Feasibility Analysis of Timor Island Mountain Rock as Selected Fill Material for Road Construction: West Kupang Quarry

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ABSTRACT

The use of locally available materials can reduce material-mobilization constraints in road construction, but their engineering suitability must be established through laboratory evaluation. This study evaluates mountain rock from the West Kupang Quarry, Timor Island, as selected fill for road construction using available physical and mechanical test data and the General Specifications of Bina Marga 2018 Revision 2 as the technical reference. A laboratory experimental method with a descriptive-quantitative approach was applied. The tests included specific gravity and water absorption, compaction, and soaked California Bearing Ratio (CBR). The material showed a bulk specific gravity of 2.559, SSD specific gravity of 2.601, apparent specific gravity of 2.669, and average water absorption of 1.658%. The maximum dry density was 1.881 g/cm³ at an optimum moisture content of 6.29%. The CBR reached 39.14%, exceeding the referenced minimum value of 10% for selected fill. These results indicate favorable density and bearing-capacity characteristics and support the potential use of the material in road earthworks. Nevertheless, gradation and plasticity data were not available in the evaluated laboratory dataset; therefore, additional testing is required before complete compliance and final field acceptance can be confirmed.

Keywords: *selected fill; California Bearing Ratio; compaction; local material; West Kupang Quarry*

ABSTRAK

Pemanfaatan material lokal dapat mengurangi kendala mobilisasi material pada konstruksi jalan, tetapi kelayakan teknisnya harus dibuktikan melalui pengujian laboratorium. Penelitian ini mengevaluasi batu cadas gunung dari Quarry Kupang Barat, Pulau Timor, sebagai urugan pilihan pada konstruksi jalan dengan menggunakan data pengujian fisik dan mekanis yang tersedia serta Spesifikasi Umum Bina Marga 2018 Revisi 2 sebagai acuan teknis. Penelitian menggunakan metode eksperimental laboratorium dengan pendekatan deskriptif-kuantitatif. Pengujian meliputi berat jenis dan penyerapan air, pemadatan, serta California Bearing Ratio (CBR) setelah perendaman. Material memiliki berat jenis bulk 2,559, SSD 2,601, apparent 2,669, dan penyerapan air rata-rata 1,658%. Berat isi kering maksimum sebesar 1,881 g/cm³ diperoleh pada kadar air optimum 6,29%. Nilai CBR mencapai 39,14%, lebih tinggi daripada nilai minimum 10% yang digunakan sebagai acuan untuk urugan pilihan. Hasil tersebut menunjukkan karakteristik kepadatan dan daya dukung yang baik serta mendukung potensi pemanfaatan material pada pekerjaan tanah jalan. Namun, data gradasi dan plastisitas belum tersedia, sehingga pengujian tambahan diperlukan sebelum kepatuhan lengkap dan penerimaan akhir di lapangan dapat dipastikan.

Kata Kunci: *urugan pilihan; California Bearing Ratio; pemadatan; material lokal; Quarry Kupang Barat*

1. INTRODUCTION

Roads are transportation infrastructure that directly support regional connectivity, the movement of people and goods, and economic activity. The performance of road construction is influenced not only by pavement-layer thickness but also by the quality of the materials forming each structural layer. In road construction, the subgrade and fill layers play important roles in providing structural support, maintaining the stability of the road body, and distributing traffic loads to the underlying layers (Hardiyatmo, 2015; Sukirman, 2010).

The use of local materials for road construction is an important alternative, particularly in regions with limited access to standard construction materials or with high costs for mobilizing materials from outside the area. However, the characteristics of local materials are strongly influenced by geological conditions, degree of rock weathering, particle shape, particle-size distribution, porosity, and material-processing methods. Therefore, the feasibility of a material for construction use cannot be determined solely from its availability or physical appearance; its physical and mechanical properties must be evaluated according to the intended engineering function.

In road earthworks, selected fill is used as a higher-quality embankment material than ordinary soil to improve the stability and bearing capacity of the road body. According to the General Specifications of Bina Marga 2018 Revision 2, selected fill must satisfy specified technical requirements, including an appropriate California Bearing Ratio (CBR), controlled plasticity characteristics, and material properties capable of providing adequate support to the road structure (Direktorat Jenderal Bina Marga, 2020). Evaluation of material characteristics is therefore an essential stage before local materials are used in road construction.

