, A_i(%) with particle diameter (mm)						Physical and technological properties								Clay content (%)	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			
$mQ_1^3{}_{đn}$	5	0.00	0.00	0.024	9.72	86.59	0.0367	3.55	2.65	1,41	52,72	2.54	2.59	1.87	1.06 1.23	0.008	0.96	Light color
m, $mvQ_2^2{}_{no}$	11	0.00	0.01	0.45	30.54	94.18	0.0582	3.25	2.65	1.45	54.34	2.55	2.59	1.82	1.25	0.02	0.39	Light color
m, mvQ_2^3	4	0.00	0.00	0.04	7.22	96.52	0.0348	3.89	2.65	1.39	52.56	2.57	2.61	1.33	1.04	0.03	0.70	Light color
Engineering requirement of A_i (%)		-	0	0 - 15	0 - 35	5 - 65	65 - 90	-	-	-	-	-	-	-	-	-	-	Light color
Concrete durability ≤ B30		-	-	-	-	-	≤ 35%	-	-	≥ 1.25	-	-	-	-	≥ 0.7	≤ 0.25	≤ 3.0	

Notes: *W: natural water content (%), Δ_s: unit weight (g/cm^3); n: porosity (%); γ_x: porous density (g/cm^3); γ_d: dry density (g/cm^3); γ_w: wet density (g/cm^3) ; H_p: water absorption (%); A_i: accumulation index (%); Ms: fineness modulus*

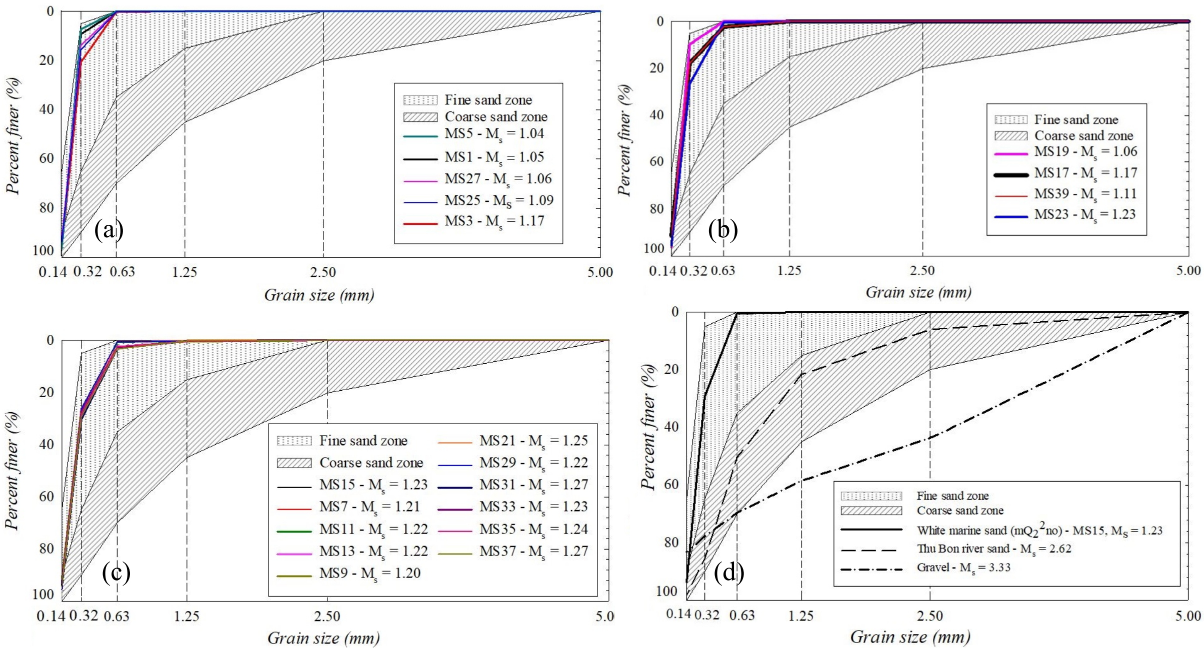

Figure 4. Marine sand gradation of (a) m,mvQ_2^3 , (b) mQ_2^2no,
(c) mQ_1^3đn, (d) white sand (mQ_2^2no), river sand and fine crushed stone

c) Marine sand potential for fine aggregate

The main input documents used for numerical calculation include: Results of field survey and samplings on March 24th-25th, and 9th-10th, 2021; Map of distribution of marine sand formations in the study area with the scale of 1:50000; 144 survey boreholes with depths from 10-15m to over 100m and the results of additional analysis of 20 samples for determining the material composition and physical and technological properties as mentioned above. In which, there are 10 boreholes drilled by the authors themselves in 2014, with a depth of 13.5-33m. Results of the calculating amount of fine sand mining in the study area provided by Quang Nam Department of Natural Resources and Environment. This research built a DEM model to determine the average height of the distribution areas for exposed marine sand on the surface. The results of determining the assessment of exploitable amount are shown in Figure 5 and Table 2.

