International Journal of GEOMATE, Jan., 2021, Vol.20, Issue 77, pp. 123-131
ISSN: 2186-2982 (P), 2186-2990 (O), Japan, DOI: https://doi.org/10.21660/2020.77.47890
Geotechnique, Construction Materials and Environment

RESEARCH THE POSSIBILITY OF USING SEA SAND IN ROADBED CONSTRUCTION IN VIETNAM

Viet-Phuong NGUYEN[1], *Duy-Hoa PHAM[1], Phu-Doanh BUI[1], Ngoc-Thinh BUI[1,2], and Dang-Viet-Anh NGUYEN[1]

[1] Faculty of Bridges and Roads, National University of Civil Engineering, Hanoi, Vietnam;
[2] Project Management Unit of Construction Investment, Haiduong, Vietnam

*Corresponding Author, Received: 23 Sept. 2020, Revised: 26 Oct. 2020, Accepted: 15 Nov. 2020

ABSTRACT: Currently, the river sand is becoming depletion leading to a rise in the price of construction material and issues related to the environment such as the depth of the river bed, lowering of the groundwater and salinity intrusion into the rivers. Meanwhile, demand for construction materials increases annually due to growth in infrastructure development demand. Therefore, finding alternative material sources is an urgent problem needing to be addressed. Specifically, sea sand has many potential abilities to replace river sand and other materials in construction. The result of the study revealed that sea sand on the coast of Vietnam accommodates most of the roadbed materials requirements according to standard TCVN 9436:2012. The study has proposed a feasible method to construct the roadbed by sea sand. The results of stability analysis by Slope/W show that the roadbed using alternating filling method considerably improves the safety factor which increases on average 13.8% in comparison with the roadbed is filled by sea sand and covered by clay. In addition, a cost comparison between the roadbed constructed by the alternating method and conventional roadbed shows that using sea sand brings a significant cost saving for the project. Moreover, using sea sand as an alternative material source also has several positive effects on the environment such as utilizing, dredging ports and seabed, making use of wild dunes, reducing the amount of river sand extracted annually, minimizing the impacts of river sand exploitation.

Keywords: Sea sand, Alternative material, Slope W, Roadbed construction, Highway, Vietnam

1. INTRODUCTION

Over the last two decades, rapid urbanization along with infrastructure development and growing population causes an increase in demand for construction material. According to the report by the UN environment, around 40 to 50 billion tonnes is the global demand for sand and gravel per year. This report also pointed out that aggregate extraction activities in the rivers are the direct reason leading to pollution, flooding, lowering of water aquifers, and worsening drought occurrence [1]. In 2016, nearly 13.7 billion tonnes of sand mined worldwide for the construction industry, 70% was consumed in Asia, in which China consumed around 5 billion tonnes [2]. Sand extracting is one of the industries with the highest commercial value over the world with $70 billion. In Vietnam, during 4 years from 2016 to 2020, the total demand for sand is estimated at around 2.3 billion m3 while the country's sand reserve is only about 2 billion m3 [3]. The road network in Vietnam is being invested with many large scale projects such as component projects of the North-South Expressway. These projects all have a huge demand for the material. In addition, the lack of material supply directly causes an increase in material prices. Only from March to April in 2017, the price of sand has increased from 1.5 to 4 times [3].

Therefore, finding alternative material sources replacing sand in construction is an urgent problem. Among the viable sources of materials, sea sand is used by many countries over the world. Annually, Britain extracts around 13 million tonnes of salty sand and gravel for construction. The other European countries also consumed [6-7] million tonnes of salty material per year [4]. More than 90% of the amount of sand is extracted for construction, in which 45% is used for concrete production. Infrastructure projects in the UK, airports in Hong Kong, city expansion in Singapore and buildings in the Middle East are typical projects using sea sand to replace river sand for construction [5-7]. Fig. 1 shows the amount of sand extracted over the world [8].

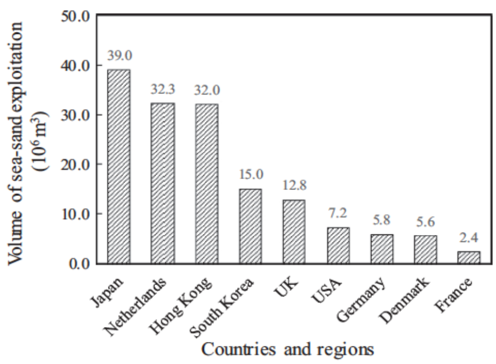

Fig.1 Amount of sand extracted over the world [8]

As for alternative materials, Vietnam has been researching many alternative materials which have great potential to replace traditional materials in highway construction such as using fly ash or dredged mud as fill material for highway embankment construction [9-11], using sludge blended with recycled clay bricks for road subgrade [12], using fly ash in pervious concrete for street permeable pavement [13], researching geopolymer concrete uses fly ash to replace ordinary portland cement as the primary binder [14,15] for rigid highway pavement. The common point of these studies is head to sustainable development objective, environmentally friendly materials and utilize waste materials of industries.

