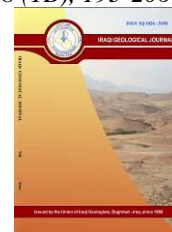




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Natural Construction Materials for Road Construction: A Case Study in Ninh Thuan Province, Viet Nam

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Abstract

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The article mentions the formation characteristics and the possibility of using natural mineral construction materials in road construction in Ninh Thuan province. Research results show that Ninh Thuan has quite rich sources of natural construction materials. Natural construction stone materials include intrusive rocks of the Deo Ca, Dinh Quan, Ca Na complexes, eruptive rocks of the Don Duong and Bao Loc Pass formations, terrigenous sediments of the La Nga formation. Natural construction soil materials include a group of relict soils weathered from on different rocks, and soils of alluvial origin (a), mixed alluvial deposits (a, ap) and marine (m) sediments. According to the potential reserves and quality of construction rocks, they can be classified in descending order into intrusive rocks, extrusive rocks and continental sedimentary rock; Soil types according to potential reserves can be ranked as apQ soils, eQ soils formed by extrusive rocks and eQ soils formed by intrusive rocks.

Keywords: Natural construction materials; Road construction; Formation

1. Introduction

In construction, many different types of materials are used. One of the common types of materials are natural soil and stone materials, widely distributed on the earth's crust. Natural construction materials are used in many different fields such as road construction, civil and industrial construction, and dam construction. To exploit and use it is necessary to research the distribution characteristics, transportability as well as evaluate the quality of this material.

In the world, different investigations have been conducted to investigate the use of natural soil and rock materials for road construction. Weinert (1980) showed that naturally occurring materials such as rock and soil constitute a significant of the materials content and cost of a road. Gidigas (1991) described of the processes of formation as well as genetic characteristics of the local gravels in West Africa. Frempong and Tsidzi (1999) studied soils in Ghana and showed that road construction costs was very high because of the limited opportunity of location suitable base material within economic haul distances The final decision of this study was that three soils have been mixed within varying proportions of readily available crushed rock aggregates and alluvial gravel for road construction. Eldin (2002) assessed the effect of traditional and industrial waste materials approved for road construction on the

surrounding environment and adjacent water bodies. Reid (2000) showed that the materials perform as well as natural aggregates, and often better than suggested by standard laboratory tests. Biswal et al. (2016) showed that suitable granular soils, aggregates or crushed stones meet the desired specifications in using for the subbase and base course materials for flexible pavements. Shukla and Patel (2019) focused on the highway construction materials its characteristics and qualities which included stone aggregates. Aleroeva et al. (2020) indicated that humidity could destroyed the foundation of road structure and water is frozen in micro cracks, breaks the coating, and at high humidity it is not recommended to use materials such as dusty sand, fine sandy loam, and dusty loam in the construction of roads. Halushko et al. (2020) studied the technology of road surface construction using alternative materials and the possibility of introducing automated systems to increase productivity. Kamal and Bas (2021) showed that the effect of road construction materials on traffic safety is key to the felicitous achievement of roadways virtue plans of management and reviewed in particular the innovative used to enhance the properties of materials used in transport structures that deals with increasing road strength and durability as well as traffic safety improvement to reduce roadways accidents. Kodithuwakku et al. (2023) analyzed the alternative materials for sustainable in road construction in Sri Lanka and indicated that fly ash, scrap rubber tyres, and building and demolition debris can be used for road construction. Akoudad et al. (2024) indicated road construction in shales may be make the instability when road embankments cut into these shales. Noori et al. (2023) used classification methods, and geophysical and geotechnical investigation approaches to provide realistic rock mass properties for a building foundation, compare results, and assess effectiveness of techniques.

In the Ninth Thuan province, in the past and upcoming years, road system has received a lot of attention. Ninh Thuan has made good progress, especially investing in new construction or upgrading and repairing, completing according to planning, a number of large and important projects such as: coastal roads, including 2 large bridges: An Dong and Ninh Chu; Tan Son - Ta Nang road; road connecting North - South expressway with National Highway 1; Hai Thuong Lan Ong street; Double road leading to both ends of Phan Rang - Thap Cham city; Van Lam Son Hai; Northern Belt, North-South Expressway, Highways 1, 27B and 27... From 2011 to the end of 2020, the total number of kilometers of newly invested and upgraded roads is 1,424.75 km; Road density compared to natural area increased from 0.34 to 0.424 km/km²; Road density compared to population increased from 2.02 to 2.48 km/1000 people. It is expected that by 2030, investment in new construction will be about 200km, upgrading, repairing and expanding about 80km, increasing road density compared to natural area from 0.424 to 0.48km/km² and compared to population increased from 2.48 to 2.82 km/1000 people. In addition, the road system, internal roads in coastal industrial zones, etc. are also gradually completed according to scale and population. Faced with that urgent task, the demand for construction materials, including natural materials, is increasing. However, the characteristics of natural construction materials in Ninh Thuan province have not been clearly presented. Therefore, this study will aim to show the characteristics of the potential source of natural construction materials and the ability to use it to serve the construction of road in Ninh Thuan province.

2. Study Area and Methods

2.1. Study Area

Ninh Thuan is a coastal province on the South Central Coast of Viet Nam, located at the intersection of three strategic traffic axes of National Highway 1A, Thong Nhat Railway and National Highway 27 to Da Lat. Ninh Thuan has Phan Rang - Thap Cham city which is the economic and political center, about 60 km from Cam Ranh International Airport, very close to major economic and tourist centers of the country. These are extremely favorable conditions to help Ninh Thuan in developing, exchanging,

and cooperating in many fields with the world and other localities throughout the country. The topography characteristics of Ninh Thuan is shown in Fig 1.