The local context of East Nusa Tenggara further emphasizes the importance of evaluating locally available materials. Sasi et al. (2025) showed that local aggregates from several quarries in North Central Timor Regency vary in physical characteristics such as specific gravity and water absorption, which must be assessed before use in roadworks. In the Kupang area and its surroundings, Adam and Sukwadi (2025) also demonstrated the potential of local rock materials for road construction; however, their use remains dependent on compliance with the applicable technical requirements.

Mountain rock from the West Kupang Quarry is one local material with potential for use as selected fill in roadworks on Timor Island. Administratively, West Kupang is located in Kupang Regency, East Nusa Tenggara Province (Badan Pusat Statistik Kabupaten Kupang, 2025). Available laboratory data for this material include specific gravity and water absorption, compaction, and California Bearing Ratio (CBR). The initial evaluation applied a selected-fill criterion of a minimum CBR of 10%. Nevertheless, material suitability must still be reviewed against the selected-fill requirements of the General Specifications of Bina Marga 2018 Revision 2, including parameters related to bearing capacity, physical properties, and other required material characteristics.

Previous studies indicate that CBR is an important parameter for determining the bearing capacity of fill materials, including assessments of local quarry materials, limestone-based materials, recycled concrete aggregates, and aggregate substitutions (Putri et al., 2023; Salcedo Fontalvo et al., 2023; Suardi et al., 2023; Toka & Olgun, 2022; Wahyuni et al., 2026). A higher CBR generally indicates a greater ability to sustain load without excessive deformation. In addition, parameters such as gradation, optimum moisture content, maximum dry density, and plasticity characteristics also affect material performance when the material is used as selected fill.

Accordingly, this study aims to: (1) identify the physical and mechanical characteristics of mountain rock from the West Kupang Quarry based on the available laboratory test data; (2) evaluate the material against the selected-fill requirements of the General Specifications of Bina Marga 2018 Revision 2; (3) identify parameters that comply, do not comply, or for which data are not yet available; and (4)

determine the need for additional testing and possible material improvement before field use. The novelty of this study lies in evaluating the West Kupang Quarry material through a compliance-gap approach to selected-fill requirements, so that the results not only indicate the potential use of the local material but also clarify the technical limits of its application in road construction.

2. METHODS

This study employed a laboratory experimental method with a descriptive-quantitative approach. Samples of mountain rock were obtained from the West Kupang Quarry and tested for their physical and mechanical characteristics to evaluate their feasibility as selected fill for road construction based on the General Specifications of Bina Marga 2018 Revision 2.

The laboratory program included tests of physical properties, compaction characteristics, and bearing capacity using the California Bearing Ratio (CBR).

2.1 Research Design

The research stages comprised a literature review of selected-fill requirements, sampling of material from the West Kupang Quarry, specimen preparation, laboratory testing, analysis of test results, evaluation of material compliance with technical requirements, and formulation of the study conclusions.

2.2 Research Location and Material

The study was conducted using mountain rock material obtained from a quarry in West Kupang, Kupang Regency, East Nusa Tenggara Province. The research object was processed quarry rock evaluated for its potential use as selected fill in road construction.

2.3 Laboratory Testing

Laboratory testing included moisture content, specific gravity, unit weight, water absorption, compaction testing to obtain the maximum dry density and optimum moisture content (OMC), and the California Bearing Ratio (CBR).

2.4 Data Analysis

The test data were analyzed by comparing the laboratory results with the requirements of the General Specifications of Bina Marga 2018 Revision 2.

2.5 Material Feasibility Evaluation

The feasibility of the material for use in road construction was evaluated using the parameters summarized in Table 1 with reference to the General Specifications of Bina Marga 2018 Revision 2.

Table 1. Material feasibility evaluation parameters

Specific gravity	Aggregate specific gravity test	See Results	Physical material characteristic
Water absorption	Absorption test	See Results	Water-absorption characteristic
Maximum dry density ($\gamma d,max$)	Compaction test	See Results	Maximum compacted dry density
Optimum moisture content (OMC)	Compaction test	See Results	Optimum moisture condition
CBR	SNI 1744	See Results	Minimum 10% for selected fill

Source: General Specifications of Bina Marga 2018 Revision 2.