Fig.2 Sea sand in the Central of Vietnam has a large reserve that has not been significantly extracted (Source: https://bacbinh.binhthuan.gov.vn/)

Vietnam has many advantages if using sea sand as an alternative material for river sand in road construction. With a coastline of 3,260 kilometers long passing through 28/63 provinces and cities will significantly shorten the distance for transporting materials to the projects. The total area of coastal sand and sand dunes in Vietnam is over 500,000 hectares, of which 264,981 hectares are in the South Central Coast region. Binh Thuan has the largest area of coastal sand and sand dunes in the countries with 125,935 hectares [16]. This shows that Vietnam has an abundant resource of sea sand, distributed throughout the country, using local materials will bring economic efficiency.

2. SEA SAND PROPERTIES

According to the research of Gutt and Collins, Sea sand also has a geological origin similar to river sand [17]. Using X-ray diffraction techniques and mineral composition analysis recently also showed similar results [18-20]. However, the surface structure of sea sand is different from river sand, mine sands leading to differences in internal friction, which affects the product using sea sand as a component material. The analysis results of the grain composition of sea sand compiled from many different studies in Fig. 3. This shows that the grain composition distribution of all sea sand samples is in or close to the specified range of fine aggregate materials used for concrete in a number of countries [21].

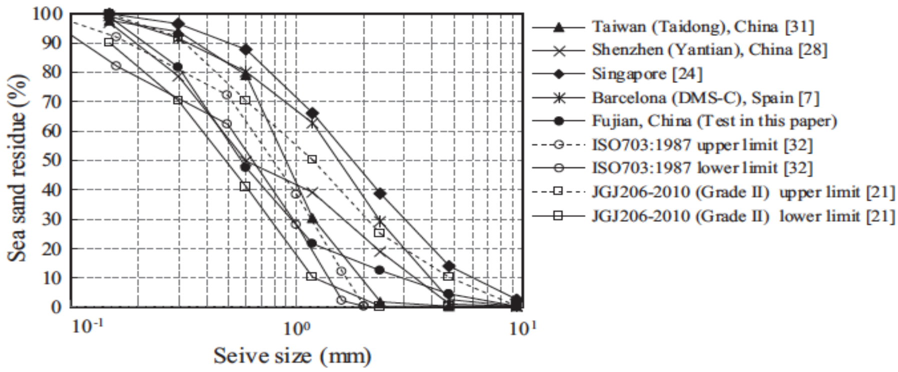

Fig.3 The typical gain aggregation of sea sand form several regions [21]

Some research pointed out that sea sand contains more salt, shells and other harmful impurities than river sand [21]. These different is shown in Table 1. The content of broken or unbroken shells is the main factor that makes the difference between sea sand and river sand [22]. Sea sand has a higher density than river sand due to the basic chemical composition of the seashell is CaCO3. The shell fragments have high strength, durability and solidity. In several studies partly replacing cement with seashell has resulted in high tensile strength in concrete compared to conventional concrete [23].

Table 1 Typical impurities content in sea sand form several regions [21]

Areas	Cl^- %	SO3 %	SO_4^{2-} %	Shell %
JGJ206-2010 Guideline	≤ 0.03	≤ 1.0	-	≤ 10
Singapore	0.29	-	0.005	-
Shenzhen, China	0.21		-	4.4
Taiwan, China	0.035	-	0.0092	-
Barcelona, Spain	0.10	0.46	-	-

Results of studies and experiments on the properties of sea sand in Vietnam in comparison with the requirements for fill material according to TCVN 9436:2012 (Highway embankments and cuttings – Construction and quality control standard) is illustrated in Table 2.

Table 2 The sea sand properties in Vietnam compared with the requirements of the fill material

Studies	Impurities, %	Soluble salt, %	CBR, %
Tran T. H. [24]	-	0.01 – 1.4	-
Hoang et al. 2017 [25]	Brighter than the standard color	0.001 – 0.007	-
Nguyen 2014 [26]	0.85	-	12.8 (K=0.95)
Vo 2018 [27]	1.5	0.38	-
Bach 2006 [28]	0.67	0.063	-
TCVN 9436:2012 [29]	≤ 10	≤ 5	≥ 6 (K=0.95)

Where K is the compaction coefficient of the sea sand layer.

Generally, sea sand in Vietnam is relatively clean, low impurities meeting the requirement of organic impurity content in the roadbed embankment (≤ 10%). The average salt content is from 0.02 to 0.1%, sea sand in Van Don has the highest salt content (1.4%). Experiment results for CBR at K= 0.95 is 12.8% (> 6% compared to requirements in TCVN 9436:2012). Consequently, sea sand basically accommodates the requirements for roadbed embankment materials specified in TCVN 9436:2012.