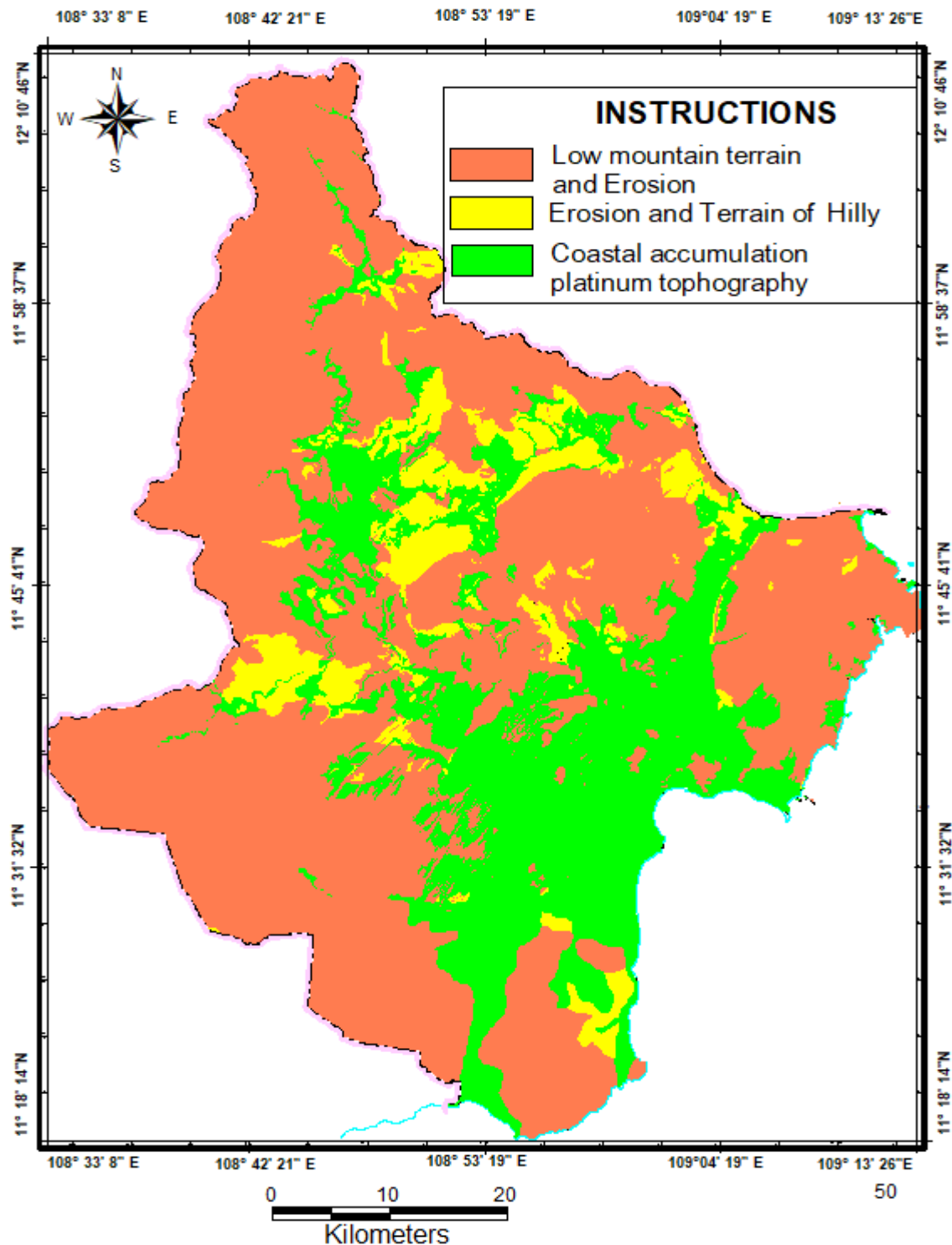


Fig. 1. Topography characteristics of Ninh Thuan province, Viet Nam

2.2. Methods

The summary of the research methods used in this study are showed in Fig. 2. Firstly, natural construction materials was validated by collected documents such as administrative maps, statistical data, topographic maps, geological map). Secondary, the field investigation and analysis of remote

sensing images in google earth in 2024 were carried out. At each location, description, drilling or excavating, and sampling for testing were carried out. After that, finally, the components of natural construction material was discussed.

