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WEATHERED MARBLE AS AN ALTERNATIVE EMBANKMENT MATERIAL FOR ROADWAY DEVELOPMENT IN NORZAGARAY, BULACAN

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ABSTRACT: Road networks facilitate socioeconomic growth in developing countries, such as the Philippines. An increased traffic volume exacerbates the gradual progression of erosion, breaching, and degradation of road embankments. Weathered marble from local quarries in Norzagaray, Bulacan, was repurposed to provide an economic solution. This study quantified the effect of five varying proportions of weathered marble and aggregate on index properties, such as specific gravity, grain size distribution, plasticity, and compaction, and assessed the capacity of the embankment against vehicular loads using the California bearing ratio and direct shear tests. A mix of 60% marble and 40% aggregate (60M40A) was determined to display the best performance in terms of maximum dry density (20.512 kN/m^3) and California bearing ratio (78%). The Proctor compaction test results indicated a very stable embankment according to the USCS criteria and good to excellent embankment performance according to the AASHTO criteria. The local criteria on embankment marked the 60M40A samples as an excellent material for the embankment base layer. The same specimen demonstrated the highest shear strength before failure and had the highest friction angle before failure (37 degrees). These results indicate that weathered marble exhibits excellent compaction behavior, yields friction angles comparable to well-graded soil, and possesses a suitable load-bearing capacity, thus establishing its feasibility as a potential material for road embankments, especially in rural areas within proximity to marble quarrying sites.

Keywords: Weathered Marble, Road Embankment, Compaction, Load-Bearing capacity, California Bearing Ratio

1. INTRODUCTION

Road networks in developing countries such as the Philippines serve as critical structures that support socioeconomic growth [1]. The prevalence of uneven terrain in rural areas in the Philippines has resulted in the construction of road embankments compacted from earthen materials such as clay infill [2]. This vital lifeline infrastructure carries 98% of local passenger traffic and 58% of local freight traffic, with 12% of cargo trucks identified as overloaded [3]. Loads heavier than the design values exacerbate the gradual erosion, breaching, and degradation of road embankments because of unstable materials, poor building procedures, seepage, and sliding [4]. Mitigating these failure modes requires embankment stabilization to ensure adequate capacity to support loads from roads and vehicles.

Despite the pronounced role of road transport, the Philippines suffers from a slow pace of expansion, poor progress in asset improvement, and weak capacity for development planning. Maintaining and boosting economic growth involves ensuring road quality by improving embankments. However, due to their harmful consequences and labor-intensive procedures, existing quarrying methods for obtaining aggregates for roads are subject to future environmental and economic constraints [5]. This study highlighted the possibility of adding waste materials to road embankments as a sustainable solution.

The use of industrial waste materials on roads is gaining popularity for solving the environmental and financial problems associated with standard materials. This strategy minimizes the demand for natural resources, improves sustainability, and reduces extraction and processing costs [6]. Due to its qualities, marble has been studied as a suitable filler for flexible construction, such as roads and foundations [7]. Marble aggregates have an acceptable particle-size distribution, density, durability, and inertness, making them excellent materials for road embankments.

Owing to inefficiencies, 70% of the materials produced by the marble industry worldwide are trash at extraction and polishing facilities [8]. In areas without proper disposal schemes, such as Norzagaray, Bulacan, weathered marble proliferated across various communities across the municipality due to its marble quarrying industry. The towns of Bulacan, notably Meycauayan City, San Ildefonso, San Rafael, Dona Remedios Trinidad, San Miguel, Norzagaray, and San Jose del Monte City have significant marble ore deposits. These towns constitute a large part of the estimated 220,000 tons of annual production and 6.7 billion tons of marble ore reserves in the country [9].

Consequently, the topic of interest in this research is to quantify the geotechnical characteristics of marble using various index property tests, such as specific gravity, grain size analysis, Atterberg limits, and maximum dry unit weight. This study also evaluated the load-bearing capacity of different mix proportions of marble and aggregate using the California Bearing Ratio and shear strength characteristics with a direct shear test under undrained loading conditions. The optimal percentage mixture of weathered marble and crushed stone for the development of roads was determined using the standards of USCS, AASHTO, and DPWH (Department of Public Works and Highways) standards.

