

COMPRESSIVE STRENGTH VARIATIONS BY ADDING MARINE SAND AS CONCRETE FINE AGGREGATE IN QUANG NAM, VIETNAM

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Abstract

Recently, considerations in partly replacing traditional concrete fine aggregate contained high river sand is concerned by marine sand to become a concern in Vietnam and the whole world. In the study area of Quang Nam (Vietnam), marine sand is selected to add to concrete fine aggregate because it meets engineering requirements for concrete fine aggregate material about fineness modulus (M_s) and salt content. The main research object is variations of concrete compressive strength (CCS) when adding marine sand to fine aggregate mixes. A proposal of concrete ratio mixes for CCS lab determinations was conducted. Two main non-destructive methods for determining CCS comprise ultrasonic pulse velocity (UPV) and rebound hammer (RH). Results highlight the adding of studied marine sand to concrete fine aggregate mix leads compressive strength of tested concrete block gives unchanged significantly during 90 experimental days in comparison to typical mixing ratio. The effect of marine sand percentage for mixed ratios was mentioned to CCS variations. Series of verification and linear regression is conducted between CCS values in design experimental time (t) to indicate the reliability and strong correlation between them in service of practical engineering aspects.

Keywords: Compressive Strength, Concrete, Fine Aggregate, Marine Sand

Introduction

Nowadays, many previous studies have applied marine sand (i.g. sand has marine origin) for construction activities very early. At the beginning of the twentieth century, Newman (1968) mentioned the problem of marine sand exploitation as a fine aggregate for concrete manufacturing. There are 4.5 million tons of marine sand exploited annually, and in America that is higher. Concrete and Cement

Association of England have published works on sand and gravel materials exploited at coastal area. In 1956, the National Conference of Sand Material in the United States issued a notice allowing utilize of marine sand for concrete making.

However, influences of salt ion Cl^- ion and SO_4^{2-} content in marine sand make cement with fast hydration and high heat of hydration. Those

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hydration processes caused many variations in the compressive strength of concrete. With a low percentage of NaCl content by $\leq 0.5\%$, the amount of cement without any effect on the strength of concrete. As following research of Hulimka and Kałuža (2020), Required chemical compounds (ettringite, gypsum, thaumazite, Candlot salt, calcium carbonate, expansive calcium chloride), forming inside concrete structure increase their volume and burst the surrounding materials, and expansive magnesium chloride; Swelling products of reinforcing steel corrosion burst the concrete cover (ion oxides and hydroxides); Soluble compounds forming in concrete discharge a portion of the matter beyond the concrete element (acid calcium carbonate). Typical marine sand completely meets engineering requirements as a fine aggregate with the content of silt/clay is not over 1% shown in Vietnam standard for concrete and cement aggregate (TCVN 7572 : 2006); JIS A1105; AASHTO T21. According to BS 882:1992), the tolerance limit for silt/clay content in fine aggregate is recommended not higher than 4%. Typical fineness modulus (M_s) in range from 2.6 to 2.9 following IS Code for M_s of fine aggregate (IS : 383-1970). In the other hand, TCVN 7572-2006 also design the typical range of M_s by 1.0 to 1.7 in adaptive to specific conditions of central Vietnam. Normally marine sand can be applied to concrete fine aggregates without exceeding 50% of the total volume of fine aggregates under two constant mix ratios as 2:1:3 (water : cement : fine aggregate) and 1:2:4:6 (water : cement : fine aggregate : coarse aggregate). Mohammed *et al.* (2017) stated a significant rising of concrete strength via applying infield sand as concrete fine aggregate. Few studies on fine aggregates to make concrete with an increase in the percentage of mixing and adding traditional materials, river sand from 0%, 25%, 50%, 75% to 100%. Making of the mixed ratio of fine aggregates is for good fineness modulus (typical fineness modulus $M_s = 2.78$) with recommended mixed ratio of gravel - fine sand is 65 : 35 to make concrete with applications for normal civil works and rural roads with the concrete road surface. Furthermore, there is an increase in the mixing ratio that increases the strength but reduces the deformation of the concrete (Osman *et al.*, 2021). Also in the study of Al-Kheetan (2019) showed the mixing ratio of the mix consist of water, fine aggregate which contains high percent of marine sand, and admixtures (by 2-4%) are 0.32, 0.37, 0.4, which lead concrete strength increases by 42% and water absorption reduced by 65%. Limeir *et al.* (2012), Dang *et al.* (2013), Dolage *et al.* (2013) and Girish *et al.* (2015) present a useful using sea dredged sand which exploits at bottom close to coastline and relevant sands have infield marine

original as construction materials. Those sand types are applied to fine aggregates in engineering concrete and mortar engineering. Xiao *et al.* (2017) using marine sand and seawater to modify concrete, and similar in Sidhardhan *et al.* (2017) applied marine sand to replace partially fine aggregate, Ravindra and Anil (2016) investigated the mechanical properties of concrete using sea marine sand and infield marine sand to partially replacing concrete fine aggregate for construction materials.

Refer to case study at present, 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. 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. That protections are limited legal privacy, even authorities banned sandy material exploitation of riverbeds. So that there were various studies on fine aggregates for adding with river sand in making of engineering concrete as Nguyen (2008), Hoang and Nguyen (2011), Nguyen and Tran (2011), Nguyen *et al.* (2016), Canh *et al.* (2021). Their researches concluded high possibility for using marine sand along central Vietnam coastline as concrete fine aggregates completely. Specifically, in the mixing of natural fine sand (with marine origin) and gravel, or a mixture of crushed sand and natural fine sand, there is an existence of river sand replacing from marine sand in concrete mix ratio but it still keeps allowable range of concrete compressive strength (CCS).

Stand on the above scientific and practical problems, this research conducted a series of laboratory tests for determining two main parameters, which can prove for high potential adding of this marine sand through concrete compressive strength (CCS) and salt content analysis via percentage of ion Cl^- and SO_4^{2-} after 90-day experimental times (t). Series of non-destructive methods as ultrasonic pulse velocity (UPV) and rebound hammer (RH) were conducted for CCS determination. Variations of CCS with t were verified with concise relevant engineering standard in the world and Vietnam for checking the reliability and correct sense of data, and carried a linear regression approach to gain more benefits in theory and practical material designs. This article desire to provide a more comprehensive understanding about marine sand, as well as suitable exploitation of local sand resources, for concrete fine aggregate in a case study of Quang Nam coastal plain of Vietnam and expand to wider fields in the world.