At Ha Noi – Hai Phong expressway project, fine-grained river sand was used to construct the roadbed. Table 3 compares the grain composition in some sea areas in Vietnam with the grain composition requirements of fill material at this expressway project. It is clear that the grain size of sea sand in Vietnam ensures the grain composition requirements to be used as road embankment material.

Table 3 The grain composition of sea sand compared with requirements of fill material at the Ha Noi – Hai Phong expressway project

Criteria	Requirements of fill material in Ha Noi - Hai Phong expressway	Seasand in Ha Tinh	Sea sand in Quang Tri
D < 0.425	> 51%	88.83	88.2 - 95.3
D < 0.075	< 10%	1.14	0.05 - 1.25

Where D is the sieve mesh sizes (the unit is millimeter).

3. PROPOSING METHOD TO CONSTRUCT ROADBED WITH SEA SAND

In theory, by comparison with the requirements in the standard, sea sand is fully qualified for use as roadbed material. However, due to some characteristics of sea sand such as fine-grained, discrete-grained, reduce volume when exposed to moisture, so certain methods are required to use sea sand as fill material.

3.1 Alternating Embankment Method of Sea Sand and Cohesive Soil

The alternating embankment of cohesive soil layers between the sea sand layers in the roadbed construction helps easy to compress the sand layer, forming a cover that enhances stability, overcome the shortcomings of sea sand when filling the roadbed. The alternating embankment method is often used for roadbeds higher than 3 meters. The layers of cohesive soil and sea sand are filled alternately with a thickness of each layer from 300mm to 500mm. The top 0.5 meters soil layer is constructed with sandy soil to form the foundation of the road surface. External of the roadbed is filled by a clay layer which plays a role in stabilizing the geometry and proofing the water and moisture affecting on the roadbed. Moreover, the clay layers also reduce salinity intrusion from sea sand to the environment. The typical cross-section of the alternating embankment is illustrated in Fig. 4.

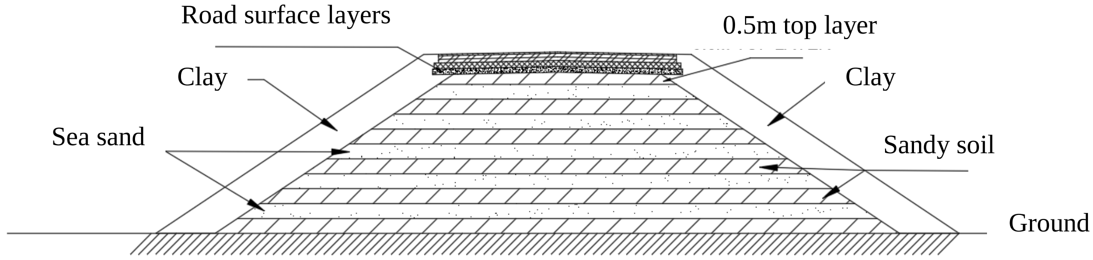

Fig.4 Typical cross-section of alterning embankment

Sea sand embankment should be stepped with a distance of 4 to 6 meters to the end of the roadbed for surface water drainage. It is necessary to design water collection ledges and ditches to drain water from the road surface to nature.

3.2 Reinforcement Roadbed with Geocells

With the properties of sea sand, it is necessary to have a method of balancing the drainage capacity and the load-bearing capacity of sea sand on the roadbed. These two properties tend to be in opposition because when increasing the drainage capacity of the material, the density of the material tends to decrease leading to a reduction in the load capacity. The solution to this problem is reinforcement roadbed with geocells. Geocells are cellular confinement systems made from strips of welded high density polyethylene (HDPE) that form a honeycomb grid when expanded and are filled with aggregate or soil. Compared with unreinforced roadbed, the roadbed is reinforced with geocell have lateral and vertical confinement, tensioned membrane effect, and wider stress distribution.

General reinforcing mechanisms of geocell is confining the in-fill soil from shearing away and derive anchorage resistance through the surrounding soil against the applied load [30]. Cells are welded together to form a homogeneous block, then vertical load forcing on the roadbed instead of causing a sliding surface just below the position of the applied load, it will be created sliding surface at the deeper soil layer (Fig. 5). Reinforcement at depths between 0.3B and 0.5B, in which B is the reinforcement width, optimizes efficiency. Furthermore, the researchers found that reinforcement with geocell increases in bearing capacity ratio (BCR) and the low strain stiffness of the reinforced system [31].