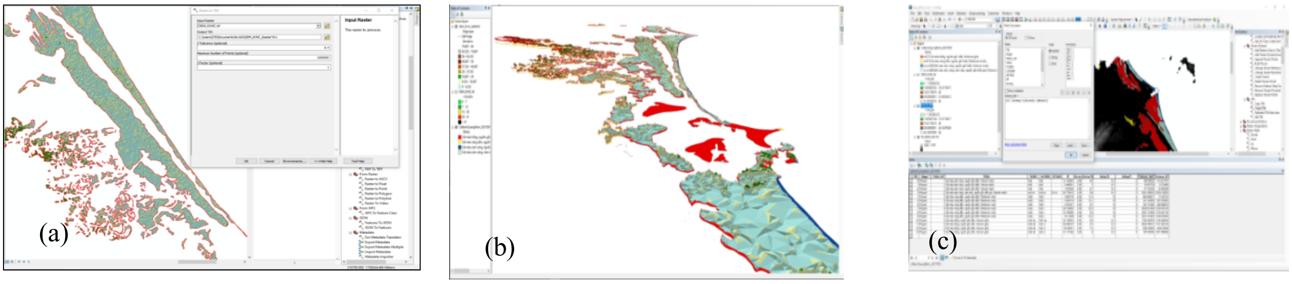

Figure 5. Calculation tool for evaluating and assessing the marine sand amount in the study area: (a) TIN 3D modeling, (b) Controlling the average elevation of terrain via a polygon-shaped zone of marine sand (c) Calculation results

Table 2. Calculation results for the marine sand amount in Quang Nam

Marine sand	Min. thickness (m)	Max. thickness (m)	Unit weight (g/cm^3)	Area (km^2)	Avg. thickness (m)	Natural amount in assessment (million m^3)	Thickness (m)	Exploited Amount (million m^3)
m, mvQ_2^3	1.1	25.8	2.66	79.05	10.5	3971.73	5.0	2815.16
mQ_2^2no	5.6	45.9	2.66	253.48	12.3	12920.71	5.0	8017.13
mQ_1^3đn	6.2	32.5	2.65	112.49	16.0	8802.18	5.0	5510.71

From Tables 2, it can be indicated that the assessing marine sandy resource amount in the study area is quite high by 3972 million m^3 (light yellow marine sand), 8802 million m^3 (dark yellow sand) to 12921 million m^3 (fine sand). The total resource reserve of marine sand is up to 25696 million m^3. However, due to its wide distribution area, large exploitable amount, and favorable mining conditions, the fine sand of the Nam O Formation (mQ_2^3no) has the highest potential for exploitation and uses as a fine aggregate for concrete and mortar compared to other sands.

Table 3. Gradation and physical-technological properties of materials mixed as fine aggregates for concrete (TCVN 7570: 2006)

No	Fine aggreagate	Accumulation index, A_i(%) with particle diameter (mm)						Physical and technological properties								Clay content (%)	Silt, mud, clay content (%)	Organic
		2.5	1.25	0.63	0.315	0.14	<0.14	W	Δ_s	γ_x	n	γ_k	γ_{bh}	Hp	Ms			
1	Fine sand of Nam O	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	1.25	0.002	0.395	Light color
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 color
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 color
Engineering requirement of Ai (%)		0-20	15-45	35-70	65-90	90-100	≤ 10%	-	-	-	-	-	-	-	-	-	-	Light color
Concrete durability ≤ B30		-	-	-	-	-	≤ 10%	-	-	≥ 1.25	-	-	-	-	2.0-3.3	≤ 0.25	≤ 3.0	

d) Determination of mixing ratio between marine sand and local materials to create a standard high-quality fine aggregate for coastal road concrete

From Table 3 and Figure 4d., it can be seen that: The river sand sample completely met the technical requirements of coarse sand for concrete production, the fine crushed stone and fine sand samples did not satisfy the requirements for particle size distribution. They are outside the allowable limit, although the fineness modulus of Nam O sand (1.25), fine crushed stone (3.33), and physical and technological properties all meet the requirements for concrete: clay content (4.208 >3%) and particle size <14mm (16.73 >10%) also exceeded the regulation. When mixing fine sand and river sand, due to the low fineness modulus of fine sand, the rate of using river sand is too high (50-70%), not meeting the goal of limiting the use of river sand. Therefore, to reduce the proportion of river sand (20-30%), selected river sand (coarse) with Ms>2 mixed with river sand and fine crushed stone to create a mixture of high-quality materials.