2. RESEARCH SIGNIFICANCE

The abundance of waste marble found in Norzagaray provides an economical and sustainable solution for construction firms in the locality. Local government agencies and private infrastructure entities can benefit from this initiative, as they could improve related road construction projects, resulting in better strength and integrity, leading to a longer lifespan. Motorists and commuters from both public utility vehicles and private automobiles will benefit from more convenient and time-friendly passages on the roads if the accessibility of the roads is improved.

3. METHODOLOGY

3.1 Source of Aggregate Samples

Marble samples were extracted from marble quarries in the municipality of Norzagaray in Bulacan. Weathered marble was used to utilize marble waste from quarrying. The marble is cream-brown to brown-gray with an unusual odor. The sizes of the marble aggregates vary but contain fewer fine particles than natural aggregates [10].

The aggregates were acquired from a local batch plant. Strong durable stones, crushed slag, fillers composed of natural or crushed sand, crushed or natural gravel, or other finely divided mineral materials make up the aggregate base course.

3.2 Test Program

This study conducted a series of tests to identify weathered marble based on its physical and mechanical properties. Index properties are quantified to identify changes in physical properties and measure improvements in ground conditions. The compaction parameters and load-bearing capacity were investigated in line with the geotechnical standards for embankments, as stated in the ASTM for testing and USCS, AASHTO, and DPWH to determine the feasibility of marble as an alternative embankment material. The shear strength parameters were also determined to provide additional insight into the improvement induced by weathered marble aggregates on the embankment structure.

3.2.1. Specific Gravity

A water pycnometer was used to identify the specific gravity of the soil that passed through a No. 4 sieve according to ASTM D854. The following formula was used to determine the specific gravity of the solids at the test temperature:

$$G_s = \frac{M_s}{M_{pw,t} - \left(M_{pws,t} - M_s\right)} \tag{1}$$

where:
G_s = specific gravity of soil
M_s = mass of oven-dried dry solids, g
M_{pw} = = combined mass of pycnometer and water at test temperature (T_t), g
$M_{pws,t}$ = combined mass of pycnometer, water, and soil solids at the test temperature (T_t), g

3.2.2. Atterberg Limits

The liquid limit, the plastic limit, and the soil plasticity index were determined according to ASTM D4318. Three trials of the liquid limit test using the Casagrande cup method were used to plot a flow curve that indicates the moisture content in which a standard groove cut closed by 0.5 inches at exactly 25 drops. The plastic limit was obtained from samples that crumbled after being repeatedly rolled into 3 mm threads.

3.2.3. Grain Size Analysis

The sample was classified based on particle distribution through sieve analysis and systematized according to ASTM D6913. The percentages of soil retained and passed through each standard sieve.

The grain size distribution of fine-grained soils is not limited to the typical sieve analysis performed for coarse-grained soils. A hydrometer test was conducted to determine the distribution of particles smaller than 75 μm via sedimentation. The grain diameter and particle distribution were obtained using Eq. (2) and Eq. (3).

$$D = K\sqrt{\frac{L}{T}} \tag{2}$$

where:
D = particle diameter, mm
K = constant dependent on the temperature of the suspension and the specific gravity of soil particles
L = effective distance, cm
T = interval of time from the beginning of sedimentation to the taking of the reading, min

$$P = \frac{\frac{100000}{M} \times G}{G - G_1}(R - G_1) \tag{3}$$

where:
P = percentage of particles in suspension

M = mass of oven-dried sample for hydrometer test,
G = specific gravity of the specimen
G_1 = specific gravity of suspension medium
R = hydrometer reading

3.2.4. Moisture-Density Relationship

The moisture-density relationship described by ASTM D698 determines the optimum moisture content and maximum dry density of the specimen. These parameters can be determined by finding the coordinates at the peak of the plotted curve in a graph where the moisture content is scaled linearly along the ordinate and the dry densities are also scaled linearly along the abscissa. The calculations began with the wet density of the soil to determine the dry density of the specimen.