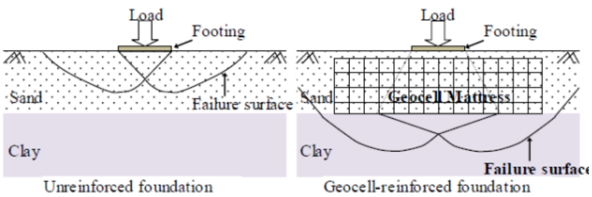

Fig.5 Foudation behavior in different configurations [30]

Each cell bearing the vertical load will generate a reaction that gradually reduces the impact of load with depth. Geocell walls under the effect of passive pressure help to limit horizontal expansion, increase density and load-bearing capacity of the cell. Additionally, the geocell walls derive interfacial resistances with surrounding soil through its apertures and develop anchorage with the soil to improve the load-bearing capacity of the reinforced-system [30].

According to A. Murali Krishna et al. [30], the optimal thickness of the geocell mattress is in the range 1-1.5D, in which D is footing diameter. As for sea sand embankment, the number of geocell layers relies on the height of the embankment and natural geology. Geocell layers are added until the roadbed reaches the designed height and stability. In Vietnam, the common geocell layer thickness for sand material is from 15cm to 18cm, which is suitable for compacting sand material.

Fig.6 Roadbed reinforcement by geocells [32]

4. EXPERIMENTAL DESIGN PROJECT

From the proposed method for the roadbed constructed with sea sand, proceeding an experimental design for practical expressway project. Nha Trang – Cam Lam Expressway project - the component projects of the North-South Expressway is chosen for experimental design. The reason for choosing Nha Trang – Cam Lam Expressway project as an experimental design project is the project's location which is located in a coastal area, convenient for transporting sea sand extracted from mines. This not only helps to significantly reduce costs for the project but also reduce fuel consumption, vehicles and environmental pollution.

4.1 Project Overview

According to the proposed plan, the project has a total length of 29km (from Km0+00 to Km29+00) passing through nine communes in two districts of Khanh Hoa province, Dien Khanh district (including Dien Tho, Dien Hoa, Dien Loc and Suoi Tien communes) and Cam Lam district (including Suoi Cat, Suoi Tan, Cam Tan, Cam Hoa and Cam Hiep Bac). The location of the project is described in Fig. 7.

Fig.7 Location of the Nha Trang – Cam Lam Expressway project [33]

The highway is designed to have 6 lanes with 4 lanes scheduled to be constructed in the first phase. In the first stage of construction, the expressway has four lanes, 17 meters wide with a design speed of 120kmph. It is component projects of the North-South Expressway to be implemented under the public-private-partnership (PPP) format with total investment capital of VND 4,000 billion.

4.2 Roadbed Design

Conduct stability analysis on the Slope/W module to evaluate the stability of alternating embankment above. The analyzed roadbed has the cross-section scale based on Nha Trang – Cam Lam expressway project, which describes in Table 3.

Table 3 Dimension of cross section elements

Elements	Dimension (m)
Roadway	14.00
Safety lane	0.5
Median strip	1.5
Shoulder	1.0
Total	17.00

Table 4 The properties of embankment materials

Model	Materials	Unit weight (kN/m^3)	cohesion (kPa)	φ (°)
Morh - coulomb	Sea sand	26.5	0	32
	Sandy soil	18.6	23.5	18.5
	Clay	19.1	33.0	16

Experiment embankment has a height of 4.2 meters, the slope of 1:2, alternating sea sand with sandy soil. The layers of sandy soil and sea sand are filled alternately, in which the thickness of each layer is 500mm. The top layer has a thickness of 680mm.

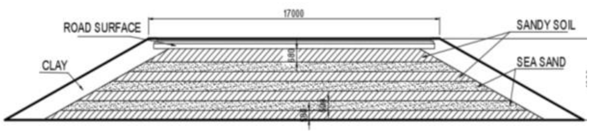

Fig.8 Experiment cross-section

Table 5 Volume of embankment material used for experiment roadbed

Material layer	Length (m)	Width (m)	Depth (m)	Volume (m^3)
Sandy soil S1	10	29.33 27.33	0.5	141.6
Sea sand S1	10	27.33 25.33	0.5	131.6
Sandy soil S2	10	25.33 23.33	0.5	121.6
Sea sand S2	10	23.33 21.33	0.5	111.6
Sandy soil S3	10	21.33 19.33	0.5	101.6
Sea sand S3	10	19.33 17.33	0.5	91.6
Sandy soil S4	10	17.33 14.61	0.68	108.6

Table 6 Stratigraphic properties below the roadbed

Layer	Unit weight (kN/m^3)	Cohesion kPa	φ (°)	Model
1c	18.3	20.6	14.7	Morh-Coulomb
3a	15.4	12.1	0	Undrain

4.3 Stability Analysis

Similar to the expressway roadbed filling by conventional material, roadbed construction by sea sand has to accommodate general requirements of the roadbed such as stable in shape, ensure sufficient strength, stable in terms of strength during the operation period. Therefore, it is necessary to evaluate the stability of the experiment roadbed by numerical analysis. Proceed stability analysis roadbed in three cases including alternating embankment roadbed, the roadbed is filled by conventional materials, and the roadbed is filled by sea sand. This will help compare the analytical results of three different types of roadbed, thereby assessing the effectiveness of the alternating embankment method.

