Analysis of Excavated Soil Utilization as Embankment Material and Foundation Layer on Singaraja – Mengwitani Road Section (BALI)

Dinul Hadi[1,a], Ria Asih Aryani Soemitro[2,b], Trihanyndio Rendy Satrya[3,c) & Noor Fachrie[4,d]

[1]*Magister Student, Civil Engineering Dept, Institut Teknologi Sepuluh Nopember, Surabaya, Indonesia*
[2]*Civil Engineering Department, Institut Teknologi Sepuluh Nopember, Surabaya, Indonesia*
[3]*Civil Engineering Department, Institut Teknologi Sepuluh Nopember, Surabaya, Indonesia*
[4]*National Road Implementation Center for East Java – Bali Region, Directorate General of Highways, Ministry of Public Works, Indonesia*

Correspondent : [a]dinulhadi1995@gmail.com, [b]ria@ce.its.ac.id, [c]trendysatrya@its.ac.id & [d]noorfachrie@pu.go.id

ABSTRACT

Road and bridge construction of the Bts. Singaraja City - Mengwitani is located in a tightly contoured hilly area, resulting in a very large volume of excavation and embankment work. Referring to the data from the field inspection of the construction work package, the soil layer in the excavation work has the potential to be used as fill material and foundation layer. This can be a solution to reduce the use of natural materials by utilizing waste materials.

This research aims to analyze the utilization of excavated soil on the National Road Bts. Singaraja City - Mengwitani. The research was conducted by identifying the physical and mechanical parameters of the excavated soil at the location of the disposal area, then examining the requirements of the general specifications of bina marga for road and bridge construction in 2018 revision 2, if it does not meet the stabilization using lime to improve the soil parameters to achieve optimal conditions. If the test specimen meets the requirements as backfill soil, then modeling will continue using the Plaxis 2D auxiliary program to calculate the maximum height of safe backfill soil.

Based on the results, the excavated soil was classified as silty sand (SM) with plasticity index varying from 5.84% to 12.63%, and CBR values varying from 6.60% to 10.12%. For the material requirements check, all excavated soils meet the requirements as ordinary backfill material, some rest area disposal sites meet the requirements as preferred backfill material, swamp backfill, and graded material backfill, and all excavated soils do not meet the requirements of foundation layer. From the modeling results of the excavated soil parameters obtained, the safe embankment height can reach 3-5 meters.

Keywords : CBR *(california bearing ratio)*, embankment, excavated soil, requirement check, stabilization

INTRODUCTION

Road Section Bts. Singaraja City - Mengwitani is a national road that connects Tabanan regency in the south with Buleleng regency in the north of Bali province. The national road Bts. Singaraja City - Mengwitani plays an important role as supporting infrastructure for the movement of goods, services and people from these two districts. The geography of this road section is a hilly road with steep climbs and descents and sharp bends. Existing road conditions on the national road section Bts. Singaraja City - Mengwitani faces several challenges that need attention. There are several critical locations that do not meet road geometric requirements. Some criteria such as road width that does not meet the standards, horizontal alignments that have a lot of overlap and very small bend fingers, and road slopes that are too steep with slopes exceeding 12%.

Road conditions that do not meet these standards greatly affect the safety and security factors of traffic on this section, one of the efforts to improve this is to make geometric improvements by making shortcut roads through the Road Development Package of Road and Bridge Bts. Singaraja City - Mengwitani. The shortcut road on the Bts. Singaraja City - Mengwitani, according to the BBPJN Jatim - Bali strategic plan, is planned to have 10 sections spread along the section, where for now 6 sections of shotcut road construction have been completed, for points 7D and 7E while work is carried out, and 2 sections will be carried out in the following year. Road and bridge construction package Bts. Singaraja City - Mengwitani points 7D and 7E are shortcut road construction in the form of 400 meters of road construction and 155 meters of bridge construction. The natural conditions traversed by the road route are in a tightly contoured hilly area so that to reach the planned elevation requires excavation work that produces a very large excavation volume.