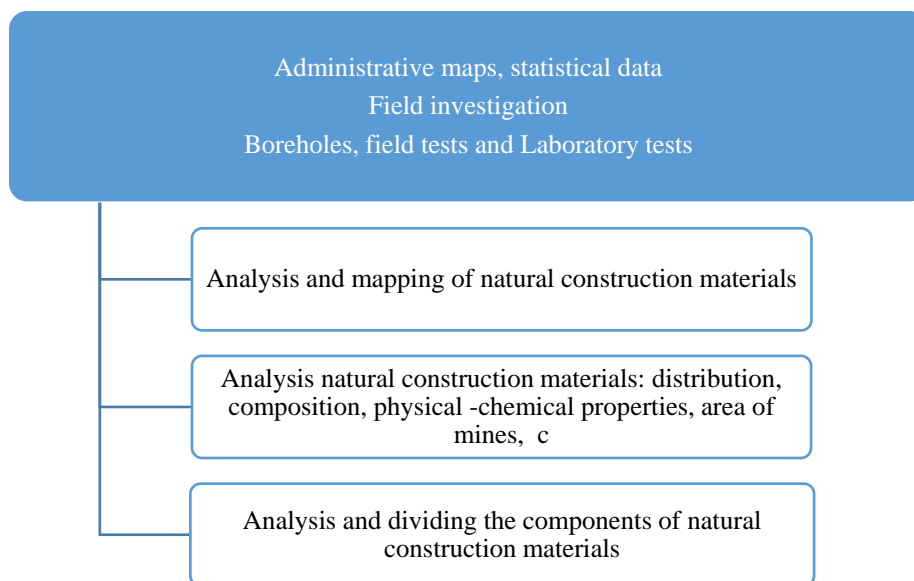


Fig. 2. Methodology used in study of natural construction materials

Firstly, Site investigation is carried out. Field survey work was carried out throughout the entire Ninh Thuan province. At survey locations, soil and rock types were identified, The distribution of natural stone materials and natural soil materials were determined, as well as soil and rock types are classified according to their origin. Drilling and experimental sampling to determine physical and mechanical properties of soil and rock types were carried out. Dig holes were carried out to determine the cross-sectional patterns of the weathered crust.

Secondly, the physico – mechanical properties of rocks were investigated in laboratory. The total samples were 250. Water content was tested according to ASTM D4643 -17. Density and Unit Weight of rock were determined in accordance with ASTM D7263 -21. Specific gravity of rock was investigated in accordance with ASTM 6473. Compressive strength of rock was determined according to ASTM 7012 - 23. Other properties of rock are calculated from experimental criteria.

Just like rocks, the physico – mechanical properties of soils were investigated in laboratory. Water content was tested according to ASTM D4643 -17. Density and Unit Weight of Soil Specimens were determined in accordance with ASTM D7263-21. Specific gravity of soil was investigated in accordance with ASTM D854-23. Liquid Limit, Plastic Limit, and Plasticity Index of Soils are investigated according to ASTM D4318-17e1. Minimum Void ratio and maximum void ratio were tested bay ASTM D2454. Other physical properties of soil are calculated from experimental properties. Shear strength of fine soils in unconsolidated undrained was tested according to ASTM D 6528 -17. Compression index of soils are measured in accordance with ASTM D2435 -11. The angle of repose according to the ASTM C1444 was tested.

Finally, the area of mines and forecast resources of each type of natural rock materials and natural soils are determined.

3. Results and Discussion

The research results on natural construction materials are shown in Fig. 3. From the research results, it shows that in Ninh Thuan, there are two sources of natural construction materials including natural stone materials and natural soil materials.

3.1. Natural Stone Materials

Construction stone sources in Ninh Thuan have been and will be exploited mainly from intrusive complexes and extrusive rock formations, showed in Figs 4, 5, 6 and Table 1. The rocks have quite good quality and quite large resource reserves.