Stability analysis of the alternating embankment according to the Bishop method gives safety factor is K = 1.445 (In this subsection, K is the safety factor of stability analysis). This safety factor is greater than 1.4, so the alternating embankment is stable according to 22TCN 262-2000 standard [34]. The alternating embankment method gives the safety factor slightly lower than the safety factor of the method of completely fill with conventional embankment material, K = 1.445 compared to K = 1.689 (Fig. 9). In addition, this safety factor is significantly greater than the roadbed filled by sea sand and covered by clay (K = 1.257). It is clear that the alternating embankment method helps to improve the stability of the embankment (from K=1.257 to K = 1.445). The analytical results show that the alternating embankment method has certain effectiveness in constructing the roadbed using sea sand.

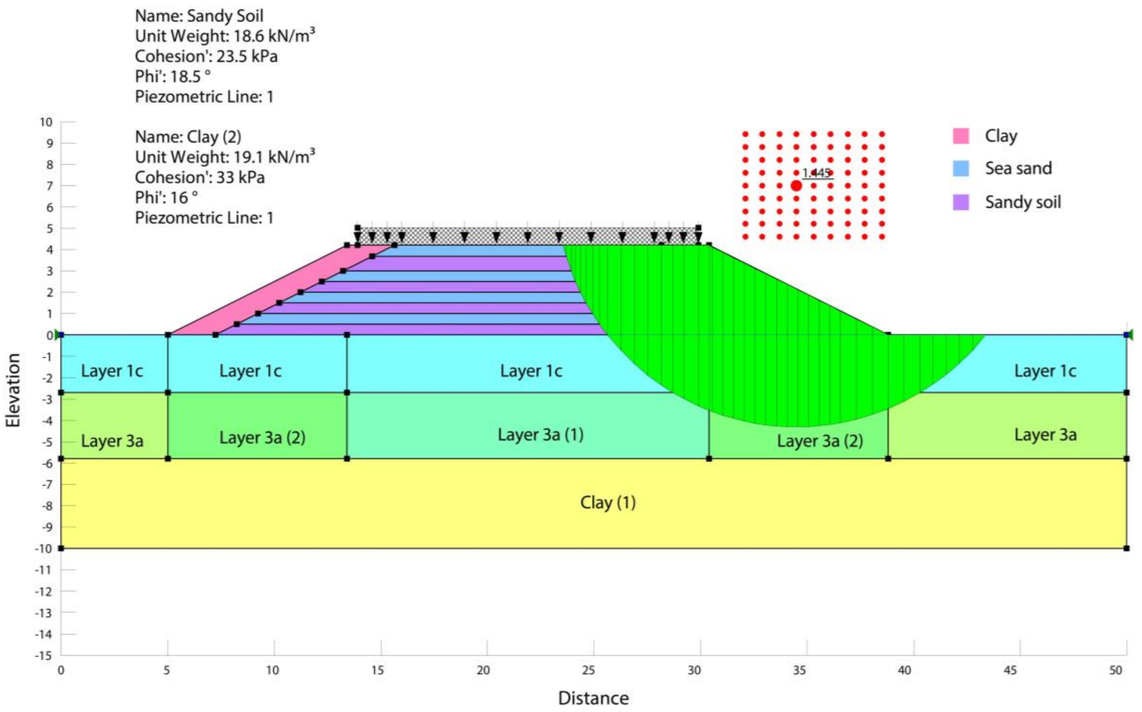

Fig.9 Stability analysis of alternating embankment

In order to clear the assessment of efficiency of the proposed method, analyzing stability with Slope/W in three cases for embankments in six different height of the embankment with the same natural geology. Case 1: Alternating embankments; Case 2: roadbed is filled by sea sand and covered by clay. The results are shown in Fig.10.