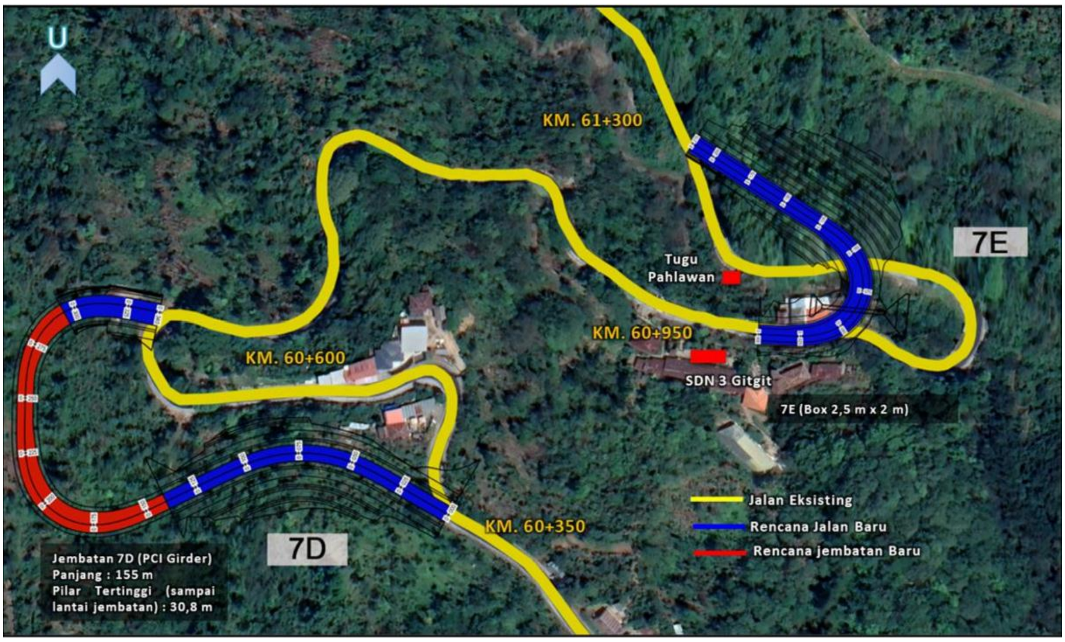

Figure 1. Location of road and bridge construction work Bts. Singaraja City - Mengwitani points 7D and 7E

Source : Satker PJN III Provinsi Bali, 2024

Referring to the contract documents for the Road and Bridge Development Package for the Bts. Singaraja City - Mengwitani obtained from PPK 3.3 of the National Road Implementation Work Unit Region III Bali Province of the East Java-Bali National Road Implementation Center has an uneven ratio of excavation and embankment where the amount of soil excavation volume produced is very large, namely +- 145,000 m3 while the use of embankment material is only +- 10,000 m3. From the existing planning design this volume of excavated soil is directly disposed of to the disposal area which is 2 km from the work site. This excavated material is a waste material that is not reused. This creates environmental problems and eliminates the potential for saving natural resources.

Figure 2. Implementation of excavation work
Source : Satker PJN III Provinsi Bali, 2024

Based on field testing data conducted by PPK 3.3 National Road Implementation Work Unit 3 Region Bali, referring to Table 1 at the location of the excavation work, the soil classification obtained for a depth of 0 - 18 m is clayey sandy soil with a high plasticity index, while for a depth of 18 - 58 m is sandstone and gravel rock.

Table 1. Soil Properties Undisturbed Sample Excavation Location Point 7E

Km/Sta		0+150	0+150	0+150	0+150	0+150
Depth (m)		1,5 - 2,0	17,5 – 18,0	21,5 - 22,0	35,5 - 36,0	47,5 - 48,0
Grain Size Analysis	Sand (%)	9,64	16,08	77,88	Gravel	Gravel
	Silt (%)	31,93	49,72	16,61		
	Clay (%)	58,29	33,04	5,50		
Atterberg Limit	Liquid Limit (%)	65,43	42,89	Sandstone	Gravel	Gravel
	Plastis Limit (%)	36,97	24,57			
	Plasticity Index (%)	28,46	18,32			
Classification	USCS	MH	ML			

Source: PJN III Bali,2024

From the secondary data collection data obtained from Satker PJN III Wilayah Bali for excavated soil in the disposal area, no physical and mechanical testing has been carried out. For the excavated soil parameters at Location 7E as shown in Table 1.1, the grain gradation and soil classification have the potential to be utilized as backfill material and foundation layers, it's just that the soil plasticity index value is still high, therefore physical and mechanical soil parameter testing is needed at the disposal area location because the soil layers at the excavation point are mixed.