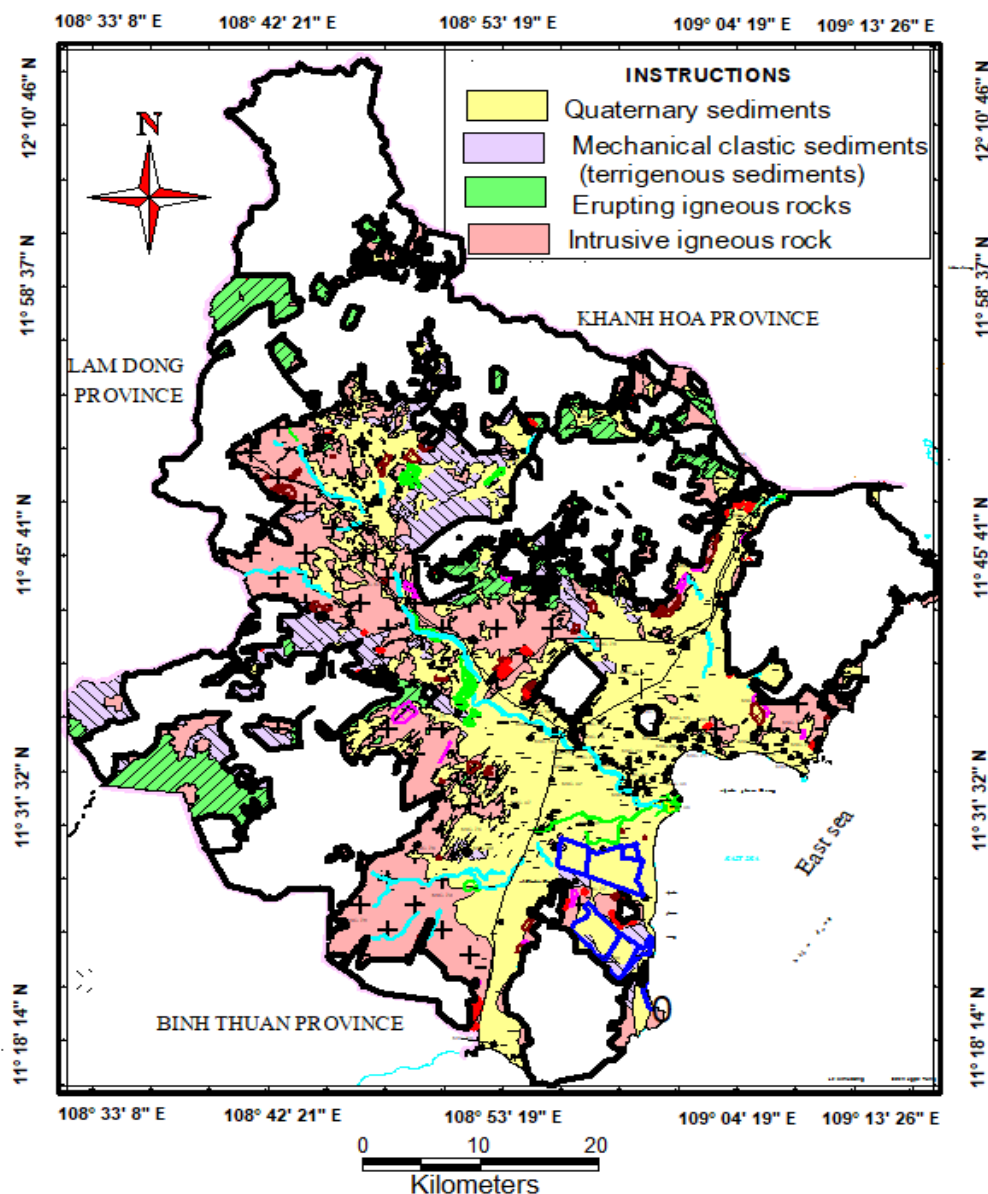


Fig. 3. Distribution of natural construction materials in Ninh Thuan province, Viet Nam

Intrusive rocks: The layer mainly composed of granite belonging to the K_1dc , K_2cn and K_1dq complexes. K_1dc rocks are exposed in the areas of Krong Pha pass, Tra Co river, Tan My bridge, Ca Na..., distributed as same as blocks with sizes ranging from a few square kilometers to over 100 square kilometers and Nui Chua blocks (300km^2), Da Cao Mountain (50km^2), Hon Rong (25km^2), west Ta Luong (15km^2), Cam Ranh peninsula (40km^2). K_2cn rocks (Nam Ninh Thuan) is quite widely distributed in the area around Da Lat and Ca Na. In addition, they are also scattered in the areas of Da Bro mountain (Phan Rang), Southeast Di Linh, Phan Dung, northeast of Tan My bridge, Chua mountain, Da Cao mountain, west of Hon Dau mountain, ... were distributed as same as blocks ranging in size from small (about 1km^2) to hundreds of km^2 . Rocks belonging to K_1dq formation are distributed mainly in the areas of Ninh Phuoc and Bac Ai districts.

Eruptive rocks: These rocks belong to Don Duong and Nha Trang Formation, has neutral and acidic composition. In general, rocks was very hard, easy to exploit and very suitable for use as aggregate for road construction, concrete and other needs. Some areas have had geological research and the quality of construction stone is satisfactory to meet market demand such as Ong Ngai Mountain, Dat Mountain, Co Lo Mountain (Thuan Bac district), Tieng Mountain, Giai Mountain (Ninh District). Son), Ta Lien Mountain (Bac Ai district), Phuoc Diem (Lac Tien), Da Giang mountain, Cha Bang, Magic mountain (Thuan Nam district). Currently, there are about 22 mines and construction quarries have been discovered, investigated and surveyed with a total forecast resource of about 2828.6 million m³, on a total distribution area of about 43.3 km². This raw material source is distributed in different areas (Fig. 3).

Terrigenous sedimentary rocks: These rocks only belong to only La Nga formation (J₁ln). The composition of the rocks in the upper part include sandstones, siltstones interspersed with claystones, the lower part is mainly siltstones and claystones. Due to the narrow distribution area, the quality of the stone is not high. This type of rocks also receives little attention.

Biochemical sedimentary rocks: mainly carbonate rocks, this mineral is found in the form of soda and coral in coastal areas. There are 4 soda storage sites discovered since 1935 by Saurin in Hoa Trinh, Van Lam, Phuoc Dong 1, Phuoc Dong 2 in Thuan Nam and Ninh Phuoc districts, Ninh Thuan province. The points are 2-10 km apart, surrounding Phan Rang - Thap Cham City. Each site is 0.5 - 1.5 hectares wide, located on Holocene yellow-brown sand accumulation. An Thanh sodium carbonate soda salt ore site is distributed over an area of about 200m², where the salt layer is white, opaque with thick of 1 centimeters. Rock contains 12.75% H₂CO₃, 9.01% Na₂CO₃; 1.87% Na₂SO₄, 1.75% NaCl, 6.8%NaOH; 0.29%MKN. Fixed residue composition include of Na₂CO₃ of 70.5%, Na₂SO₄ was 11%; NaCl was 14%.



Fig. 4. Outcrop at Cha Bang Granite quarry



Fig. 5. Outcrop of granite of Ca Na complex at Ca Na port



Fig. 6. Outcrop of La Nga formation at national highway 27B

Table 1. Physico - Mechanical properties used as construction materials in Ninh Thuan, Vietnam

Physico - Mechanical properties	Granite					Bedrock
	Sandstone	Rhyolite	Strongly weathering	Moderately weathering	Slightly weathering	
Water content, %	4.45	4.7	4.18	2.59	1.22	1.30
Unit weight, kN/m ³	21.2	25.1	25.3	26.6	26.1	27.4
Dry unit weight, kN/m ³	20.3	24.0	24.3	26.0	25.8	27.1
Specific gravity, kN/m ³	27.5	27.8	27.7	27.8	27.9	27.9
Void ratio, e	0.36	0.16	0.15	0.07	0.08	0.03
Porosity, n, %	26	14	12	7	8	3
Water absorption, G, %	3.1	3.0	1.9	1.6	0.5	0.5
Compressive strength, R, MPa	2.7	4.9	24.1	76.0	113.3	141.4
Saturated compressive strength, R _{bh} , MPa	4.2	8.1	31.5	89.5	118.0	147.7
Softening coefficient, K _m	0.63	0.60	0.68	0.85	0.96	0.96