3.2.5 Shear Strength

The direct shear test is the most common method for determining the shear strength parameters of soil specimens. ASTM D3080 states that the shear strength of a saturated soil is influenced by several factors such as applied stress, consolidation time, strain rate, and stress history. In the direct shear test, the shear strength was expressed in terms of the maximum shear stress. Simultaneous shearing with axial loading also requires the determination of normal stress.

The Mohr–Coulomb failure criterion can be determined from a plot of normal stress vs. shear stress. This model is based on the failure of a material as a critical combination of normal and shear stresses. An idealized linear function is the limiting set of stress coordinate values that determines the failure envelope of a particular specimen. This function in Eq. (4) is defined by the normal stress, cohesion, and angle of internal friction.

$$\boldsymbol{\tau_f = c' + \sigma'^{\tan\phi'}} \quad (4)$$

where:
c' = cohesion based on effective stress
' = drained angle of internal friction
σ' = effective stress in the failure plane, kN/m^2
τ_f = shear strength, kN/m^2

3.2.6. California Bearing Ratio

The potential strength of the subgrade, subbase, and base course materials, including recycled materials for use in the construction of flexible roadways and airport pavements, can be assessed using ASTM D1883. The test determined the California bearing ratio of specimens compacted at their optimum moisture content. The final CBR value was determined by selecting the highest ratio obtained after reaching a penetration of 2.5 mm or 5.00 mm.

$$CBR_{2.5} = \frac{P_{specimen}}{1000\ psi} \times 100\% \quad (5)$$

$$CBR_{5.0} = \frac{P_{specimen}}{1500\ psi} \times 100\% \quad (6)$$

where:
$P_{specimen}$ = load or pressure sustained by the specimen at the penetration level of 2.5mm or 5.0mm penetration level

3.3 Research Design

The flowchart shown in Figure 1 displays the methodological sequence of this study, from sample preparation until the last test was performed.

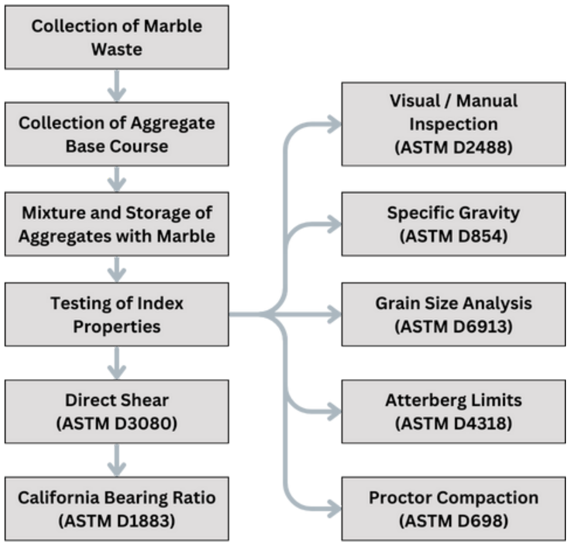


Fig. 1 Methodology sequence for the study

The mix proportions of weathered marble and aggregate, as shown in Table 1, were divided by using percentage by mass and conducting the geotechnical test programs with three separate trials. The average results of the three trials were considered the final values of the targeted parameters.

Table 1 Proportions of Marble-Aggregate Mix

Designation	Mix Proportion (Percent by Mass)		
	Marble	Aggregate	Trials
100M0A	100%	0%	3
60M40A	60%	40%	3
40M60A	40%	60%	3
20M80A	20%	80%	3
0M100A	0%	100%	3

3.4 Criteria for Assessment

The physical and mechanical properties of the specimens were evaluated using USCS, AASHTO, and DPWH standards. The USCS outlines details on compaction characteristics and embankment values for every type of sand [12], as shown in Figure 2.