From the results of the soil parameter data at the excavation point in the Road and Bridge Construction Package Bts. Singaraja City - Mengwitani, the excavated soil material is quite good and strong, seen from the grain gradation which is dominantly filled with sand and gravel and the plasticity index value is not too high. This excavated soil material is expected to be able to be used as embankment and foundation layer material, therefore it is necessary to conduct further research and analysis to test its physical and mechanical parameters and examine the requirements for embankment and foundation layer material in accordance with the general specifications of Bina Marga for Road and Bridge Construction 2018 Revision 2, as well as test the stability of the material and calculate the maximum height of embankment that can be used. If the excavated soil does not meet the requirements, it is necessary to carry out chemical soil stabilization to improve the physical and mechanical parameters of this excavated soil to reach its best condition.

Table 2. Guidelines for selecting stabilization materials based on grain gradation and plasticity index

Material That Passes Sieve no.200	>25% that passes sieve no.200 (0,075 mm)			<25% that passes sieve no.200 (0,075 mm)		
Plasticity Index, PI (%)	≤ 10	10 - 20	≥ 20	≤ 6 PI x p ≤ 60	≤ 10	≥ 10
Stabilization Materials Cement and binder mixes	Suitable	Doubt	Not Suitable	Suitable	Suitable	Suitable
Lime	Doubt	Suitable	Suitable	Not Suitable	Doubt	Suitable
Asphalt (Bitumen)	Doubt	Doubt	Not Suitable	Suitable	Suitable	Doubt
Asphalt / Cement mixes	Suitable	Doubt	Not Suitable	Suitable	Suitable	Doubt
Granular	Suitable	Not Suitable	Not Suitable	Suitable	Suitable	Doubt

Source: Hicks,2002

Based on the results of soil parameters in the work of the Road and Bridge Construction Package Bts. Singaraja City - Mengwitani Point 7D and 7E, if referring to the research of Hicks (2002) in the Alaska Department of Transportation ang Public Facilities Research & Technology Transfer for soil materials with percent passing sieve no.200 more than 25% and plasticity index above 20% then the suitable stabilization material used is lime. Soil stabilization with lime is basically the same as soil stabilization with cement, such as testing techniques and implementation. The difference is that lime is more suitable for soil stabilization for clay soils, and less suitable for granular soils. Quicklime or lime solution can be used for the treatment of excessively wet or dry soils. For highway applications, lime-soil stabilization is widely used for building subbase or subgrade improvements, Lime-soil stabilization has been widely used in highway, airport, railroad and road works projects in the project area (Hardiyatmo, 2022).

Based on the above background, this research is very important to analyze the utilization of excavated soil on the Singaraja - Mengwitani national road section, in order to determine the value of the physical and mechanical parameters of the excavated soil, and to check whether the excavated soil meets the requirements as an embankment material and foundation layer in accordance with the general specifications of bina marga for road and bridge construction in 2018 revision 2. Then if the embankment material meets the requirements, modeling will be carried out to calculate the height of the embankment that is safe and stable in field conditions, and if it does not meet, stabilization efforts will be made using lime (CaOH)2 additives to increase the excavation soil parameters to reach optimum conditions.

LITERATUR REVIEW

Based on the 2018 general specifications for road and bridge construction works (revision-2) of the Directorate General of Highways of the Ministry of Public Works and

Housing, embankment is divided into four types: ordinary embankment, preferred embankment, granular preferred embankment on swamp land and granular back fill.