The forecast resources of rocks used as construction materials in Ninh Thuan province are shown in Table 2. As showed as in Table 2, granite is the most common rock in Ninh Thuan province and distributed in Ninh Hai district, Bac Ai district, Ninh Son district, Ninh Phuoc district and Thuan Nam district. The eruptive rocks distributed in Thuan Bac district.

Table 2. Forecast resources of rocks used as construction materials in Ninh Thuan province

Location	No	Name of mines	Types of rocks	Area of mines (ha)	Forecasting resources (Million m ³)
Thuan Bac district	1	Giac Lan	Eruptive rocks	8.900	1.059
	2	Co Lo			
	3	Tay Ca Rom	Granite		
	4	Ba Phao Kich mountain			
	5	Ong Ngai			
Ninh Hai district	6	Da Dai mountain	Granite	1.900	182.2
	7	Ong Cau mountain			
	8	Nui Quyt mountain			
Bac Ai district	9	Ta Lien mountain	Granite	5.600	338.6
	10	Ma Tu mountain			
	11	Tieng mountain			
	12	Hon Gio mountain			
	13	Do mountain			
Ninh Son district	14	Do Cam Lien mountain	Granite	16.600	908.6
	15	Hon Giai mountain			
	16	Ngong mountain			
	17	Thon Do			
Ninh Phuoc district	18	Nui Chot	Granite	880	18.4
	19	Hon Bang mountain			
	20	Gop Dai			
	21	Mong Liem			
Thuan Nam district	22	Jaty Mine	Granite	10.360	314.8
	23	Nui Giang			
	24	Lac Tien			
	25	Magic			

3.2. Natural Soil Materials

There are many different types of soil used for construction materials, which can be divided according to their origin and showed in Table 3 and Fig. 7.

Residual soil group (eQ): These soils include weathered residual soils from granitic intrusive igneous rocks and eruptive rocks of the Deo Bao Loc formation, eruptive rocks of the Don Duong formation and mechanically clastic sedimentary rocks of the La Nga formation. Below are some typical weathered crust sections on some common bedrock types as shown in Table 3. As compared with the results of Jaafer et al. (2024), the soil can be divided in three zones, the first zone extends at 2 to 9 m depth including three layers, and the second zone extends at (9 to 15) m depth in Basrah City, Southern Iraq.

Table 3. Section of weathered crust on some typical bedrocks

Weathering zone and sub-zone	Distribution depth (m)	Thickness (m)	Description of soil and rock
The rocks of La Nga J_2ln formation in Phuoc Binh commune, Bac Ai district			
Land zone - V	0 - 1.5	~ 1.5	Grayish brown, sandy clay, clayey sand with some gravels and plant remains
Dispersion zone (completely weathered zone) - IV	1.5 - 4.2	2.7	Yellowish gray, brownish gray, whitish gray, sandy clay, clayey sand with gravel
Strong weathering zone (gravel clay) - III	4.2 - 10.0	5.8	Yellowish grey, brownish grey, brown, small, very dense, grit, gravel
Medium weathering zone (Clocked zone) - II	10.0 - 15.0	5.0	The original rock weathered into blocks. The cracks are filled with debris. The surface of large cracks shows that the original rock composition has changed. The original rock is cracked but still intact.
Lightly weathered zone -I	>15.0		The crack surface has not changed color. The rock is still solid, white gray, blue gray RQD = 75 - 90%
The rocks of La Nga K_2dd formation in Phuoc Tan commune, Bac Ai district			
Land zone - V	0 - 0.5	~ 0.5	Grayish brown, gray, loose, sandy clay with some gravels and plant remains
Dispersion zone (completely weathered zone) - IV	0.5 - 5.5	5.0	Upper layer: The thickness is 1 meters. There are composed of yellowish grey, greyish brown, blueish gray, dense to very dense, clayey sand with sand, gravel or small grit. Lower layer: Bedrock weathered completely into bluish gray, grayish brown, dense, clay, sandy clay, and in some places there contains grit, gravel.
Strong weathering zone (gravel clay) - III	5.5 - 8.0	2.5	Brownish gray, dense, clayey gravel
Medium weathering zone (Clocked zone) - II	8.0 - 15.0	5.0	Greenish gray, cracked, rhyolite is moderately weathered, green-gray cracked. Rock-quality designation (RQD) is 65%.
The rocks of Deo Bao Loc $J_3 dbl$ formation in Ma Noi commune, Ninh Son district			
Land zone - V	0 - 0.3	~ 0.3	Yellowish gray, grayish brown, loose, sandy clay with a lilte gravel
Dispersion zone (completely weathered zone) - IV	0.3 - 3.5	~3.2	Yellowish brown, greyish brown, whitish gray, stiff to very stiff, clay, sandy clay with a lilte gravel
Strong weathering zone (gravel clay) - III	3.5 - 12.5	9.0	The rock is completely weathered into yellowish gray, brownish gray, dark gray, very dense to dense, gravel, clayey sandy.
Medium weathering zone (Clocked zone) - II	12.5 - 20.0	7.5	Andesite rock is weathered, cracked, blue-gray, white-gray, in medium hard state. Rock-quality designation (RQD) is 26%