Materials and Methods

Research materials

This kind of marine sand is widely distributed with white color in the Quang Nam coastal plain in Central Vietnam indicated via Figure 1. The total exposure area of this sand by 253.5 m², and main sand forms as sand dunes, sand bars, and sand base fields enlonged in wide area. The average height of study sand formation is from 5m to 10m high, and the distributed depth of study sand by 20m via soil profiles from Figure 1(b) to Figure 1(d). Also, in research Thien *et al.* (2021), there is a special case of study marine sand forming with distributed wide up to 4.7 km and over 300 m² of area.

From Thien *et al.* (2021), this kind of marine sand met the technical requirements for concrete production following Vietnam standard of aggregates for concrete - Specifications (TCVN 7572-2006), and relevant standards as AASHTO T27, AASHTO T112, AASHTO T21, AASHTO T71, JIS A1105, and JIS A1102. However, percent of gravel, and fine sand used for this study did not

satisfy the requirements for Vietnam standard grain size curve by laying outside the allowable limit (Figure 2a and Figure 2b). By increasing high percentage of marine sand, the river sand percentage can be reduced as much and can support the local over river sand exploitations and mitigate river negative processes.

The fineness modulus (M_s) of studied marine sand in the range from 1.0 to 1.7 as following (TCVN 7572-2006) indicated in Figure 2(a). It is usable fine aggregate in this research and M_s (1.0-1.7) of marine sand much increase for sample collected deeper in Figure 2(b) under TCVN 7572-2006. All 13 collected samples of marine sand were experimented with in terms of physical and technological properties all meet requirements for concrete fine aggregate: M_s ($1.23 > 0.7$), clay content ($0.02 < 0.25$), and A_i at 14 mm (94.2% in range 90% - 100%) also updated to Vietnam standard (TCVN 3118-1993) (Table 1). Other relevant material properties for concrete fine aggregate as river sand and fine crushed stone are shown in Table 1 with engineering requirements for concrete fine aggregate.

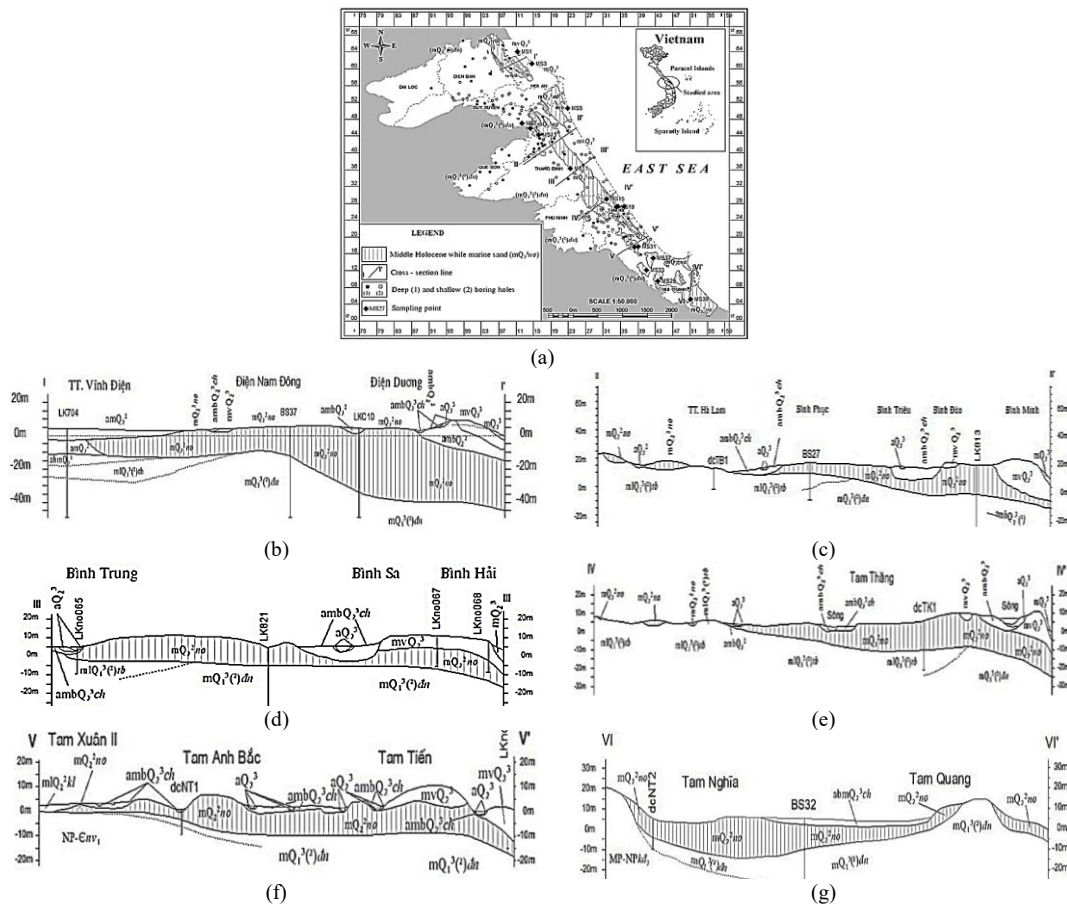


Figure 1. (a) Map of study marine sand distribution; and profiles of study marine sand: (b) I-I', (c) II-II', (d) III-III', (e) IV-IV', (f) V-V', (g) VI-VI' in Quang Nam coastal plain of Vietnam

Thien *et al.* (2021) stated that 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. So, to reduce the proportion of river sand (20%-30%), selected river sand (coarse) with $M_s < 2.0$ mixed with fine sand and gravel to create a mixture of high-quality materials. As for this study, via Figure 2(a), all marine sand is conducted particle analysis and their results located inside the zone of fine sand

with $M_s < 1.7$ that indicate logically, and reliability of study experiments and all study marine sand is considered as added material for concrete fine aggregate. The change of M_s values for study marine sand has tightly followed the depth from the surface as deeper through Figure 2(b).