Ordinary Embankment

The selected materials should not include highly plasticized soils, classified as A-7-6 according to SNI-03-6797-2002 (AASHTO M145-91 (2012)) or as CH according to the "Unified or Casagrande Soil Classification System". Where the use of highly plasticized soils is unavoidable, such materials should be used only at the base of embankments or in backfills that do not require high bearing capacity or shear strength. Such plasticized soils should in no way be used in the 30 cm layer directly below the base of the pavement or kerb or kerb subgrade. In addition, the backfill for this layer when tested to SNI 1744:2012, shall have a CBR value not less than the characteristic bearing capacity of the subgrade taken for design and shown in the drawings or not less than 6% if not otherwise specified (CBR after 4 days soaking when compacted to 100% maximum dry density (MDD) as specified by SNI 1742:2008).

Preferred Embankment

Preferred fill shall be used as a capping layer on soft soils having a field CBR of less than 2.5% which cannot be improved by compaction or stabilization. Stockpiles classified as preferred stockpiles shall consist of earth or rock material complying with all of the above provisions for regular stockpiles and in addition shall have such properties depending on the intended use, as may be ordered or approved by the Superintendent of Works. In all cases, all selected backfill shall, when tested in accordance with SNI 1744:2012, have a CBR of at least 10% after 4 days of soaking when compacted to 100% maximum dry density in accordance with SNI 1742:2008. Preferred backfill materials used in slope or embankment stabilization works or in other situations requiring sufficient shear strength when carried out by normal dry compaction, the preferred backfill may be well-graded stone or clayey gravel or passive clay or low plasticity clay. The type of material selected, and approved by the Superintendent of Works will depend on the steepness of the slope to be constructed or embanked, or on the stresses to be borne.

Granular Preferred Embankment On Swamp Land

Preferred graded backfill shall be used on swampy soils, waterlogged areas and similar locations where ordinary and preferred backfill materials cannot be satisfactorily compacted. The preferred backfill material on swampy soils and for situations where overlaying in saturated or flooded conditions is unavoidable shall be stone, sand or gravel or other clean grained material with a maximum Plasticity Index of 6%.

Granular Back fill

Granular backfill should be used for backfilling in the influence areas of structures such as abutments and retaining walls and other critical areas where compaction by equipment is limited. The oprite area granular backfill material shall consist of crushed gravel, stone, rock fill or natural sand or a good mix of a combination of these materials graded non-continuously and having a maximum Plasticity Index of 10%. The gradation of oprite area graded backfill shall be as shown in Table 3 below:

Table 3. Gradation of granular back fill

Sieve Size		Percent of Weight That Passes
ASTM	**(mm)**	
4’’	100	100
No.4	4,75	25 - 90
No.200	0,075	0 – 10

Source: Bina Marga, 2018

Aggregate Foundation Layer

Based on the 2018 general specifications for road and bridge construction works (revision-2) of the Directorate General of Highways of the Ministry of Public Works and Housing, aggregate foundation layers are divided into four types, namely Class A, Class B, Class C, and Class S. In general, Class A aggregate foundation layer is the quality of the upper foundation layer for the layer under the paved layer, and Class B aggregate foundation layer is for the lower foundation layer. Class S aggregate foundation layer is used for uncovered shoulders and Class C aggregate foundation layer can be used for uncovered shoulders for LHRT < 2000 vehicles/day.

The material properties required for all aggregate foundation layers are that they should be free from organic matter and clay lumps or other undesirable materials and once compacted should meet the gradation requirements (using wet sieving) given in Table 4 and satisfy the properties given in Table 5

Table 4. Gradation of aggregate foundation layer

Sieve Size		Percent of Weight That Passes		
ASTM	**(mm)**	**A Class**	**B Class**	**S Class**
2’’	50		100	
1,5’’	37,5	100	88 - 95	100
1’’	25	79 - 85	70 - 85	77 – 89
3/8’’	9,50	44 - 58	30 - 65	41 – 66
No.4	4,75	29 - 44	25 - 55	26 – 54
No.10	2,0	17 - 30	15 - 40	15 – 42
No.40	0,425	7 - 17	8 - 20	7 – 26
No.200	0,075	2 - 8	2 - 8	4 – 16