Table 4. Gradation and physical-technological properties of fine aggregate for concrete after mixing

No	Mixing ratio %			Accumulation index, A_i(%) with particle diameter (mm)						Physical and technological properties								Clay content (%)	Silt, mud, clay content (%)
	Fine 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_k	γ_{bh}	Hp	Ms		
1	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	2.46	2.016	Light color
2	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	Light color
3	55	15	30	12.65	18.18	26.54	50.84	91.82	100	3.34	2.669	1.460	54.72	2.557	2.599	1.631	2.00	2.059	Light color
4	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	Light color
5	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	Light color
6	45	10	45	18.79	24.44	33.77	54.66	91.65	100	3.23	2.683	1.467	54.68	2.564	2.608	1.731	2.23	2.801	Light color
7	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	Light color
8	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	Light color
9	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	Light color
10	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	Light color
11	55	0	45	14.91	20.15	30.35	60.61	95.39	100	3.25	2.665	1.461	54.82	2.546	2.591	1.756	2.21	2.559	Light color
12	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	Light color
13	45	0	55	19.30	27.85	35.81	57.24	91.05	100	3.59	2.670	1.472	55.13	2.542	2.590	1.882	2.31	3.223	Light color
14	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	Light color
15	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	Light color
Engineering requirement of Ai (%)				-	0	0 - 15	0 - 35	5 - 65	65 - 90	-	-	-	-	-	-	-	-	-	Light color
Concrete durability ≤ B30				-	-	-	-	-	≤ 35%	-	-	≥ 1,25	-	-	-	-	≥ 0,7	≤ 3,0	

According Table 4, this research proposes 15 mixing ratios of fine aggregate for concrete making, presented in table 4. From Table 4, it can be seen that most of the mixing ratios have a quite high fineness modulus (Ms=2-2.59, equivalent to coarse sand), relatively satisfy physical and technological properties (% of group particles <0.14mm ≤35%) but the remix curve is out of the allowable range, there are only 3 mixing ratios of high fineness modulus (2.41-2.51) and the blending curve is within allowable limit for mixing ratios (% fine sand: % river sand: % fine crushed stone) of No.2 (50:20:30); No.8 (30:30:40) and No.9 (40:20:40). Therefore, it is recommended to use these 3 mixing ratios (PT523, PT334, PT424) to produce concrete for coastal roads in the study area.

4. CONCLUSIONS

Most marine sand formations have a wide distribution and large amount in Quang Nam coastal plain, but only Nam O fine marine sand has the largest amount and favorable distribution conditions for future exploitation and uses following Vietnamese engineering standard.

In term of concrete with higher strenght, it is necessary to have approriate study on mixing of marine sand with other materials with a higher fineness modulus to create an optimum fine aggregate. The gradation and physical-technological properties of the 3 types of marine sand in the study area all meet the standard of fine sand as a fine aggregate for low-grade concrete with strength B15-B25.

Highly recommendation for using 3 mixing ratios as No.2, No.8 and No.9 to produce concrete for purpose of coastal roads in the study area.

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Tóm tắt:

ĐÁNH GIÁ KHẢ NĂNG SỬ DỤNG CÁT NGUỒN GỐC BIỂN LÀM CỐT LIỆU NHỎ CHO BÊ TÔNG Ở QUẢNG NAM

Mục tiêu của bài báo là sử dụng hệ thống các phương pháp nghiên cứu khác nhau để đánh giá trữ lượng các thành tạo cát nguồn gốc biển vùng Quảng Nam, đồng thời xác định tỷ lệ phối trộn hợp lý giữa loại cát này với các loại vật liệu địa phương để tạo nên hỗn hợp cốt liệu nhỏ cho chế tạo bê tông đường ven biển. Kết quả nghiên cứu đã xác định được 03 thành tạo cát biển: cát vàng nghệ hệ tầng Đà Nẵng (mQ_1^3đn), cát trắng hệ tầng Nam Ô (mQ_2^2no) và cát vàng nhạt (m,mvQ_2^3), với tổng trữ lượng tài nguyên dự báo là 25696 triệu m^3. Trong đó, cát trắng Nam Ô có diện phân bố rộng, trữ lượng lớn, điều kiện khai thác thuận lợi và có tiềm năng lớn nhất (trữ lượng tài nguyên khai thác lên đến 8017 triệu m^3), có thể khai thác sử dụng làm cốt liệu nhỏ cho bê tông. Ngoài ra, nghiên cứu này cũng đã xác định được 03 tỷ lệ phối trộn giữa cát mịn, cát sông và đá mi (50:20:30; 30:30:40; 40:20:40) để tạo nên hỗn hợp cốt liệu nhỏ hợp chuẩn cho chế tạo bê tông.

Từ khóa: Cát nguồn gốc biển, cốt liệu nhỏ, cát mịn, bê tông

Ngày nhận bài: 04/8/2021
Ngày chấp nhận đăng: 19/8/2021