Ultrasonic pulse velocity (UPV) and Rebound Hammer (RH) experiments

There are various non-destructive methods for CCS determination in laboratory, as for this article used Ultrasonic Pulse velocity (UPV) and Rebound Hammer (RH). These UPV and RH selections come from promising to evaluate the compressive strength of concrete in construction; Appears more appropriate to conditions on-site measurements, very convenient, fast and with a reasonable cost; And the prediction of concrete strength value indicates more reliable. For each design mix ratio, there are 3 individual samples made and relevant values of CCS are determined base on mean value from them. All processes are following series of standards as TCVN 3118 - 1993 (Vietnam standard), AS 1012.9, ASTM C39, ASTM C873, BS EN 12390-3, AASHTO T22, IS : 13311 (Part 1) - 1992.

UPV test in this research is following Vietnam Standard (TCVN 3118 - 1993.), BS 4408 : pt.5 and ASTM C597-16A. This test uses complex system of stress waves develops, which includes both longitudinal and shear waves and propagates through studied concrete cubes in Figure 3(a). Electronic timing circuits enable the transit time t of the pulse to be measured (Jedidi and Malek 2014; 2017). There are many reports for this UPV application as Lopez *et al.* (2016) researched the concrete compressive strength estimation by UPV test in Parana, Brazil with a similar concept for this research. Hong (2020) proposed a compressive strength estimation equation from the correlation between the ultrasonic pulse velocity and the compressive strength according to the age of the concrete by

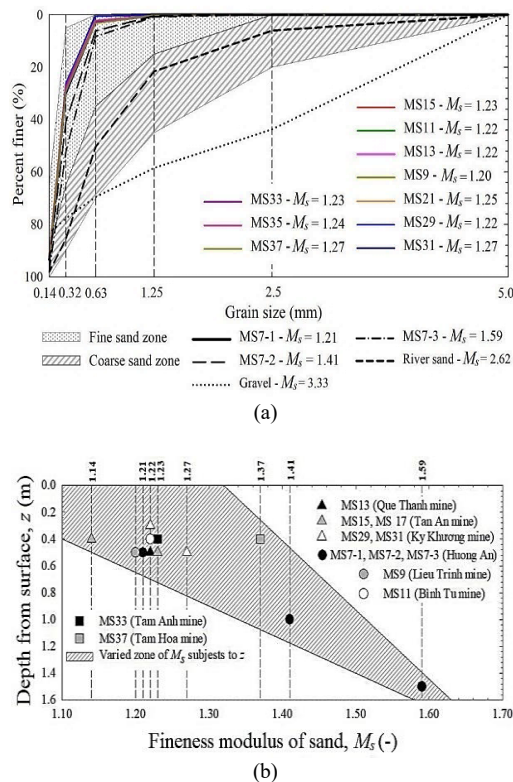


Figure 2. (a) Grain size distribution curve of study marine sand samples, river sand and gravel; (b) M_s variations objected to depth in the study area

Table 1. Typical gradation and physical-technological properties of 13 study marine sand samples obtained from laboratory experiments

Material		Accumulation index, A_i (%) with particle diameter (mm)					Physical-technological properties							Clay (%)	Silt (%)
		2.5	1.25	0.63	0.31	0.14	W	γ_x	n	γ_d	γ_w	H_p	M_s		
Marine sand		0.00	0.01	0.45	30.54	94.2	3.25	1.45	54.3	2.55	2.59	1.82	1.23	0.02	0.3
Vietnam Standard Requirement	A_i (%)	0-20	14-45	35-70	65-90	90-100	-	-	-	-	-	-	-	-	-
	B30	-	-	-	-	-	-	≥ 1.25	-	-	-	-	≥ 0.7	≤ 0.25	≤ 0.3

Notes: W - natural water content (%); n - porosity (-); γ_x - porous density (g/cm^3); γ_d - dry unit weight (g/cm^3); γ_w - water unit weight (g/cm^3); H_p - water absorption (%); A_i - accumulation index (%); M_s - fineness modulus; B30: Tier of concrete strength from 20-35 MPa

applying the ultrasonic pulse velocity method, which is one of the non-destructive testing methods. The analysis shows that the accuracy of Ultrasonic Pulse Velocity Test does affected by the concrete age. Where as it matures, the accuracy of UPV Test increases. Therefore in the determination of both depth and location of deteriorations in any concrete aspects, there is only Indirect Method would be possible though it is least satisfactory upon sensitivity and defined path length. In general, Ultrasonic Pulse Velocity Method showed better accuracy ranging from 60% to 99% respectively to the ages from day the 3rd till the 28th (at final strength). So that applying UPV for this research work is fessible for concrete compressive strength.

RH test follows standards of Vietnam Standard (TCVN 3118 - 1993), BS EN 12504-2:2001, and ASTM C805/C805M-18 for engineering concrete material in Figure 3(b). The main study concrete compressive strength (CCS) was conducted rebound hammer for studied concrete blocks in considerable detail and these results are well adapted to other previous reports. International scientific reports used this rebound hammer test to measure the surface hardness of concrete. The estimation of strength of concrete by RH method cannot be held to be very accurate, it just stops at acceptable accuracy, and probable accuracy of prediction of concrete compressive strength in a structure is $\pm 25\%$ in normally.

By test scenario installations, 12 concrete blocks with cubic size by 150×150×150 mm were made following each design mix ratio in Table 2. The ultimate results comprise concrete compressive strength (CCS) against experimental time (*t*) by 3 days, 7 days, 14 days, 21 days, 28 days, 60 days, 90 days. For 1 concrete mix ratio, there are 3 test samples for compression testing and the ultimate results are the mean of them. The

percentage of cement and water for concrete block making for the compressive test by 0.57 (Table 2) is adapted to normal concrete block range from 0.4 to 0.6, this value keeps porous of dry concrete block is minimum and acceptable via standards of Eurocode 2.