As shown in Table 3 and Fig. 7, there are some comments:

Alluvial soil group (a): distributed along the valleys of Da Dang, Da Nhim, and Cai Phan Rang rivers. Because their distribution area is too narrow, on the 1:200,000 scale map, they are merged into river sediments of Quaternary age without division. The composition consists mainly of coarse particles: sand, pebbles, gravel and many boulders. Sediment thickness is 2-10m. The youngest sediment is a low mudflat with an absolute age of C14 from the tree trunk giving a value of 1100 ± 50 years. In shelf II (Da Nhim river shelf), from tree trunks mixed in pebbles, C14 analysis gave a value of $33,000 \pm 100$ years.

Soil group of marine origin (m): includes saline silica sand, this source is abundant and can be used as construction material for transportation; Offshore or coastal coral sand can also be used to build traffic and housing.

Soil group of mixed alluvial and flood origin (ap): has the most widespread distribution, often scattered into small areas in the delta part of the province, along large rivers and streams in the region. Sediment composition is heterogeneous, often consisting of alternating layers of sand, clay, and gravel. Stratigraphy of Quaternary sediments in some typical boreholes in the Ninh Thuan province delta is shown in Table 4, Table 5, Table 6.



Fig. 7. Sandy clay mine (ap) mixed with quartz sand, feldspar, upper manure mixed with iron oxide deposits in Hoa Son commune, Ninh Son District, Ninh Thuan province

Thus, as shown as in Tables 4, 5, 6, the sedimentary soil layers have many different origins, are located next to each other, and the thickness is usually not large. The thickness of soil was commonly approximately 10m. Due to the influence of terrain and climate, the land distribution characteristics in Ninh Thuan also have their own characteristics.

Groups of weathered residual soils from intrusive rocks are often thin or absent on the surface of the original rock. The main reason is that the terrain developed on these rocks is often steep so they are washed away strongly.

Table 4. Stratigraphy at some locations in the delta of Ninh Thuan province

No layer	Origin of soil and rock (age)	Distribution depth (m)	Thickness (m)	Description of soil and rock
<i>Thanh Tin Primary School, Phuoc Hai Commune, Ninh Phuoc District</i>				
1	nQ	0 - 0.5	0.5	Backfilling sand: Fine-medium grained, yellow-gray, medium dense, sand
2	aQ	0.5 - 2.5	2.0	Blueish grey, darkish gray, firm, sandy clay
3	aQ	2.5 - 4.5	2.0	Grayish brown, greyish yellowish, firm, clayey sand
4	aQ	4.5 - 6.5	2.0	Gray, stiff to very stiff, clay
5	(ap) Q	6.5 - 15.0	8.5	Yellowish gray, whitish gray, greyish brown, stiff to very stiff, clayey sand with gravel
<i>Phuoc Dan town, Ninh Phuoc district</i>				
1	aQ	0 - 4.2	4.2	Yellowish gray, whitish gray, greyish brown, stiff to very stiff, sandy clay
2	K ₂ đc	4.2 - 12.0	7.8	Light gray, hard granite
<i>Phan Rang City, Thap Cham</i>				
1	aQ	0 - 5.0	5.0	Gray, loose, fine sand
2	mQ	5.0 - 8.0	3.0	Gray, soft to very soft sandy clay with a few shells
3	(ap) Q	8.0 - 11.0	3.0	Grey, stiff to very stiff, sandy clay with gravel
4	J ₂ ln	>11		Gray, hard, sandstone, siltstone

Table 5. Physico - Mechanical properties of sandy soil

Physico - Mechanical properties	Origin of soil					
	eQ	eQ	eQ	eQ	eQ	eQ
Gravel,%	0.0	20.3	25.5	15.2	18.5	31.5
Sand,%	80.0	63.3	55.0	64.6	65.5	44.5
Silt,%	20.0	16.3	19.5	17.0	16.0	16.5
Clay,%	0	0	0	3.2	0	7.5
Unit weight, γ , kN/m ³	17.6	19.1	18.0	19.4	18.6	19.3
Dry unit weight, γ , kN/m ³	16.3	17.5	16.7	18.1	17.2	17.5
Void ratio,e,%	0.602	0.507	0.589	0.452	0.537	0.595
Porosity, n,%	37.6	33.6	37.0	31.1	34.9	33.5
Water content, W,%	7.73	9.06	9.08	7.06	8.43	10.27
Minimum unit weight, γ , kN/m ³	16.6	17.8	17.0	18.5	17.5	18.0
Maximum Unit weight, γ , kN/m ³	18.3	19.6	18.7	21.2	19.3	19.8
Specific gravity, γ , kN/m ³	26.1	26.3	26.2	26.4	26.4	26.3
Minimum Void ratio, e _{min}	0.537	0.463	0.534	0.410	0.484	0.466
Maximum Void ratio, e _{max}	0.640	0.609	0.687	0.551	0.633	0.613
Density, D	0.57	0.70	0.64	0.71	0.65	0.74
Angle of repose at dry states, degree	36.1	43.5	37.1	44.1	34.6	42.7
Angle of repose at saturation states, degree	39.4	46.8	40.4	47.4	37.9	46.0