3. RESULTS

Table 2. Specific gravity and water absorption test results

URAIAN		I	II	Satuan
Berat Benda Uji Kering Permukaan Jenuh (Bj)		3860	3500	gram
Berat Benda Uji Dalam Air (Ba)		2313	2207	gram
Berat Benda Uji Kering Kering Oven (Bk)		3773	3465	gram
URAIAN		I	II	Rata - Rata
Berat Jenis (Bulk)	$\frac{Bk}{Bj - Ba}$	2,439	2,680	2,559
Berat Jenis (SSD)	$\frac{Bj}{Bj - Ba}$	2,495	2,707	2,601
Berat Jenis (Apparent)	$\frac{Bk}{Bk - Ba}$	2,584	2,754	2,669
Penyerapan Air	$\frac{Bj - Bk}{Bk}$ x 100%	2,306	1,010	1,658

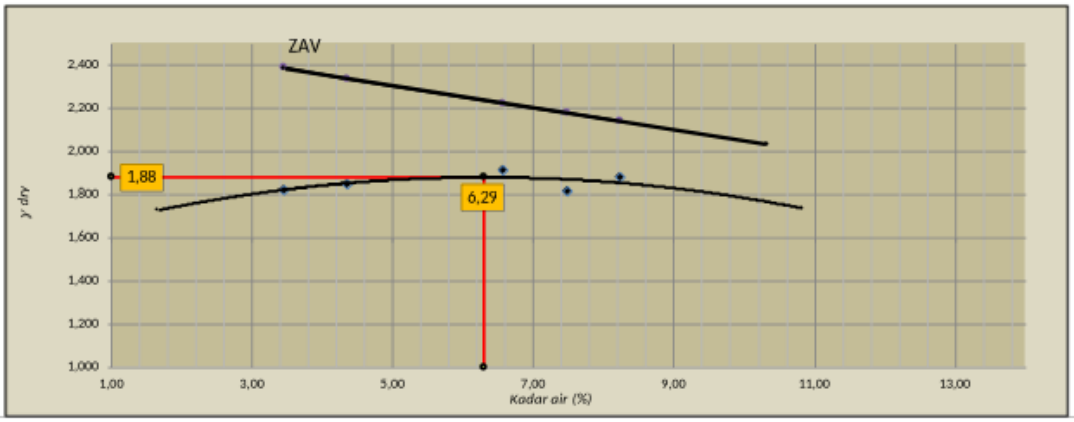
Source: Laboratory test results; original laboratory record reproduced without alteration.

The specific gravity and water absorption test results in Table 2 show an average bulk specific gravity of 2.559, saturated surface-dry (SSD) specific gravity of 2.601, and apparent specific gravity of 2.669. These values indicate that the mountain rock material has a relatively dense particle structure. The differences among bulk, SSD, and apparent specific gravity arise from the different moisture and pore-volume conditions considered in each test condition. SSD specific gravity represents aggregate that is water-saturated internally while its surface is dry, whereas apparent specific gravity excludes the volume of permeable pores that can absorb water.

The average water absorption was 1.658%, indicating that the mountain rock absorbs water equivalent to 1.658% of its oven-dry mass. This relatively low absorption suggests that the aggregate does not contain excessively large permeable pore volumes and therefore has favorable resistance to water ingress. The result supports the potential durability of the material under moisture exposure and its use as a construction material.

Table 3. Compaction test results

PENAMBAHAN AIR (%)			4%	5%	6%	7%	8%
1	Berat Mold + Cth Basah		5135,00	5097,00	5164,00	5230,00	5314,00
2	Berat Mold		1672,00	1672,00	1672,00	1672,00	1672,00
3	Berat Cth Basah	1 - 2	2060,00	2110,00	2231,00	2131,00	2224,00
4	Volume Mold		1092,328	1092,328	1092,328	1092,328	1092,328
5	Berat Isi Basah	3 : 4	1,886	1,932	2,042	1,951	2,036
6	Berat Isi Kering	(5)/(1+(Ka)	1,823	1,851	1,917	1,815	1,881
KADAR AIR							
1	Berat cawan + Cth basah		120,00	120,00	130,00	115,00	140,00
2	Berat cawan + Cth kering		116,00	115,00	122,00	107,00	130,00
3	Berat Air	1 - 2	4,00	5,00	8,00	8,00	10,00
4	Berat cawan		0,00	0,00	0,00	0,00	0,00
5	Berat cth kering	2 - 4	116,00	115,00	122,00	107,00	130,00
6	Kadar Air	(3:5)*100%	3,45	4,35	6,56	7,48	8,23



Source: Laboratory test results; original laboratory record reproduced without alteration.