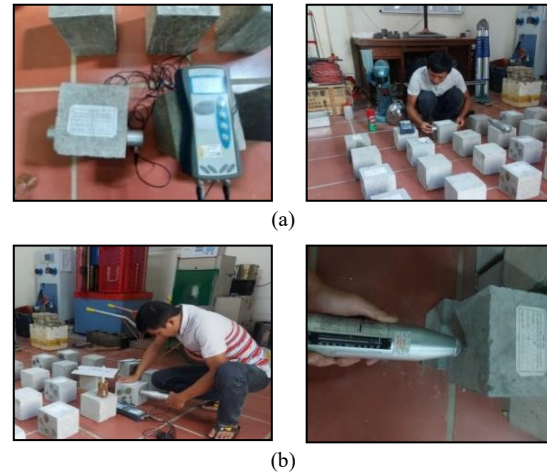


Figure 3. (a) Ultrasonic pulse velocity and (b) Rebound hammer for this study

When selecting the ratio of water/cement for design concrete mix ratio, too much water will result in segregation of the sand and aggregate components from the cement paste. Also, water that is not consumed by the hydration reaction may leave concrete as it hardens, resulting in microscopic pores (bleeding) that will reduce final strength of concrete. A mix with too much water will experience more shrinkage as excess water leaves, resulting in internal cracks and visible fractures (particularly around inside corners), which again will reduce the final strength.

Table 2. Design mixing ratios for 1 test sample of concrete fine aggregate

Concrete mixing ratios	Ref. name	Materials for concrete mixing ratio						Water/Cement
		Cement (kg)	Water (kg)	Coarse aggregate (m ³)	Marine sand (m ³)	River sand (m ³)	Fine crushed stone (m ³)	
100% R	CP00	23.87	13.65	82.46	0.00	46.88	0.00	0.57
50% M : 20% R : 30% F	CP01	23.87	13.65	82.46	22.72	9.38	14.00	0.57
30% M : 30% R : 40% F	CP02	23.87	13.65	82.46	13.63	14.06	18.67	0.57
40% M : 20% R : 40% F	CP03	23.87	13.65	82.46	18.17	9.38	18.67	0.57

Notes: R - River sand; M - Marine sand; F - Fine crushed stone

Results and Discussion

Salt Content in Marine Sand

This section results prove and supply term of highly potential when selecting and possibility adding marine sand to fine aggregate following Vietnam standard of aggregates for concrete and mortar - Specifications (TCVN 7570 : 2006; TCVN 7572-2006). As typical studying for checking the salt intrusion inside any concrete structures, there are 2 main chemical ion parameters usually selected mainly ion Cl^- and ion $\text{SO}_4^{2-} < 0.05$ indicated in Table 3. The change of salt content is an important parameter in terms of descision of study marine sand as concrete fine aggregate. Also, low percent of salt content ensures without serious corrosive process when apply concrete structures in realistic conditions.

Content of Chloride ion (Cl^-)

One of representative chemical compound to ion Cl^- as normally Sodium Chloride (NaCl). When the amount of NaCl , which is characterized by ion Cl^- , is higher, the strength and elastic modulus of concrete turn to decrease. The effects of Cl^- ion on cement concrete that mentioned in many previous projects of researches. Some reports innovated the above knowledge by using fresh water to mix with marine sand because it brings no effect to physical and technological properties and specific strength of concrete.

Marine sand should not be used to make prestressed concrete because salted content can erode and easily break reinforced steel structures. In addition, salted content will accelerate the concrete hardening rate without any need for additional mixtures. However, using marine sand with clean or washing out salt content will enhance salt scaling resistance and shrinkage process of concrete. In this work, the series of salt content determination was carried out via SMEWW-4500

Cl^- B :2017, and TCVN 7572 :2006. Refer to this research, in Table 3, rising of Cl^- content marine sand materials for concrete test increase with deeper location via sample MS17-1 (0.5 m) to MS17-3 (2.5 m) by more than 1.0% with 1 m deep that can be clarified from Figure 1 that this marine sand formation caused. In general that all value of Cl^- varied in range from 0.03% to lower 0.05%, especially there are 3 samples that take a little bit more than 0.05% of Cl^- percentage as MS17-3 (0.052%), MS31 (0.053%), MS37 (0.07%). That proves the potential for using as a concrete fine aggregate of study marine sand in Quang Nam coastal plain, Vietnam. The rising of salt content can be clarified via a sample location that is more close to the coastal line and the salt intrusion occurs as much. The widespread corrosion agent is sodium chloride (NaCl), found naturally in the area close to the seawater zone and a part of intrusted groundwater (Hulimka and Kaluza, 2020). And their report present there are many transferring from salt environments during the deicing of concrete working surfaces.

Content of sulfate ion (SO_4^{2-})

This chemical test was conducted by standards of SMEWW-4500- SO_4^{2-} E : 2017; ASTM C88; EN 1367-2; BS 812 (Part 121) for sulfate content in studied marine sand. Sulfate salt is regularly considered to be the degradation mechanism causing the concrete deterioration in the evaporation zone of partially buried concrete elements in the sulfate environment (Liu *et al.*, 2014). Another kind of salt content analysis is linked to the percentage of sulfate ion (SO_4^{2-}) and series of this chemical experimental for study marine sand in making of testing concrete block. The value ranges from 0.03% to 0.04% of major marine sand samples are meet the Vietnam engineering standard (TCVN 7572:2006) for concrete by $\leq 0.05\%$ of the concrete weight.