Source: Bina Marga, 2018

Table 5. Properties of aggregate foundation layer

Properties	Aggregate Foundation Layer		
	A Class	**B Class**	**S Class**
Abrasion of coarse aggregate	0 – 40%	0 – 40%	0 – 40%
Coarse aggregate, retained on sieve No.4	95/90	55/50	55/50
Liquid limit	0 - 25	0 - 35	0 – 35
Plasticity Index	0 - 6	4 - 10	4 – 15
Clay material	0 – 5%	0 – 5%	0 – 5%
CBR soaked	Min. 90%	Min. 60%	Min. 50%
Comparison of percent passing sieve No.200 and No.40	Max. 2/3	Max. 2/3	-

Source: Bina Marga, 2018

Stabilization

Soil stabilization is an effort to change or improve the technical properties of soil to meet certain technical requirements. (Hardiyatmo, 2022. Soil stabilization is defined as changing the properties of the original soil to meet the necessary technical requirements. Soil stabilization can use mechanical means (ex: compaction) or chemical means that are useful to increase the durability of soil property values. Some of the objectives of soil stabilization are to increase the strength and impermeability of the soil under existing conditions (Olaniyan et al, 2011).

Widely used stabilization methods are mechanical stabilization and chemical stabilization. Mechanical stabilization is to increase the strength and bearing capacity of the soil by improving the structure and improving the mechanical properties of the soil, while chemical stabilization is to increase the strength and bearing capacity of the soil by reducing or eliminating unfavorable technical properties of the soil by mixing the soil with chemicals such as cement, lime or pozzolan (Harneini, 2013).

Stabilization using additives or often called chemical stabilization aims to improve the technical properties of soil, by mixing soil with additives in a certain ratio. The mix ratio depends on the desired mix quality. If the mixing is only intended to change the gradation and plasticity of the soil, and ease of working, then only a few additives are required. However, if the stabilization is intended to change the soil to have high strength, then more additives are required. Materials that have been mixed with these additives must be spread and compacted properly (Hardiyatmo, 2022).

RESEARCH METHOD

The first method used in this research is the research preparation stage which aims to study literature studies and supporting theoretical bases related to the topic and objectives of the research. After the preparation stage is complete, data collection is carried out, namely in the form of secondary data and primary data. Secondary data collects all planning documents, implementation documents and results of existing soil investigations at the case study site under review, while for primary data collection, namely carrying out direct investigations at the study site and taking soil samples (undisturbed) which are considered representative areas for further research in the laboratory. Next, laboratory tests are carried out to determine the physical and mechanical parameters of the soil left over from the excavation. Physical parameter testing takes the form of specific gravity, Atterberg limit and grain gradation tests. Meanwhile, mechanical parameter testing takes the form of direct shear testing, standard proctor compaction testing, and laboratory CBR testing.

The results of the laboratory tests were analyzed and an examination was carried out on the requirements as stockpile material and foundation layers which were included in the general specifications for clan construction for road and bridge construction work in 2018 revision 2. If the stockpile inspection meets the requirements, the next step is to immediately carry out modeling to calculate the stability of the slope and the maximum height of the stockpile that is safe to work with the Plaxis 2D auxiliary program, but if the stockpile and foundation layer inspection does not meet the requirements, stabilization efforts will be made using added lime to improve the physical and mechanical parameters of the initial soil until it reaches optimum condition. After the stabilization is complete, the soil parameters are checked again for requirements and a model is carried out to calculate the stability of the pile slope. The results of these tests, examinations, stabilizations and modeling were analyzed and discussions were carried out to reach conclusions on this research.