Letter	Name	Max Dry Unit Weight (lb/ft^3)	Compaction Characteristics	Value for Embankments
SW	Well-graded sands or gravelly sands, little or no fines	110-130	Good; tractor	Very stable, pervious sections, slope protection required
SP	Poorly-graded sands or gravelly sands, little or no fines	100-120	Good; tractor	Reasonably stable, may be used in dike section with flat slopes
SM	Silty sands, sand-silt mixtures	110-125	Good with close control; rubber-tired or sheepsfoot roller	Fairly stable, not particularly suited to shells, but may be used for impervious cores or dikes
SC	Clayey-sands, sand-clay mixtures	105-125	Fair, rubber-tired or sheepsfoot roller	Fairly stable, use for impervious core or flood-control structures

Fig. 2 Compaction characteristics and embankment performance for various types of sand [12]

AASHTO detailed a guide for the design of pavement structures in Figure 3, mainly focusing on the relationship between the maximum dry density (MDD) and optimum moisture content (OMC) of the soil in producing its anticipated embankment performance from a selection of materials [13]. Using the AASHTO general soil classification, which differs in soil classification and Atterberg limits, the behavior of granular materials and plastic soils with different levels of optimum moisture content was assessed.

AASHTO Groups	Visual Description	Maximum Dry Density (lb/ft^3 or kN/m^3)	Anticipated Embankment Performance
A-1	Granular Material	115-142 (18-22.3)	Good to Excellent
A-2	Granular Material with soil	110-135 (17.3-21.2)	Fair to Excellent
A-3	Fine Sand and sand	110-115 (17.3-18)	Fair to Good
A-4	Sandy silts and silts	95-130 (14.9-20.4)	Poor to Good
A-5	Plastic silts and clays	85-100 (13.3-15.7)	Unsatisfactory
A-6	Silt – Clay	95-120 (14.9-18.8)	Poor to Good
A-7-5	Plastic Silty Clay	85-100 (13.3-15.7)	Unsatisfactory
A-7-6	Clay	90-115 (14-18)	Poor to Fair

Fig. 3 Criteria for selection based on anticipated embankment performance [13].

Items 200 and 201 of the DPWH Standard Specifications for Public Works Structures [14] require the subbase and the base course to consist of durable and hard aggregates, composed of crushed stones, crushed gravel, crushed slag, natural sand fillers, or other crushed mineral matter. For a composite material to be classified as an aggregate subbase course, the percentage passing through sieve no. 200 should be less than or equal to two-thirds of the percentage passing through the sieve no. 40 to be utilized and tested for the CBR test and classified into subbase and base course embankment materials. The DPWH standards also separate the classification of the performance of subgrade soils according to the CBR value, as shown in Table 2 [15].

Table 2 Criteria for General Rating and Embankment Use based on CBR Value

CBR value	General rating	Use/s
0 – 3	Very Poor	Subgrade
3 – 7	Poor to Fair	Subgrade
7 – 20	Fair	Subbase
20 – 50	Good	Base and Subbase
> 50	Excellent	Base

4. RESULTS AND DISCUSSION

4.1 Specific Gravity

The specific gravity of the marble used was 2.680, which resembled the results of previous studies involving this material [16]. Specific gravity is another essential factor in road embankments, with aggregate specific gravities typically ranging from 2.5 to 3.0 [17]. Indian codes also specified that the specific gravity of the base and subbase courses used in road construction should be between 2.4 and 2.9, with coarse aggregates having a minimum specific gravity of 2.5 [18]. The US Federal Highway Administration (FHWA) also indicated that the average specific gravity of the waste rock to be used in embankments is typically 2.65, which is closely approximated by the 100M0A sample [19].

Table 2 Specific Gravity of each mixture proportion

Material	Specific Gravity
100M0A	2.640
60M40A	2.795
40M60A	2.830
20M80A	2.781
0M100A	2.650

The specific gravity of the material proportion played a role in satisfying these standards, with the 40% marble and 60% aggregate mix having the highest specific gravity, as shown in Table 2. The final values for each proportion were used in subsequent calculations for the compaction specimen.

4.3 Atterberg Limits

The tested soil samples were nonplastic because they could not be rolled into threads of 3.2 mm thickness at any moisture level, and they lacked binders in their composition. Nonplastic soils are characterized in soil classification systems as soils with little to no plasticity index. Hence, they cannot exhibit plastic-like characteristics, and the liquid or plastic limit cannot be attained. Marble, a metamorphic rock containing carbonates, is predominantly composed of calcite ($CaCO_3$), dolomite ($CaMg(CO_3)_2$), and possibly serpentine [19]. It is a non-clay mineral with limited flexibility due to its chemical makeup, which is mostly calcium carbonate. Nonplastic aggregates, such as marble waste materials, can be used in embankments, especially as base materials, and subbases [18]. Non-plastic aggregates are often easier to handle and compact, making them suitable for road building. Compliance with AASHTO, USCS, and DPWH requirements assures their usefulness as foundation and subbase materials in building embankments.