Table 3. Results of salt content analysis for marine sand in study area

No	Sample name	Depth (m)	Cl^-	SO_4^{2-}	Co-ordinary	
			%	%	X	Y
1	MS7-1	0.5	0.040	0.046	21230	17469
2	MS7-2	1.5	0.046	0.048	21230	17469
3	MS7-3	2.5	0.052	0.053	21230	17469
4	MS9	0.5	0.045	0.052	21430	17458
5	MS11	0.4	0.039	0.039	22343	17363
6	MS13	0.4	0.048	0.046	21619	17443
7	MS15	0.3	0.039	0.039	23176	17290
8	MS21	0.5	0.049	0.051	23445	17272
9	MS29	0.3	0.039	0.039	24353	17095
10	MS31	0.5	0.053	0.045	23908	17177
11	MS33	0.4	0.045	0.045	24090	17121
12	MS35	0.4	0.039	0.039	23817	17175
13	MS37	0.4	0.070	0.047	24255	17149

Exception of MS17-3 and MS9 samples with a fine higher than standard value for this percentage by 0.053% and 0.052%, respectively. Similarly to shelf seas that were connected to the salt intrusion zone by deep feeder channels. These channels supplied the necessary minerals to facilitate sodium chloride and gypsum precipitation, which make much sulfate ion and other relevant salt analysis ions rising.

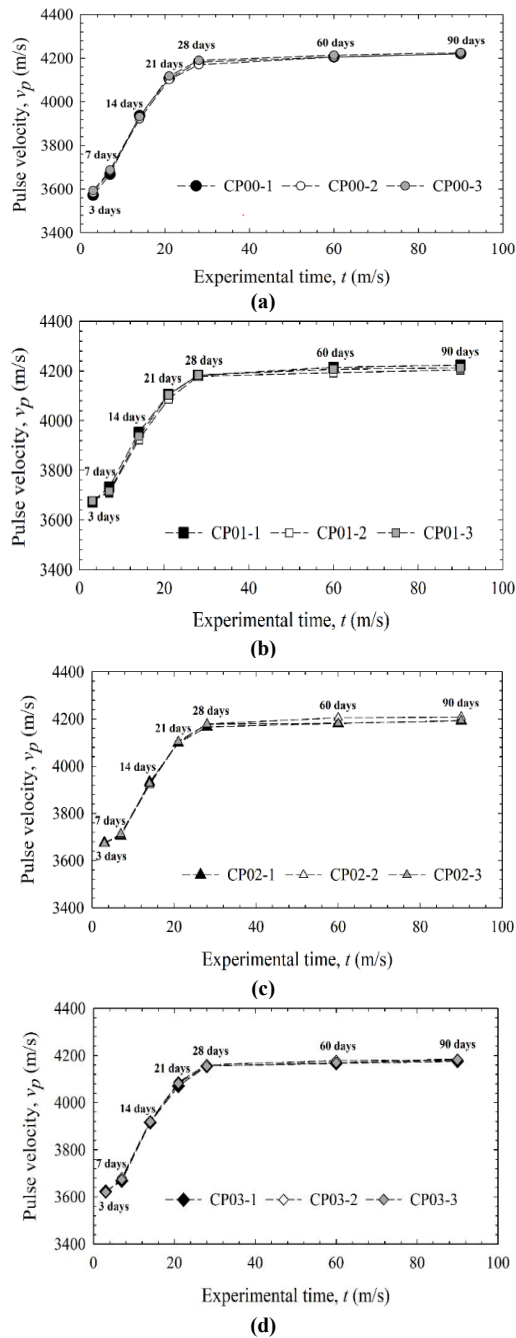


Figure 4. Results of v_p for each design mixing ratios (a) CP00, (b) CP01, (c) CP02, and (d) CP03 in this study

Variations of Concrete Compressive Strength (CCS)

CCS obtained from UPV and RH in combination with design concrete mixing ratios from Table 2, series of 168 experiment data obtained UPV and RH test are shown in Figures 4 and 5 respectively. According to Figures 4 and 5, there are 3 sample preparations for each mixing ratio (CP00, CP01, CP02, CP03). They are numbered from 1 to 3 with relevant values of v_p and RN parameters (rebound number) following experimental times (3 days to 90 days). All rising of above of v_p and RN are shown via representative curves (Figures 4 and 5). Due to acceptable accuracy of studied experimental methods, the rising of UPV and RN value provide the first sights and trend rise plots of concrete compressive strength (CCS) variations in this study. This study determined representative values of v_p and RN as mean values (following TCVN 3118-1993). Those mean mentioned tested values are used for identified concrete compressive strength (CCS) with high presentative and reliability in Figure 6. The identifications of CCS following mean v_p and RN are followed to Vietnam standard of aggregates for concrete and mortar - Specifications (TCVN 3118-1993). The CCS values are extracted and looked-up via mentioned standards based on, and converting results corresponding to each non-destructive concrete method. Typical CCS values are adapted to high saturation and also monitor the swelling phenomenon.

CCS variations from 3 to 28 days

During the first period from 3 days to 28 days, the hydration process develops rapidly, refer to the high incline angel of all plots in Figure 7 and Table 7. All design mixing ratios are not many differences each together with similar in CCS values and incline angle. Only first almost a month, the hydration reacts strongly with the concrete mix compound and penetrates through porous concrete structure. That can be explained that the effects of a marine sand percentage added to concrete fine aggregate in this period is not much or no effect on to whole concrete mix. There is no obvious distinction among the effects of each mixed component at this time. Mean CCS value from the 3rd day (11.47 Mpa) increase to the 28th day (26.03 Mpa) by more than 227% (or more than 2.27 times rising) for all concrete mixing ratios (Figure 6). The added percentages of marine sand as fine aggregate to concrete mix lead inconsiderable effects to CCS rising. By linking to practical conditions a time from 3 to 28 days is a critical consideration and appropriately ensures concrete structural stability and construction safety. The marine sand adding still shows itself

a possibility to keep more satisfying and safe for concrete making with strength 25-30 Mpa.