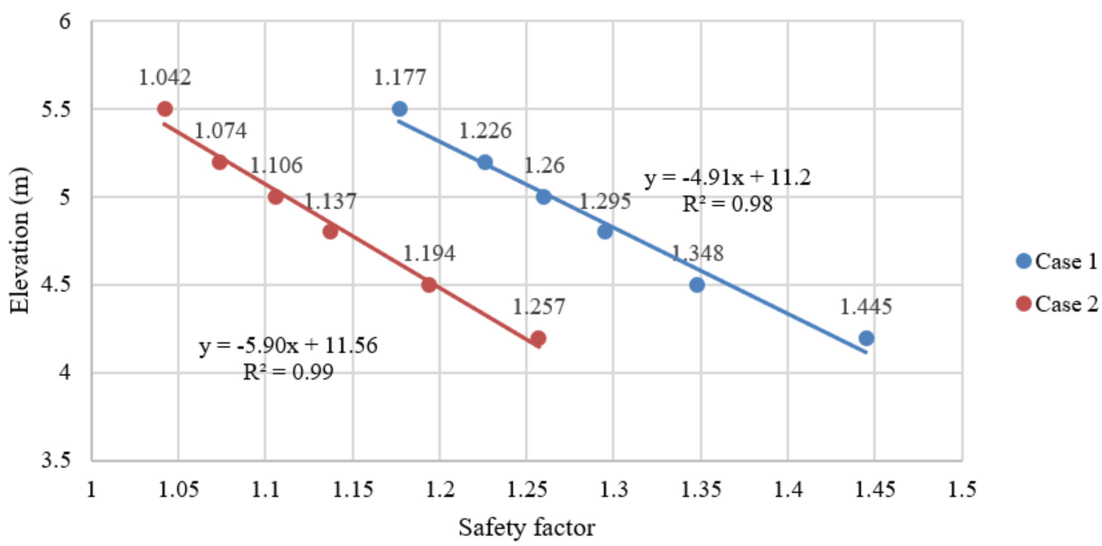

Fig.10 Stability results of three cases for embankments in six different height of the embankment with the same natural geology

As can be seen from the Fig.10, the correlation between the roadbed elevation and safety factor is a linear function. The stability results indicate that the safety factors in case 1 are significantly higher than these in cases 2. Specifically, the safety factor has increased by an average of 13.8% when applying the alternating embankment method. This proves the possibility of the alternating embankment in using sea sand in roadbed construction. Furthermore, the maximum height of the alternating embankment meeting the required safety factor according to 22TCN 262-2000 [34] (The safety factor of embankment analyzed by Bishop method must higher than 1.4) is 4.34m, while these of cases 2 are 3.3m. It is clear that the alternating embankment allows higher filling while ensuring stability.

4.4 Analyzing the Economic Efficiency of the Project

The experimental design shows that the alternating embankment method is feasible in roadbed construction by sea sand. The economic comparison between using sea sand in roadbed and using conventional embankment material will show certain economic efficiency.

According to the Price of construction materials in Khanh Hoa province in the fourth quarter of 2019 issued by the Department of Construction, the People's Committee of Khanh Hoa province and the average cost of sea sand extracting in Vietnam, the cost of materials and transportation are presented in Table 7.

Table 7. Cost of materials and transportation

Material	Price (VND/m^3)	Distance (Km)	Transp. cost ($VND/Km.m^3$)
Sandy soil	55,000	20	3,200
Sea sand	25,000	2	3,200

Table 8. Calculate material costs for 2 options (for 10m long experimental design)

Material	Unit	Volume of material		Unit price (VND)	Cost (VND)	
		Alternating embankment method	Conventional method		Alternating embankment method	Conventional method
Sandy soil	m^3	473.50	808.42	119,000x1.2	80,235,928	115,442,718
Sea sand	m^3	334.92		31,400x1.2		

The calculation result for the experimental design section with a length of 10m shows that up to 3,52 billion/km of expressway can be saved if using sea sand in the expressway roadbed construction. This brings significant economic efficiency when Vietnam’s coastal road projects are being implemented with a large total investment.

5. SOCIO-ECONOMIC EFFICIENCY AND ENVIRONMENTAL IMPACT ASSESSMENT OF UTILIZING SEA SAND FOR ROADBED CONSTRUCTION IN VIETNAM

5.1 Socio-economic Efficiency

Currently, the Vietnamese Government is approving investment and construction of coastal roads, so utilizing the large reserves of the sea sand brings great socio-economic significance in the situation that the amount of river sand in nature is predicted in short supply and depleted in the following years. According to the Decision 129/QĐ-TTg of The Prime Minister of Vietnam regarding approving the detailed planning on Vietnam’s coastal roads. In the first stage from 2010 to 2020, Vietnam will construct, upgrade and renovate about 892km of the coastal road with an estimated capital of VND16,012.69 billion and continue to implement about 1,058 km in the post-2020 period with a capital of VND12,119.62 billion. Using sea sand for coastal projects helps to utilize local materials, reduces the amount of river sand extraction. Moreover, this gives rivers time to recover the quantity of sand which are mined and decreases riverbank landslides affecting life and property of people who live in the riverbank according to the provisions of Decree No.23/2020/NP-CP on Management of river bed sand and gravel and protection of river beds, banks and terraces.