DATA COLLECTION

In this study, soil sampling was carried out on soil left over from excavations from the Bts Road and Bridge Construction Package. Singaraja City – Mengwitani Bali Province. Soil sampling is carried out when the excavation work process has been completed and the material is at the disposal area location so that the original soil layer has been mixed. The soil sample taken is a disturbed soil sample at a depth of 0 – 1 m from the ground surface. The disposal area location for the road and bridge construction package itself has 2 locations, namely the disposal location for the old shortcut area 7A and the disposal rest area location. Based on visual soil conditions and data variations, the soil sample points taken for testing are 4 points, namely 2 points at the old shortcut location, hereinafter referred to as point 7A and point 7D, then 2 more points at the distal rest area location, hereinafter referred to as point RA-1 and point RA-2.

RESEARCH ANALYSIS

Initial Soil Laboratory Testing

Tests on the physical and mechanical properties of the initial soil were carried out at the Soil and Rock Mechanics Laboratory, Department of Civil Engineering, Faculty of Civil Engineering, Planning and Earth, Sepuluh Nopember Institute of Technology. Physical property testing includes specific gravity (Gs), soil consistency, and grain gradation. Then, for testing mechanical properties, including standard prctor compaction, Direct Shear, and bath CBR. The results of laboratory tests can be seen in Table 6 below:

Table 6. Initial soil laboratory test results

Description	7A	7D	RA-1	RA-2
Physical Properties Testing				
1. Spesifik Gravity Testing				
- Spesific Gravity	2,62	2,65	2,67	2,67
2. Atterberg Limit Testing				
- Liquid Limit	37,35 %	56,76 %	43,54 %	31,29 %
- Plastic Limit	29,34 %	44,13 %	33,79 %	25,45 %
- Plasticity Index	8,01 %	12,63 %	9,75 %	5,84 %
3. Sieve Analysis Testing				
- Gravel	24,79 %	4,88 %	6,58 %	30,73 %
- Sand	50,83 %	49,72 %	50,34 %	55,67 %
- Silt	22,06 %	43,69 %	39,89 %	11,89 %
- Clay	2,32 %	1,71 %	3,19 %	1,71 %
- USCS Classification	SM	SM	SM	SM
- AASHTO Classification	A – 4	A – 7 – 5	A – 5	A – 4
Mechanical Properties Testing				
1. Proctor Standard Compaction Testing				
- Optimum Water Content	26,68 %	46,43 %	37,62 %	16,36 %
- Dry Volume Weight	1,47	1,10	1,20	1,50
2. Direct Shear Testing	g/cm³	g/cm³	g/cm³	g/cm³
- Cohession				
- Internal Friction Angle	0,15	0,18	0,51	0,10
- Internal Friction Angle	kg/cm²	kg/cm²	kg/cm²	kg/cm²
Correlation	75,33°	70,12 °	57,92 °	53,25 °
3. CBR Laboratory Testing	30 °	27 °	27 °	30 °
- CBR value	6,60 %	7,68 %	7,21 %	9,75 %

Source: processed by the Author, 2024

Overall, the physical and mechanical parameter values of the 4 sample points were almost uniform, namely with the classification of silty sand soil (SM) with low and medium plasticity. The test results obtained are also in accordance with the existing theoretical basis, but there is a slight correction in the shear angle value because the value obtained is somewhat deviated from the correlation value for silt sand soil types so that the shear angle value is adjusted to the existing theoretical basis.

Requirement Check

The material requirements as fill and foundation layer materials used in this research refer to the General Specification of Highways for Road and Bridge Construction Work Revision 2. These material requirements are juxtaposed with the results of tests on physical and mechanical soil parameters that have been carried out to assess whether the soil is disposed of in the Bts Road and Bridge Construction Package area. Singaraja City – Mengwitani is included in the requirements and can be used as a replacement material for carrying out heap and foundation layer work on the Bts Road and Bridge Development Package. Singaraja City – Mengwitani next. The following are the results of examining stockpile and foundation layer requirements for the 4 soil samples of the tested area disposal:

Table 6. Initial soil laboratory test results

No	Material Type	7A	7D	RA1	RA2
1	Ordinarry Embankment	V	V	V	V
2	Preferred Embankment	X	X	X	V
3	Granular Preferred Embankment On Swamp Land	X	X	X	V
4	Granular Back Fill	X	X	X	V
5	Foundation Layer – A Class	X	X	X	X
6	Foundation Layer – B Class	X	X	X	X
7	Foundation Layer – S Class	X	X	X	X