Table 6. Physico - Mechanical properties of clayey soil

Physico - Mechanical properties	Origin of soil	
	eQ	eQ
Gravel,%	10.8	8.0
Sand,%	45.8	50.5
Silt,%	24.8	24.0
Clay,%	18.5	17.5
Liquid limit, W_L , %	35.1	37.2
Plastic limit, W_P , %	22.2	23.8
Plasticity index, I_p	12.8	13.4
Liquidity index, I_s	-0.13	-0.09
Water content, %	23.8	25.0
Unit weight, γ , kN/m^3	18.3	18.5
Dry unit weight, γ_c , kN/m^3	14.8	14.8
Specific gravity, Δ , kN/m^3	26.7	26.8
Void ratio, e	0.808	0.806
Porosity, n,%	44.5	44.6
Degree of saturation, G_s , %	79.2	83.2
Cohesion, C, kPa	26.4	25.6
Internal friction angle, ϕ , degree	22.2	23.3
Coefficient of compression, kPa^{-1}	4.67	4.60
	3.22	3.65
	2.68	2.50
	1.75	1.45
Deformation Modulus, E_0 , MPa	12.31	11.51

The residual soil group developed on extrusive rocks which mainly belongs to Don Duong formation usually has greater thickness. The main reason is that the terrain here is often lower, gentler hills, more developed vegetation, and bedrock has a weaker resistance to weathering agents.

The soil group developed on mechanically crushed sedimentary rocks which mainly belongs to La Nga formation also has a greater thickness, and the conditions are similar to the residual soil on erupted rocks. However, in terms of composition, it is more resistant to weathering than the volcanic rocks of the Don Duong formation, so the thickness of the weathered layer is thinner.

Soil groups of alluvial origin are also less common because the Ninh Thuan's terrain is mainly mountainous and steep, so the rivers are short, the river bed slope is large, and the ability to accumulate river sediment is limited. Sediment components are mainly loose soil. In addition, Nu et al.(2020a, 2020b), Luan et al. (2021), Khuyen et al. (2024), Son et al. (2020) showed that the soft soil of alluvial origin widely distributed in other areas of Viet Nam.

Soil groups of alluvial pluvial soil (ap) and alluvial diluvia pluvial (adp) soil was distributed in large area. The main reason is still determined by terrain and climate. The composition of the soil is of low fineness, sometimes mixed with weathering primary minerals (feldspar).

Soil group of marine origin has a narrow distribution range, found in narrow coastal strips and the soil is often contaminated with soluble salts. The marine soil group includes discrete soils such as sea sand and mud mixed with sea sand due to alluvial deposits from rivers.

Finally, the forecast resources of some types of soil construction materials in Ninh Thuan province of Viet Nam showed in Table 7.

Table 7. Forecast resources of some types of soil construction materials in Ninh Thuan province

No	Soil type	Location	Area of mines (ha)	Forecasting resources (Million m ³)
1	eQ	Ba Rau mountain, Ong Ngai, Tay Hon Dung, Thuan Bac District	5 800	23.5
2	eQ	Ong Cau Mountain quarry (Thanh Hai commune); Quyt Mountain (Tri Hai commune), Ninh Hai district	3300	19.8
3	eQ	Phuoc Tien, So Ngang, Deer Mountain, Phuoc Chinh, Bac Ai District	4800	24.2
4	eQ	Tan Binh, Lam Son (Lap La village), Hon Ngang, Goose Mountain, Luong Tri, Hoa Son, Hon Giai, My Hiep, Ma Noi (Do village), Hanh Tri, Tan Lap 2, Ninh Son District	4300	28.5
5	ap, adp, mQ, pQ ₂	Hoa Thanh, An Hai, Hoai Trung, Phuoc Thai Chong Mountain, Phuoc Huu, Phuoc Vinh, Ninh Phuoc District	16200	162.36
6	mQ _{1pt} , N _{2mv}	South of Mavieck Mountain, Northwest of Mavieck Mountain, Phuoc Dinh, West of Cha Bang Mountain, Thuan Nam district	4200	16.84

From the research results in Table 7, it shows that alluvial soil (eQ) accounts for about 34.9% of the distribution in Thuan Bac, Phuoc Chinh, Bac Ai, Ninh Son districts. Soils (ap, adp, mQ, pQ₂) account for the largest area, accounting for about 58.9%, distributed in Phuoc Huu, Phuoc Vinh, and Ninh Phuoc districts. The marine soils (mQ_{1pt}, N_{2mv}) are distributed in Thuan Nam district.

4. Conclusions

Ninh Thuan province has more than 3/4 of the area of low mountains and hills with hot and dry tropical climate, high radiation and temperature. Ninh Thuan has the lowest rainfall in Vietnam, in which the evaporation is higher than rainfall... This province also has quite complex geological conditions, including a large area of intrusive rocks, a smaller area of extrusive rocks and terrigenous sediments.

Ninh Thuan is rich in construction stone resources, especially intrusive stones. Rocks used for construction materials include: granitic intrusions of all types (acid and neutral), sedimentary rocks (volcanic and terrigenous) of different complexes and formations with large reserves, quite good quality, and quite convenient exploitation to serve road construction.

The soil construction material resources are not poor but not rich either, consisting mainly of soil originating from weathered remains from erupted rocks (common on bedrock of the Don Duong formation), terrigenous sediments; soils of river and flood origin (ap).