5.2 Environmental Impact Assessment

In the sea sand contains a certain amount of soluble salt. Therefore, using sea sand for roadbed construction will have several impacts on the farmland. During the construction and operation period due to the effects of weather, climatic, hydrological conditions, soluble salts and ions will be able to follow the water affecting the surrounding, especially agricultural land. Salinity can influence the growth and yield of plants, so it is necessary to have appropriate irrigation measures to minimize the effects of salinity on farmland. In addition, most of the grain size of sea sand is fine-grained. As a result, during transportation material and construction roadbed under the impacts of weather (wind, sun) will cause dust to the surrounding environment and residential areas.

Similar to the soil environment, surface water resources and groundwater can also be salty by using sea sand in roadbed construction. The salinity will affect the quality of irrigation water as well as the living of people in the project area.

The process of extracting sea sand is mainly in the form of utilizing, dredging ports and seabed, making use of wild sand dunes, thus having little impact on the environment and land resources. However, some issues should be noticed: if not properly assessed for impacts, sand extraction will lose the geological balance, change the flow, even affect the border points on the sea.

6. CONCLUSION

This paper initially evaluates the possibility of using sea sand in expressway roadbed construction in Vietnam through the comparison of sea sand properties with the requirements for embankment materials according to TCVN 9436:2012 standard. Simultaneously, proposing a method of roadbed construction using sea sand and stability analysis of an experimental cross-section by Slope/W. Initial results show that the construction of the roadbed by sea sand is highly feasible and meets most requirements of the embankment material. There are four main points making sea sand possibility to use in highway roadbed construction in Vietnam. Firstly, the alternating embankment method proposed in this paper is simple and feasible to apply in practice. Secondly, the results of stability analysis by Slope/W show that the roadbed using alternating filling method considerably improves the safety factor which increases on average 13.8% in comparison with the roadbed is filled by sea sand and covered by clay. Thirdly, a cost comparison between the roadbed constructed by sea sand and conventional roadbed shows that using sea sand brings a significant cost saving for the project. Finally, Using sea sand as an alternative material source also has a number of positive effects on the environment such as utilizing, dredging ports and seabed, making use of wild sand dunes, reducing the amount of river sand extracted annually, minimizing the impacts of river sand exploitation. In addition, through the research, there are some suggestions for the specification of construction and acceptance for the roadbed using sea sand in the future. First, during the roadbed construction stage, vehicles are not allowed to move on the roadbed, especially trucks carrying materials. Because sand is loose, even when the sand layer has been compacted to the required compactness, this layer still is rutted by the local axle load. This can affect the density and flatness of the roadbed. Therefore, it is necessary to construct immediately the sandy soil layer above the sand layer after completing the sand layer, and do not allow the truck to move over and dump material in piles then level material. Second, the clay layers should be filled immediately after completing the sea sand layers in order to reduce salinity intrusion from sea sand into the environment. This research is developed based on the authors' master thesis [35], however, it is necessary to have more researches in the direction of the experimental model to more accurately evaluate the factors affecting this material. These researches and experiments will be considered to implement in the following sections of future research.

7. ACKNOWLEDGMENTS

The article is carried out in the national-level research project funded by the Ministry of Science and Technology of Vietnam.

8. REFERENCES

[1] Gallagher, L., & Peduzzi, P. (2019). Sand and Sustainability: Finding new solutions for environmental governance of global sand resources.

[2] The economist, (2017). An improbable global shortage: sand.

[3] News Center VTV24 (2017), Vietnam forecast to run out of construction sand by 2020.

[4] http://www.bmapa.org/uses/construction.php

[5] Limeira, J., Agulló, L., & Etxeberria, M. (2012). Dredged marine sand as a new source for construction materials. Materiales de Construcción, 62(305), 7-24.

[6] http://www.marineaggregates.info/marine-aggregates-in-structural-concrete.html

[7] Peduzzi, P. (2014). Sand, rarer than one thinks. Environmental Development, 11, 208-218.

[8] Garel E., Bonne, W., Collins, M. B., & Peffer, C. (2019). Offshore sand and gravel mining.