4.4 Grain Size Analysis

Particle size distribution is one important representation of soil that greatly describes its geotechnical capabilities such as bearing capacity and embankment performance. The test conducted successfully classified five sample mixtures (100M0A, 60M40A, 40M60A, 20M80A, 0M100A) based on their sieve gradation using the ASTM D6913 procedure which was shown in Figure 4. The particle size distribution revealed that the mixtures 100M0A, 60M40A, and 40M60A met the requirements for group A-1-a in the AASHTO soil group classification, while the mixtures 20M80A and 0M100A met the conditions for group A-1-b.

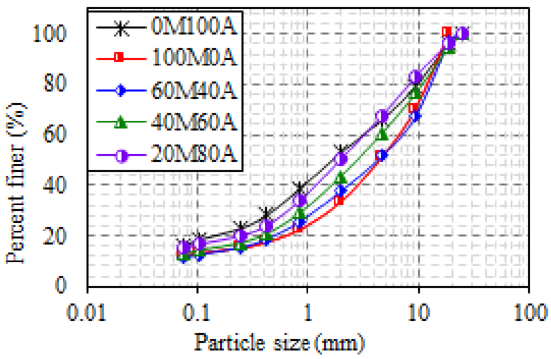


Fig. 4 Comparison of grain size distribution curves of each mix proportion

The gradation of the specimen also satisfied the criterion set by DPWH in comparing the passing percentages for sieves #40 and #200. Table 3 shows that the percentage passing through the #200 sieve is marginally less than 2/3 of the percentage passing through the #40 sieve.

Table 3 Comparison of Passing Percentages for Sieve #40 and #200

Material	Passing #40	2/3 of Passing #40	Passing #200
100M0A	18.37%	12.25%	11.14%
60M40A	18.45%	12.30%	11.26%
40M60A	20.84%	13.89%	12.90%
20M80A	24.06%	16.04%	15.22%
0M100A	28.34%	18.89%	16.39%

4.5 Compaction

The specimen met the requirements established by USCS and AASHTO for the design and construction of embankments as shown in Table 4. These criteria indicate that the embankment of roads containing the tested materials is stable and capable of supporting heavy vehicular loads.

The remarks in Table 4 consider the maximum dry density and the soil classification determined following the grain size analysis. Both the USCS and AASHTO criteria indicate positive remarks on the embankment performance of the mixed specimen. Among all proportions, the sample with 60% marble and 40% aggregate showed the best performance. The other test sample met the standards, with the 20% marble and 80% aggregate combination having the greatest MDD value. Calcium ions in marble possess a strong affinity for water and can impact the water retention capacity of soil and drainage characteristics. These ions can facilitate the flocculation of particles, resulting in the formation of larger aggregates and increased pore spaces.

Table 4 Maximum Dry Density and Anticipated Embankment Performance of Test Specimens

Material	MDD (kN/m^3)	Remarks	
		USCS	AASHTO
100M0A	18.165	Good Reasonably Stable	Good to Excellent
60M40A	20.512	Good Very Stable	Good to Excellent
40M60A	20.664	Good Reasonably Stable	Good to Excellent
20M80A	21.782	Good Reasonably Stable	Good to Excellent
0M100A	19.164	Good Fairly Stable	Good to Excellent

4.6 Shear Strength

The direct shear test stress-strain behavior for varying mix amounts exhibited similar patterns, with greater shear stresses corresponding to larger effective normal stresses. The study illustrated the shear strain and volumetric strain behavior concerning the shear stress applied to the soil. Table 5 shows the shear strength achieved at the failure of each mix proportion in three trials with different loadings according to ASTM D3080 (98.07 kPa for trial 1, 196.13 kPa for trial 2, and 392.27 kPa for trial 3).