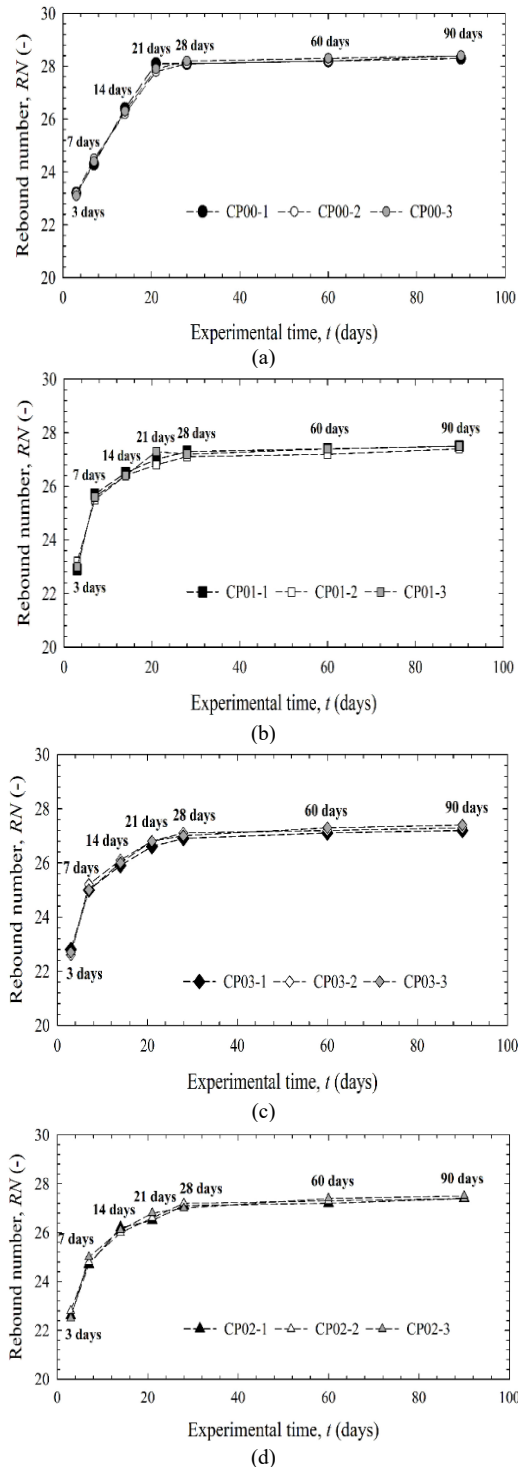


Figure 5. Results of RN for design mixing ratios (a) CP00, (b) CP01, (c) CP02, and (d) CP03 in this study

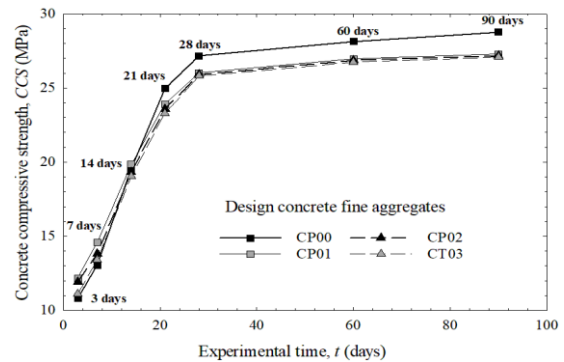


Figure 6. Concrete compressive strength (CCS) following experimental time (t)

CCS variations after 28 days

Continuously, with time over design time 28 days, this research continued conceptual concrete experiments up to 90 days. Figure 6, this time present the slow rising of CCS of all concrete mixed ratios. The mean rising of CCS at the 28th day (26.03 MPa) to the 90th day (27.25 MPa) by 104% (or more than 10.4 times rising) in comparison to 227% rise of before 28 days. By this period after 28 days, the hydration reacting rate goes slow (reach to the saturated condition in chemical reactions) and the concrete block is turned to shrinkage process to become hard concrete rock. However, for this process, the effect of marine sand is tracking via Figure 6 that more added of marine sand the CCS quite reduces but that reduction is in allowable range for concrete making with all value in the range from 25 to 30 MPa with high expectation. Changes in marine sand added percentage cause a similar rising magnitude of CCS for this period. In practical, concrete structures usually become more solid, hardening, and low deformation for this period and also gain much strengthen. With the time 90 days by adding more marine sand, the CCS meets the requirements of Vietnam engineering standards and relevant abroad standards as TCVN 3118-1993 (Vietnam standard), AS 1012.9, ASTM C873, BS EN 12390-3, AASHTO T22, IS : 13311 (Part 1)-1992 for concrete making and ensures long-term concrete structure durability and general construction safety.

Verification of CCS results

Obtained CCS values are verified with engineering standard and requirement for concrete quality control such as TCVN 3118-1993 (Vietnam standard), AS 1012.9, ASTM C39, ASTM C873, BS EN 12390-3, AASHTO T22, IS : 13311 (Part 1) - 1992. From above standards, the resreach present

a shade zone for ideal concrete compressive strength in Figure 7. This ideal UCS range is divided into 2 parts in updating to 2 time periods before and after 14 days, and mentioned standard. Before 14 days, required standards suggest typical value of CCS or ideal CCS from 10 to 25 Mpa, and after 14 days this suggestion turns from 17 to 28 Mpa.

Via Figure 7, all study values of CCS laid almost inside the shade zone for ideal concrete compressive strength. That show obviously high ability and adaptations of study concrete types in practical and commercial term of concrete structures. The verification results present a correct selection or high potential of studied marine sand for using and adding to concrete mixing ratio and for local concrete making demands in Quang Nam coastal plain, Vietnam.

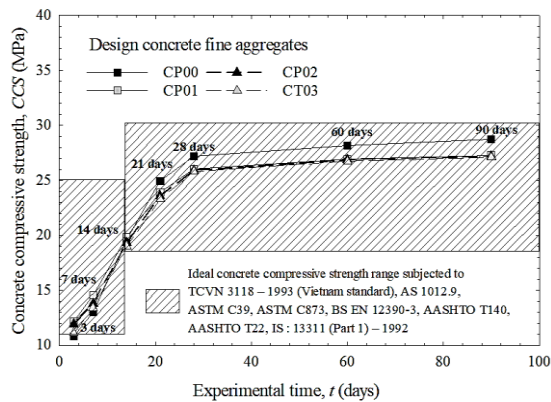


Figure 7. Verification of CCS subjected to required engineering standards

Linear regression between CCS and t

Stand on varied behavior between CCS with t , this article conducted two mathematic linear regression for estimating quantitatively CCS as a dependent variable based on independent variable as t variations. Data of CCS from Figure 6 were used for this linear process and divided into 2 periods before and after 28 days. The selection of mean CCS comes from insignificant differences among test results for each design mixing ratio. Two linear equations and reference lines of studied input data of CCS for each period before and after 28 days are shown in Figures 8a and Figure 8b.