[9] Phuong N. V. and Vinh, D. V. (2017). Some orientations to use fly ash in road construction under Vietnam conditions. Tap chi Khoa hoc Cong nghe Xay dung, 11(2), pp.22-25. http://stce.nuce.edu.vn/index.php/vn/article/view/766

[10] Hoang T., Nguyen, V. P., & Thai, H. N. (2020). Use of coal ash of thermal power plant for highway embankment construction. In CIGOS 2019, Innovation for Sustainable Infrastructure (pp. 433-439). Springer, Singapore. DOI:

https://doi.org/10.1007/978-981-15-0802-8_67
[11] Phan H.D. and Vu M.Q., Performance of consolidation techniques for improvement of newly deposited dredged mud by scale model test. International Journal of GEOMATE, Dec., 2020, Vol.19, Issue 76, pp. 134–140. DOI: https://doi.org/10.21660/2020.76.55005
[12] Muhammad R.I., Ken K., Taro U., Nguyen T.D., Tong K.T., Nguyen V.T., and Nguyen H.G., Compaction characteristics and cbr of sludge blended with recycled clay bricks for road subgrade application. International Journal of GEOMATE, Nov., 2020, Vol.19, Issue 75, pp.133-143. DOI: https://doi.org/10.21660/2020.75.39591
[13] Van Dong, N., Hanh, P. H., Van Tuan, N., Minh, P. Q., & Phuong, N. V. (2020). The effect of mineral admixture on the properties of the binder towards using in making pervious concrete. In CIGOS 2019, Innovation for Sustainable Infrastructure (pp. 367-372). Springer, Singapore. DOI: https://doi.org/10.1007/978-981-15-0802-8_56
[14] Pham T.T., Nguyen T.T., Nguyen N.L., Nguyen V.P., A neural network approach for predicting hardened property of geopolymer concrete. International Journal of GEOMATE, 2020, Vol.19, Issue 74, pp.193–201. DOI: https://doi.org/10.21660/2020.74.72565
[15] Nguyen T.T., Phan Q.M., Pham T.T., Nguyen V.P., Experimental study on mechanical and hydraulic properties of porous geopolymer concrete. International Journal of GEOMATE, 2020, Vol.19, Issue 74, pp.66–74. DOI: https://doi.org/10.21660/2020.74.41280
[16] Mai T.H., Tran N., Nguyen V.T., Nguyen V.D., Do T.Q., Nguyen C.M., Le H.M. (2016). Research on scientific basis for the planning of sustainable development of coastal sand dunes in the South Central Coast.
[17] Gutt W., & Collins R. J. (1987). Sea-dredged aggregates in concrete. Building Research Establishment Information Paper, (7).
[18] Hasdemir S., Tuğrul, A., & Yılmaz, M. (2016). The effect of natural sand composition on concrete strength. Construction and Building Materials, 112, 940-948.
[19] Liu W., Xie Y. J., Dong, B. Q., & Xing, F. (2014). Study on characteristics of dredged marine sand and the mechanical properties of concrete made with dredged marine sand. Bulletin of the Chinese ceramic society, 33(1), 15-22.
[20] Atul V. (2015). Evaluation of sea sand and river sand properties and their comparison.
[21] Xiao, J., Qiang, C., Nanni, A., & Zhang, K. (2017). Use of sea-sand and seawater in concrete construction: Current status and future opportunities. Construction and Building Materials, 155, 1101-1111.
[22] Newman K. (1968). Aspects of workability, strength, shrinkage and creep, sea dredged aggregates for concrete. In Proceedings of a Symposium, Sand and Gravel Association of Great Britain, Buckinghamshire.
[23] http://www.ccement.com/news/content/8319967782405.html
[24] Tran T.H. (2015). Researching on using sea sand to produce cement concret for construction of road pavement. Science Journal of Transportation, Issue 2, pp. 8-14.
[25] Hoang M.D., Nguyen K.T. (2017). Research on using dune sand at site for cement concrete road on Phu Quoc Island, Journal of Construction Science and Technology, Issue 3.
[26] Nguyen V.T. (2014). Research on the possibility of using natural sandy materials in the construction of coastal road in Ha Tinh. Master thesis, National University of Civil Engineering, Hanoi, Vietnam.
[27] Vo T.D. (2018). Technology for cleaning salty sand turn into construction material meets the standard TCVN 7570: 2006. Phan Thanh Clean Sand Technology Joint Stock Company.
[28] Bach L.V. (2006). Study to use sea sand of Binh Thuan and Vung Tau for production of cement concrete in road construction.
[29] TCVN 9436:2012 - Highway embankments and cuttings – Construction and quality control.
[30] Krishna, A. M., & Biswas, A. (2015). Geocell reinforced foundations.
[31] Chung W., & Cascante, G. (2007). Experimental and numerical study of soil-reinforcement effects on the low-strain stiffness and bearing capacity of shallow foundations. Geotechnical and Geological Engineering, 25(3), 265-281.
[32] http://midwestconstruct.com/geosynthetic-products/soil-stabilization
[33] The Transport Engineering Design Inc (TEDI), Profile of Technical design stage – Construction and investing component projects of The North-South Expressway, Nha Trang-Cam Lam.
[34] TCVN 262:2000 – Process of surveying the design of highway roadbeds on soft soil – Design standard.
[35] Bui N. T. (2020). Research the possibility of using sea sand in roadbed construction. Master thesis, National University of Civil Engineering, Hanoi, Vietnam.