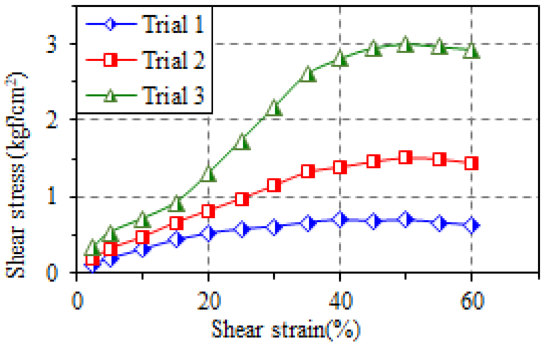
The stress-strain and volumetric strain behavior was examined and measured in drained condition. It was achieved by allowing the marble-aggregate mix to fully consolidate before applying the shear loads.

Table 5 Shear Strength at Failure of Each Specimen

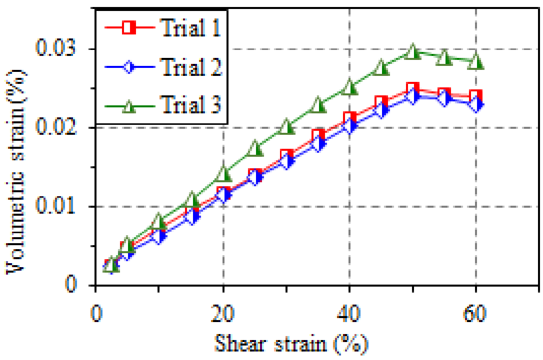
Mix Proportion	Trial 1 kg/cm^2	Trial 2 kg/cm^2	Trial 3 kg/cm^2
100M0A	0.9	1.44	2.52
60M40A	0.69	1.51	3
40M60A	0.75	1.46	2.92
20M80A	0.85	1.6	2.95
0M100A	0.9	1.41	2.71

The 60% marble and 40% aggregate mixture (60M40A) had the highest shear strength among the evaluated samples with 3 kg/cm^2, whereas the 100% marble (100M0A) mixture had the lowest with 2.52 kg/cm^2.

Yielding higher shear stress values results in higher overburden pressure obtained and resisted by the soil sample. Every sample sustained a significant amount of shear stress from the equipment until it reached the critical state where it experienced failure. This failure will be measured as the corresponding shear stress sustained within a certain load.



(a)



(b)

Fig. 5 Shear Stress vs. Shear Strain (a) & Volumetric Strain vs. Stress Strain (b) of 60M40A Mix.

Figure 3 illustrates the corresponding behavior of the best proportion of marble-aggregate mix (60M40A) under shear stress – shear strain and volumetric strain – shear strain when the load is increased from 1 kg/cm^2 to 2 kg/cm^2 to 4 kg/cm^2. A huge increase in volumetric strain at the initial phases of the test can be observed. It was also shown that the rate of volumetric strain constantly increases until its critical state and abruptly decreases before the end of the test. This could be an indication of the inconsistency of the particle sizes of the marble-aggregate mix where finer particles can easily fill in the void spaces and re-arrange the soil upon application of pressure.

Table 6 Friction Angle of Each Mix Proportion

Material	Angle of Friction at	Cohesion (kPa)
100M0A	28°	35.304
60M40A	37°	5.394
40M60A	36°	1.961
20M80A	35°	17.162
0M100A	31°	24.517

On the other hand, Table 6 shows the corresponding angle of friction produced by each mix proportion. As the quantity of marble in the mix rose, the angle of friction also increased, with the 60M40A combination having a maximum angle of 37°

The angle of friction of the marble-aggregate mix is in the range of 28° to 37° with a cohesion value of 1.961 kPa to 35.304 kPa. The samples 40M60A, 20M80A, and 0M100A mix acquired 36°, 35°, and 31° respectively, which fell into the typical range of values for medium and silty sand at 30° to 36° and 32° to 35°. With a 28° angle, the 100M0A mixture was classified as loose sand. The angles of friction match the USCS soil types and relative density, with fine-grained and well-rounded sand mixes having low friction angles and coarse-grained and angular sand mixes having high friction angles. FHWA indicated that waste aggregate should have friction angles greater than 35 degrees [17], which makes specimens with 20% to 60% marble good options for embankments.