Those linear regression establishments indicated a strong relationship between mentioned parameters via a coefficient of determination (R^2) of 0.98 and 0.92 for CCS variations before and after 28 days. The inclined slopes were 0.6 and 0.021 for the experimental time before and after 28 days. By Figure 8(a), at the early time from 3 days to 28 days, CCS for

all mixing ratios rise as much in a short time and have higher linking to t , the inclined slope of reference by 0.6 is higher by 2.8 times than for after 28 days in Figure 8(b). A short conclusion for this section can be drawn that there is an essential correlation between CCS and t . Conceptual linear regression can be applied and support in terms of practical engineering concrete fine aggregate design especially using in the study area. By the linear regression approach, it shows an easy and convenience for estimating variations of CCS during practical construction time and concrete stability with any proportion of added studied marine sand content to concrete mix ratio.

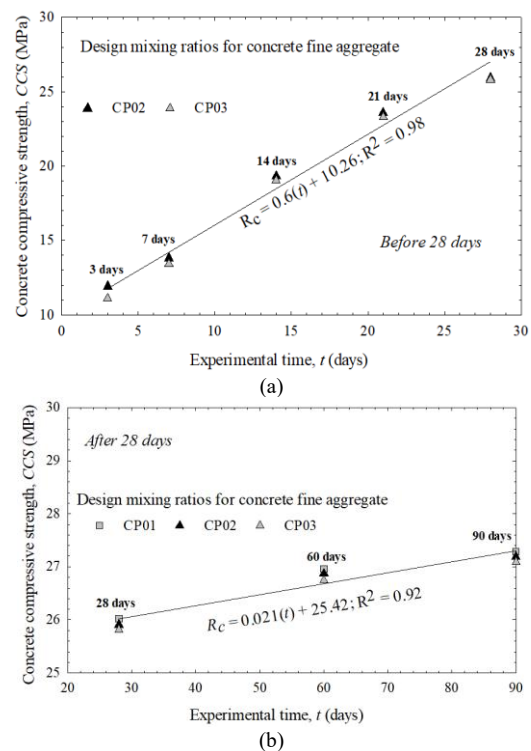


Figure 8. Linear regression between CCS and t of concrete fine aggregates (a) before and (b) after 28 days

Conclusions

Studied marine sand (with M_s by 1.7 - 2.0) in the study are Quang Nam coastal plain in central Vietnam proves itself with highly potential for adding to concrete fine aggregate with concrete strength from 25 to 30 MPa. Even study sand links to marine formed origin but the content of Chloride ion (Cl^-) and Sulphate ion (SO_4^{2-}) adapted well to engineering standard for concrete making in practical. With lower salt content contain in study marine sand, this sand

type can be used in any concrete structures, and combine to iron material as steel, iron, without corrosive processes.

The concrete compressive strength (CCS), determined via series of non-destructive methods as UPV and RH shows an increase significantly with experimental time (t) from 3 days to 28 days and lightly rise of CCS from 28 days to 90 days. A notable point that at the first time period from the 3rd day to the 14th day reflect higher CCS values of mixes added studied marine sand than mix without them (ref. Figure 6). But for the duration after the 14th day, there is a significant rise and faster reach to high CCS value for mix has river sand than mix contain study marine sand. This research point can become a base for the selection of suitable concrete mix ratio in adapting to realistic construction and design conditions.

Through series of linear regression approaches, variations of CCS are a strong correlation to experimental time (t) and this will bring more convenience in estimating concrete compressive strength CCS when add marine sand to the concrete fine aggregate in practical conditions. The design equation indicates inconsiderable differences when replacing concrete fine aggregate with marine sand instead of traditional river sand. Proposed equations indicate inconsiderable effects to final concrete compressive strength variations when rising the percentage of studied marine sand. Research finding provide necessary and conviniences for concrete structure design in practical.