Based on the compaction test results in Table 3, the maximum dry density (γd,max) was 1.881 g/cm³ at an optimum moisture content of 6.29%. The relationship between moisture content and dry density shows that increasing moisture content initially increases dry density until the optimum condition is reached, after which the dry density decreases. At a moisture content of 6.29%, the amount of water in the material is therefore at the most favorable level for compaction, allowing the particles to achieve their densest arrangement and the maximum dry density.

The maximum dry density of 1.881 g/cm³ was subsequently used as the reference parameter for preparing the CBR specimens, with specimen compaction adjusted to the maximum density obtained from the compaction test. The compaction result therefore provides the basis for evaluating the bearing capacity of the West Kupang Quarry material through CBR testing.

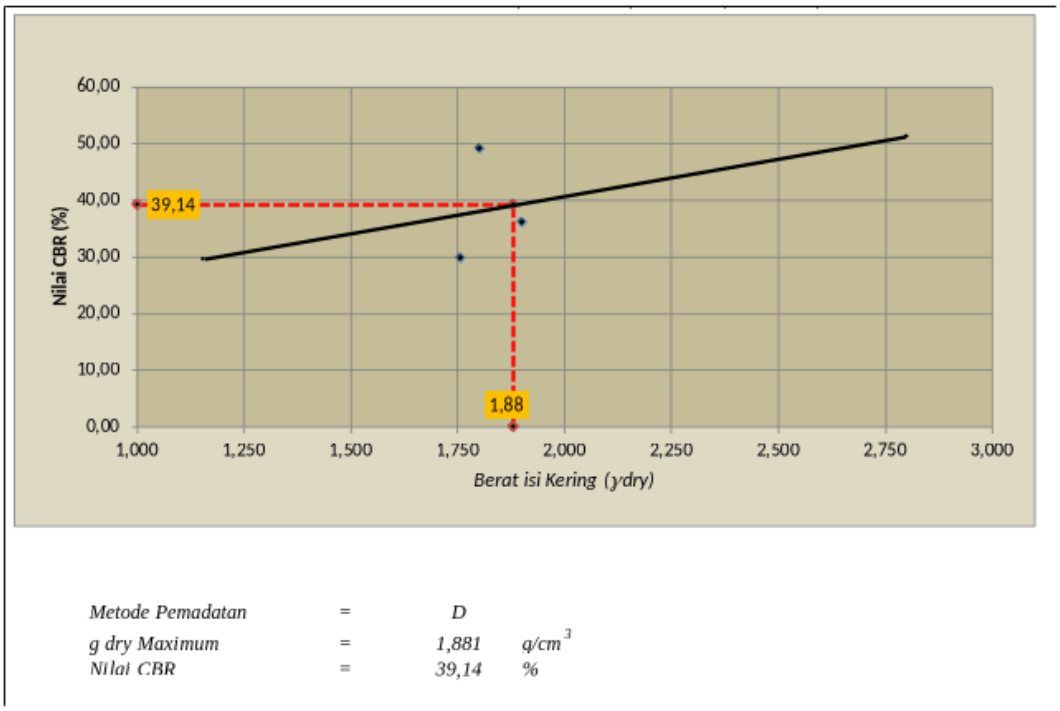


Figure 1. CBR determination graph

The California Bearing Ratio (CBR) test was used to determine the bearing capacity of the material from the relationship between dry density and CBR. The maximum dry density obtained from the preceding compaction test, 1.881 g/cm³, was used as the reference condition for determining the material CBR. From the plotted relationship between dry density and CBR, a CBR value of 39.14% was obtained at the maximum dry density condition.

The test results indicate that the mountain rock from the West Kupang Quarry has good bearing capacity, with a CBR of 39.14%. This value exceeds the minimum CBR criterion of 10% for selected fill referenced in the General Specifications of Bina Marga 2018 Revision 2.

4. DISCUSSION

The feasibility assessment of mountain rock from the West Kupang Quarry was conducted to characterize its physical and mechanical properties and to evaluate its suitability for road construction. The laboratory program included specific gravity, water absorption, compaction, and California Bearing Ratio (CBR) testing.