Among the types of soil used as road embankment materials, weathered residual soils on erupted rocks of the Don Duong formation have a wide distribution range. These soils have been used for building of some roads in Ninh Thuan province. However it has been confirmed that such soils have swelling and shrinkage properties. Therefore, additional research is needed for the future

References

- Aleroeva, L.S., Magomadov, I.Z., Mamasurov, S.K., Mamatsuev, R.A., Aptaeu, K.K., Aisungurov, N.D., Istamulov, A.M., Bekishev, A.L., 2020. Materials used in the construction of roads, IOP Conference Series:

- Materials Science and Engineering, 905 (2020), 012002. <https://iopscience.iop.org/article/10.1088/1757-899X/905/1/012002/pdf>.
- Akoudad, A., Asmi, H.E., Qandil, M.E., Zian, A., Senhaji, A.S., Zandar, S., Darkik, I., Marzouki, A., Bargach, K., 2024. The role of geological and geotechnical factors in shale slope instability: case of landslides on road embankments (Tizi Ouadrene Sector-Rif Extern, Morocco). *Iraqi Geological Journal*, 57(1B), 83-97. <https://doi.org/10.46717/igj.57.1B.7ms-2024-2-16>.
- Biswal, D.R., Sahoo, U.S., Dash, S.R., 2016. Characterization of granular lateritic soils as pavement material, *Transportation Geotechnics*, 6, 108-122. <https://doi.org/10.1016/j.trgeo.2015.10.005>.
- Eldin, N.N., 2002. Road construction: materials and methods. *Journal of Environmental Engineering*, 128(5), 423-430. [https://doi.org/10.1061/\(ASCE\)0733-9372\(2002\)128:5\(4](https://doi.org/10.1061/(ASCE)0733-9372(2002)128:5(4).
- Frempong, E.M., Tsidzi, K.E.N., 1999. Blending of marginally suitable tropical sub-base materials for use in base course construction. *Construction and Building Materials*, 13(3), 129-141. [https://doi.org/10.1016/S0950-0618\(99\)00015-X](https://doi.org/10.1016/S0950-0618(99)00015-X).
- Gidigas, M.D., 1991. Characterization and use of tropical gravels for pavement construction in West Africa. *Geotechnical and Geological Engineering*, 9, 219-260.
- Halushko, V., Halushko, A., Uvarov, D., Uvarova, A., 2020. Selection of effective material for road construction. *Technology Audit and Production Reserves*, 5(1), 33-36. <http://doi.org/10.15587/2706-5448.2020.215048>.
- Jaafer, I.M., Salih, A.H., Laftah, A.A., Al-Khersan, E.H., 2024. Engineering site investigation inside Basrah city, southern Iraq using cross-hole seismic refraction technique (A case study). *Iraqi Geological Journal*, 57(1E), 52 -71. <https://doi.org/10.46717/igj.57.1E.4ms-2024-5-15>.
- Kodithuwakku, H.D.D.P., Ramachandra, T., Kajavathani, P., 2023. Alternative materials for sustainable road construction in Sri Lanka. *Proceedings of the 11th World Construction Symposium*, 110-122. <https://doi.org/10.31705/WCS.2023.10>.
- Kamal, I., Bas, Y., 2021. Materials and technologies in road pavements - An overview. *Materials Today Proceedings*, 45(5), 2660-2667.
- Khuyen, N.H., Nu, N.T., Duong, N.T., Son, B.T., Binh, B.V., 2024. analysis instability of the riverbank – a case study of Tien Riverbank in Cai Be district, Tien Giang province, Vietnam. *Iraqi Geological Journal*, 57(1E), 72-90. <https://doi.org/10.46717/igj.57.1E.5ms-2024-5-16>.
- Luan, V.N., Nu, N.T., Toan, D.M., 2021. Consolidation properties of Ho Chi Minh city soil, Vietnam. *Iraqi Geological Journal*, 54(1A), 1-10. <https://doi.org/10.46717/igj.54.1A.1Ms-2021-01-22>.
- Noori, K.M.G., Alshkane, M.A.Y., Rashed, K.A., 2023. Geotechnical and geophysical investigations of estimating rock mass properties. *Iraqi Geological Journal*, 56(2B), 39-64. <https://doi.org/10.46717/igj.56.2D.4ms-2023-10-10>.
- Nu, N.T., Duong, N.T., Son, B.T., Thinh, P.T., 2020a. Investigation of salt, alum content in soft soils and their effects on soil properties: case study in coastal areas of Vietnam. *Iraqi Geological Journal*, 53(2A), 19-34. <https://doi.org/10.46717/igj.53.2A.2Rw-2020-08-02>.
- Nu, N.T., Toan, D.M., Thinh, P.H., Son, B.T., 2020b. Determination of particles and minerals content in soft clay soil of the Mekong delta coastal provinces, southern Vietnam for inorganic adhesives stabilization. *Iraqi Journal of Science*, 61(4), 791-804. <https://doi.org/10.24996/ij.2020.61.4.11>.
- Reid, J.M., 2000. The use of alternative materials in road construction. *Transport Research Laboratory*.
- Shukla, A.K., Patel, S.S., 2019. A concept of using local materials in road construction. *International Research Journal of Engineering and Technology (IRJET)*, 4(5), 1775-1783.
- Son, B.T., Nu, N.T., Duong, N.T., Ngoc, N.A., 2020. Application the point foundation (pf) method for soft soil improvement: a case study from Vietnam. *Iraqi Geological Journal*, 53(2D), 1-18. <https://doi.org/10.46717/igj.53.2D.1MS-2020-10-23>.
- Weinert, H.H., 1980. Natural road construction materials of southern Africa, *Research Space*, 298.