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References

- AASHTO T21, Standard Method of Test for Organic Impurities in Fine Aggregates for Concrete.
- AASHTO T22, Standard Method of Test for Compressive Strength of Cylindrical Concrete Specimens.
- AASHTO T27, Standard Method of Test for Sieve Analysis of Fine and Coarse Aggregates.
- AASHTO T112, Standard Method of Test for Clay Lumps and Friable Particles in Aggregate.
- AASHTO T71, Standard Method of Test for Effect of Organic Impurities in Fine Aggregate on Strength of Mortar.
- Al-Kheetan, M.J., Rahman, M.M., Chamberlain, D.A. (2019). Optimum Mix Design for Internally Integrated Concrete with Crystallizing Protective Material. *Journal of Materials in Civil Engineering*, 31(7):04019101. [https://doi.org/10.1061/\(ASCE\)MT.1943-5533.0002694](https://doi.org/10.1061/(ASCE)MT.1943-5533.0002694)
- AS 1012.9:2014, Methods of testing concrete Compressive strength tests - Concrete, mortar and grout specimens.
- ASTM C39, Concrete Cylinder Compression Testing.
- ASTM C873, Standard Test Method for Compressive Strength of Concrete Cylinders Cast in Place in Cylindrical Molds.
- ASTM C88, Standard Test Method for Soundness of Aggregates by Use of Sodium Sulfate or Magnesium Sulfate.
- ASTM C597-16, Standard Test Method for Pulse Velocity Through Concrete.
- ASTM C805/C805M-18, Standard Test Method for Rebound Number of Hardened Concrete.
- BS 882:1992, Specification for aggregates from natural sources for concrete.
- BS 12390-3:2019, Testing hardened concrete Part 3: Compressive strength of test specimens.
- BS 4408, Recommendations for non-destructive methods of test for concrete - Part 5.
- BS EN 12504-2:2001, Testing concrete in structures. Non-destructive testing - Determination of rebound number.
- BS 812-121, Testing Aggregates - Part 121: Method for Determination of Soundness.
- Canh, N.V, Thuy, N.T, and Thien, D.Q (2021). Estimate Engineering Ability of Local Sand Material for Concrete and Mortar in Quang Tri, Hanoi, Vietnam. *Journal of Water Resources and Environmental Engineering*, No. 73, Vietnam, pp. 43-52.
- Dang, T. A., Kamali, S., and Prince, W.A. (2013). Design of new blended cement based on marine dredged sediment. *Construction and Building Materials*, 41:602611. <https://doi.org/10.1016/j.conbuildmat.2012.11.088>
- Dolage, D.A.R. and Dias, M.G.S. and Ariyawansa, C.T. (2013). Offshore sand as a fine aggregate for concrete production. *British Journal Apply Science Technology*, 3:813-825. <https://doi.org/10.9734/BJAST/2013/3290>
- Eurocode 2: Design of concrete structures.
- Jedidi M. and Machta K. (2014). Destructive and Non-destructive Testing of Concrete Structures. *Jordan Journal of Civil Engineering*, 8(4).
- Jedidi M, Abroug A, Moalla B, and Benjeddou O (2017). Non-destructive Testing for the Diagnosis and Repair of a Reinforced Concrete Building. *International Journal of Architecture, Engineering and Construction*, 6(1):20-28. <https://doi.org/10.7492/IJAEC.2017.003>
- JIS A1102, Method of test for sieve analysis of aggregates.
- JIS A1105, Method of test for organic impurities in fine aggregate.
- Girish, C. G., Tensing, D., and Priya, K.L. (2015). Dredged offshore sand as a replacement for fine aggregate in concrete. *International Journal of Engineering Sciences & Emerging Technologies*, 8(3):88-95.
- Hoang, P.H. and Nguyen, T.L. (2011). Research on self-compacting concrete using local materials. *Journal of Science and Technology, University of Danang*, 2(43).
- Hong, S., Yoon, S., Kim, J., Lee, C., Kim, S., and Lee, Y., (2020). Evaluation of Condition of Concrete Structures Using Ultrasonic Pulse Velocity Method. *Applied Sciences*, 10(2):706. <https://doi.org/10.3390/app10020706>
- Hulimka, J. and Kałuza, M. (2020). Basic Chemical Tests of Concrete during the Assessment of Structure Suitability-Discussion on Selected Industrial Structures. *Applied Sciences*, 10(1):358. <https://doi.org/10.3390/app10010358>
- Limeira, J. and Agullo, L., and Etxeberria, M. (2012). Dredged marine sand as a new source for construction materials. *Materiales de Construcción*. 62.
- Liu, Z., Deng, D., and Schutter, G. (2014). Does concrete suffer sulfate salt weathering? *Construction and Building Materials*, 66:692-701. <https://doi.org/10.1016/j.conbuildmat.2014.06.011>

- Lopez, Y., Vannali, L., and Jose, V. (2016). Concrete Compressive Strength Estimation by Means of Non-destructive Testing: A Case Study. *Open Journal of Civil Engineering*, 6(4):503-515. <https://doi.org/10.4236/ojce.2016.64043>
- Malek, J. (2020). Evaluation of the Quality of Concrete Structures by the Rebound Hammer Method. *Cur Trends Civil & Struct Eng.*, 5(5):000621. <https://doi.org/10.33552/CTCSE.2020.05.000621>
- Mohammed, M., Abdelouahed K., and Allaoua B. (2017). Compressive strength of dune sand reinforced concrete. *AIP Conference Proceedings*, 1,814. <https://doi.org/10.1063/1.4976242>
- Newman, K. (1968). Sea-dredged aggregates for concrete. *Proceedings of the Symposium: Sea-dredged Aggregates for Concrete, Sand and Gravel Association Great Britain, Buckinghamshire, UK.*
- Nguyen, T.S. (2008). Study on the change of strength of sand concrete when using fine fillers. *Journal of Transport Science*, 24.
- Nguyen, T.S., and Tran, L.T. (2011). Sand concrete uses Central Coastal sand to manufacture self-inserting concrete bricks and woven panels in road construction. *Transport Magazine*, (8), Hanoi.
- Nguyen, D.V. (2016). Research and find sources of raw materials as construction materials to replace river bed sand in Thua Thien Hue province. *Provincial scientific research project, Vietnam.*
- Osman, G., Mirac, O., Aliakbar, G., Togay, O. (2021), Recycling waste concretes as fine aggregate and flies ash as the binder in the production of thermal insulating foam concretes, *Journal of Building Engineering*, 38:102,232. <https://doi.org/10.1016/j.jobbe.2021.102232>
- Sidhardhan, S., Jansi, S.S., Meylin, J.S. (2017). Study on sea sand as a partial replacement for fine aggregate. *Journal of Advances in Chemistry*, 13(4):6,166-6,171.
- SMEWW-4500 Cl- B:2017, Standard Methods for the Examination of Water and Waste water for Determination of Chloride content.
- SMEWW-4500-SO42- E:2017, Standard Methods for the Examination of Water and Waste water for Determination of Sulfate content.
- Ravindra, V., and Anil, K.B. (2016). Mechanical Properties of Concrete with Marine Sand as Partial Replacement of Fine Aggregate. *Int. Journal of Engineering Research and Applications*, 6(2):08-11.
- Thien, D.Q., Hai, L.D., Dinh, C.H.T., Chinkulkijniwat, A., Thanh, H.T., Hoang, H.T. (2021). Potential Fine Aggregate of Concrete and Mortar Making from Marine Sand: A Case Study of Quang Nam Coastal Plain in Vietnam. *The 2nd IVSCT 2021, Suranaree University of Technology, Thailand.*
- Vietnam Standard of Aggregates for Concrete and Mortar - Specifications (TCVN 7572: 2006).
- Vietnam Standard of Heavy weight concrete - Method for determination of compressive strength (TCVN 3118: 1993).
- Xiao, J., Qiang, C., Nanni, A., and Zhang, K. (2017). Use of sea-sand and seawater in concrete construction: current status and future opportunities. *Construction and Building Materials*, 155:101-1111. <https://doi.org/10.1016/j.conbuildmat.2017.08.130>