Table 4. Summary of laboratory test results

No	Uraian	Acuan Metode	Hasil Uji	Spesifikasi
1	Percobaan Pemadatan (γd) Max	SNI 03 1743 -2008	1,881 Gr/cm³	~
2	Kadar Air Optimum	SNI 03 1743 -2008	6,29 %	~
3	Berat Jenis Efektif	SNI 03 1964 -1990	2,603 Gr/cm³	~
4	CBR Laboratorium Sesudah Perendaman	SNI 03 1744 -1989	39,14 %	Min 10 %

Source: Laboratory test results; original laboratory record reproduced without alteration.

The specific gravity test yielded a bulk specific gravity of 2.559, SSD specific gravity of 2.601, and apparent specific gravity of 2.669. These values indicate a relatively dense material structure. The variation among the specific gravity values results from differences in the moisture condition and pore volume considered by each test method. The comparatively high specific gravity values suggest that the material particles are sufficiently dense to contribute to the stability of a compacted construction layer.

The average water absorption was 1.658%, indicating relatively low water uptake. Low absorption suggests that the aggregate has a limited volume of permeable pores and is therefore less susceptible to water penetration. This characteristic is important because aggregates with lower absorption generally show better durability when exposed to changing environmental moisture conditions.

The compaction test produced a maximum dry density ($\gamma d,max$) of 1.881 g/cm³ at an optimum moisture content of 6.29%. This condition indicates that 6.29% moisture provides the most favorable water content for particle rearrangement during compaction and produces the maximum density. The maximum dry density was then used to establish the compaction condition for the CBR specimens.

At the maximum dry density of 1.881 g/cm³, the material achieved a CBR of 39.14%. This value indicates good load-bearing capacity. Compared with the General Specifications of Bina Marga 2018 Revision 2, the measured CBR satisfies and substantially exceeds the referenced minimum requirement of 10% for selected fill. The high CBR therefore supports the potential use of the West Kupang Quarry material in road earthworks where adequate bearing capacity and stability are required.

Overall, the available physical and mechanical test results indicate favorable characteristics for the West Kupang Quarry material. The specific gravity values, relatively low water absorption, compaction response, and high CBR demonstrate adequate density, resistance to water absorption, and bearing capacity for road-construction applications. On the basis of the parameters actually tested, the material shows strong potential for use as selected fill and related road earthwork material.

The compliance-gap perspective is important when interpreting these results. The available laboratory records provide evidence for specific gravity, water absorption, compaction, and CBR, but they do not provide the gradation and plasticity data identified in the specification framework discussed in this study. Consequently, the measured CBR can be considered compliant with the referenced minimum requirement, whereas complete compliance with all selected-fill requirements cannot be confirmed from the present dataset alone. Completing the unavailable tests before field use would close this compliance gap and provide a more comprehensive basis for material acceptance.

5. CONCLUSION

Based on the available tests of specific gravity and water absorption, compaction, and California Bearing Ratio (CBR), mountain rock from the West Kupang Quarry exhibits favorable physical and mechanical characteristics for use as selected fill in road construction. The bulk specific gravity was 2.559 and the average water absorption was 1.658%. Compaction testing produced a maximum dry density of 1.881 g/cm³ at an optimum moisture content of 6.29%, while the CBR reached 39.14%, exceeding the referenced minimum CBR requirement of 10%. These results demonstrate good density and bearing capacity. However, because the available dataset does not include all specification-related parameters identified in this study, particularly gradation and plasticity characteristics, the conclusion should be interpreted as feasibility based on the tested parameters. Additional testing of the unavailable parameters is recommended before final field acceptance as selected fill.

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AUTHOR CONTRIBUTIONS

Agnesius Tlonaen was solely responsible for the conceptualization, methodology, laboratory investigation, data collection, data analysis and interpretation, validation of the results, preparation of the original manuscript, review, editing, and final approval of the manuscript for publication.

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This research received no external funding.

CONFLICT OF INTEREST STATEMENT

The author declares that there is no conflict of interest regarding the publication of this article.

DATA AVAILABILITY STATEMENT

The laboratory data and supporting records used in this study are available from the corresponding author upon reasonable request.

ETHICAL STATEMENT

This study was based on laboratory testing of construction materials and did not involve human participants or experimental animals. All cited data sources and technical references have been acknowledged.

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