Given that aggregates are non-plastic, the obtained cohesion values can be described as apparent cohesion. Slight variations in the moisture content across samples, and in the particle, sizes may result in the inconsistency in cohesion values.

4.7 California Bearing Ratio

The bearing test utilized in this study is where a gradual penetration of 1.270 millimeters per minute loading rate is applied to different sets of blows (10, 25, and 56). This test uses a constant value of piston cross-sectional area, and penetration (measured in inches) has an interval of 0.025 inches. For every level, there are corresponding sets of dial readings which can be later converted as stress (psi) for computing the initial CBR value of the soil specimen.

Under soaked conditions, the 60M40A mixture had the greatest CBR value of 78%. Table 7 shows a summary of the achieved CBR values of each mixed proportion and their general rating for road embankments. This value, according to the criteria set by DPWH [15], identifies it as an outstanding base material for road pavement and embankments.

Table 7 CBR Values of Each Mix Proportion and its General Rating

Mix Proportion	CBR value	General rating	Use/s
100M0A	50 %	Good	Base and Subbase
60M40A	78 %	Excellent	Base
40M60A	66 %	Excellent	Base
20M80A	60 %	Excellent	Base
0M100A	42 %	Good	Base and Subbase

Furthermore, it had the maximum stress resistance in the penetration bearing test at a depth of 0.2 inches, outperforming all other mixes, including pure marble. The combination also satisfied the grain size distribution criterion, adding to its dependability as an embankment material. The mixes 40M60A and 20M80A were likewise evaluated as exceptional for usage as aggregate base material, while the mixtures 100M0A and 0M100A were assessed as good for aggregate base and subbase material.

5. CONCLUSIONS

This study investigated the effectiveness of weathered marble as a material for embankment in roadway development. All samples did not exhibit plasticity given the significant presence of larger aggregates. The soil gradation across all specimens satisfied the DPWH requirement for embankments, with each marble-aggregate proportion having two-thirds of their respective %passing#40 slightly exceeding their respective %passing #200

USCS criteria for embankment performance indicated that the compaction characteristics of each trial mix correspond to favorable stability and bearing performance. The 60M40A sample had the best performance given the 20.512 kN/m^3 dry unit weight and its grain size distribution coinciding with the well-graded sand classification in USCS. The AASHTO approach indicated the same mix as A-1-a, which corresponds to an anticipated good to excellent performance.

Among the studied samples, the mixture of 60M40A has the highest shear strength rating, while 100M0A has the lowest. The 60M40A sample obtained the highest shear strength failure for 2 out of 3 normal stress values, resulting in a friction angle of 37 degrees, exceeding the FHWA requirement of 35 degrees for aggregate friction angles.

As an embankment material, the load-bearing capacity of each sample ranges from good to excellent. Mixtures of 100M0A (50%) and 0M100A (42%) are rated as good for both base and subbase courses, while mixtures of 60M40A (78%), 40M60A (66%), and 20M80A (60%) are rated as excellent for the base course according to DPWH standards.

Results showed that 60M40A possessed the highest potential among all the mixtures applicable for road pavement construction, particularly from the effect of the California bearing ratio and proctor Test consisting of the maximum dry density (MDD) and optimum moisture content (OMC) that greatly affect the embankment performance of a soil. It is the most recommended base course for road pavements, which will mostly deal with the applied loads. Also, it demonstrated the highest shear strength resisted before failure and had the highest friction angle before failure among all the mixtures. Other mixtures such as 100M0A and 0M100A could also be used as embankment material, but limited only to the base, compared to 40M60A, 20M80A, and 60M40A which are applicable for both base and subbase layers. Thus, 60M40A has the greatest embankment performance in comparison to other material mixtures depending on the numerical findings based on performed geotechnical tests.

This study concludes that the weathered marble exhibited excellent compaction behavior, yielded friction angles comparable to well-graded soil, and possessed a suitable load-bearing capacity, thus establishing its feasibility as a potential material for road embankments especially in rural areas within proximity to marble quarrying sites.

6. ACKNOWLEDGMENTS

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