Source: processed by the Author, 2024

Results of the examination of the requirements for fill and foundation layer materials for the soil of the Bts Road and Bridge Construction Package area proposal. Singaraja City – mengwitani shown by Table.. The results of the requirements examination show that all parts of the disposal area soil are suitable and can be used as ordinary landfill material, because all disposal soil samples tested meet the requirements of the 2018 Revision 2 General Bina Marga Specification for Road and Bridge Construction Work as ordinary landfill material. For some of the land, the rest area proposal area represented by the RA-2 sample can be used as selected pile material, swamp piles, and backfill of granular material, because the parameters assessed meet the requirements of the General Specification of Highways for Road and Bridge Construction Work in 2018 Revision 2. The main thing that differentiates it from other point soil samples is the CBR value. The CBR value at the RA-2 sample point exceeds 10%, while for other disposal soil samples it does not reach 10%.

For the inspection of foundation layer requirements, all disposal soil does not meet the requirements as foundation layer material for class A, class B and class S. It can be seen from the results of the examination that the disposal material does not meet the requirements for grain gradation and CBR values for foundation layer materials. Disposal soil is predominantly sand with a fairly high percentage of silt, while grain gradation requirements for foundation layer materials are predominantly filled by coarse aggregate. The CBR value required in the requirements ranges from 50% - 90%, while the CBR value of excavated soil obtained ranges from 6.60% - 10.12%.

Excavated Soil Stabilization

The results of testing the physical parameters of excavated soil are a classification of silty sand soils with low plasticity. As can be seen from the grain gradation test in the Table.. it shows that the soil remaining from excavations in the area disposal is dominated by sand with a percentage of 49.72% - 55.67%, then for fine aggregate that passes through sieve No. 200 it ranges from 13.60% - 45.40%. Then for soil consistency testing, seen in Table 6 it shows that the excavated soil plasticity index value ranges from 5.84% - 12.63%.

Referring to the Table 2 according to Hick (2002) in the Alaska Department of Transportation Ang Public Facilities Research & Technology Transfer, for materials with a filter pass percentage of no.200 exceeding 25% and a Plasticity Index value below 10% then the lime material is doubtful or not suitable for use as a stabilization material, for soil types with these parameters the material suitable for use as a stabilization material is granular and a binder mixture in the form of cement/asphalt.

As a result of the inspection of stockpile material requirements carried out, all excavated land at the area disposal site meets the requirements as ordinary stockpile material and at some locations the rest area disposal site meets the requirements as selected stockpile material, swamp fill, and backfill of granular material. Based on the results of soil consistency testing which explains that excavated soil has a low plasticity index value and refers to theoretical references regarding chemical stabilization, it can be concluded that chemical stabilization with lime material in the soil left over from excavations from the Bts Road and Bridge Construction Package. Singaraja City – Mengwitani is not suitable for use.

Slope Stability Modeling for Embankment

Modelling of stockpile construction using the Plaxis 2D auxiliary program. The stockpile stability model is calculated based on several conditions as follows:

1. Modelling of the stability of the emabnkment was carried out on all types of excavated soil samples
2. The width of the top side of the pile or road body is 10 meters
3. Variations of embankment slope, starting from 1:1.5, 1:2, and 1:3
4. Variations of embankment height, starting from 1m, 2m, 3m, 4m, and 5m
5. Groundwater level parallel to the ground level of the base
6. At the very top, a traffic load of 10 kN is given
7. Variations of subgrade are soft soil, medium soil, and stiff soil
8. Safety factor for slope stability is 1,5 (SF=1,5)

Embankment Slope Variation 1:1,5

Referring to SNI 8460:2017 regarding slope safety figures (SF>1.5), the slope variation of 1:1.5 material disposal area is able to reach the height of the pile as follows:

Table 7. Height of embankment from slope variation 1:1,5

No	Jenis tanah Dasar	(7A)	(7D)	(RA1)	(RA-2)
1	*Soft Soil*	3 Meter	4 Meter	4 Meter	4 Meter
2	*Medium Soil*	4 Meter	5 Meter	5 Meter	5 Meter
3	*Stiff Soil*	5 Meter	5 Meter	5 Meter	5 Meter

Source: processed by the Author, 2024

Embankment Slope Variation 1:2

Referring to SNI 8460:2017 regarding slope safety figures (SF>1.5), the slope variation of 1:2 material disposal area is able to reach the height of the pile as follows:

Table 8. Height of embankment from slope variation 1:2

No	Jenis tanah Dasar	(7A)	(7D)	(RA1)	(RA-2)
1	*Soft Soil*	3 Meter	4 Meter	4 Meter	4 Meter
2	*Medium Soil*	5 Meter	5 Meter	5 Meter	5 Meter
3	*Stiff Soil*	5 Meter	5 Meter	5 Meter	5 Meter

Source: processed by the Author, 2024

Embankment Slope Variation 1:3

Referring to SNI 8460:2017 regarding slope safety figures (SF>1.5), the slope variation of 1:3 material disposal area is able to reach the height of the pile as follows:

Table 9. Height of embankment from slope variation 1:3

No	Jenis tanah Dasar	(7A)	(7D)	(RA1)	(RA-2)
1	*Soft Soil*	4 Meter	4 Meter	4 Meter	4 Meter
2	*Medium Soil*	5 Meter	5 Meter	5 Meter	5 Meter
3	*Stiff Soil*	5 Meter	5 Meter	5 Meter	5 Meter

Source: processed by the Author, 2024

CONCLUSIONS

Based on the results of the analysis and calculations presented in the previous chapter, the following points can be concluded:

1. Classification of excavated land in the Bts Road and Bridge Construction Package. Singaraja City - Mengwitani is an SM (silty sand) with a low and medium plasticity index. Then the CBR value varies from 6.60% to 10.12%.
2. The result of the inspection of the requirements for embankment and foundation layer materials is that all soil in the disposal area can be used as ordinary embankment material, then some of the disposal rest area (RA-2) can be used as selected embankment material, granular preferred embankment on swamp and granular back fill. Aggregate foundation layer materials cannot be used because the distribution of grain gradations and soaked CBR values does not meet existing requirements.
3. The results of laboratory tests on initial soil are known that excavated soil has a low to medium plasticity index, then the percent passes through sieve No. 200 exceeds 25%, according to Hick (2002) in the Alaska Department of Transportation ang public Facilities Research & Technology Transfer, for materials with % passes through sieve greater than 25% and plasticity index value <10% then a suitable form of stabilization is granular or a binder mixture such as cement and asphalt, meanwhile, lime is not effective to use. Then, because the laboratory test results for landfill meet the requirements, lime stabilization does not need to be used.
4. The height of the embankment that is safe to implement from the dissipation material is 3 - 5 m. From modeling, it can be seen that the slower an embankment, the SF value will be increase. Then the softer of subgrade, the SF value will decrease further.

REFERENCES

[1] Badan Standardisasi Nasional (2008). *SNI 1742-2008 Cara uji kepadatan ringan untuk tanah*. Badan Standardisasi Nasional, Jakarta.

[2] Badan Standardisasi Nasional (2008). *SNI 1744-2012 Metoda uji CBR Laboratorium.* Badan Standardisasi Nasional, Jakarta.

[3] Badan Standardisasi Nasional (2012). *SNI 3638:2012 Metode Pengujian Kuat Tekan Bebas Tanah Kohesif*. Badan Standardisasi Nasional, Jakarta.

[4] Balai Besar Pelaksanaan Jalan Nasional Jawa Timur - Bali. (2024). *Pembangunan Jalan dan Jembatan Bts. Kota Singaraja – Mengwitani Titik 7D dan 7E.* Provinsi Bali.

[5] Bina Marga (2018). *Spesifikasi Umum 2018 Untuk Pekerjaan Konstruksi Jalan dan Jembatan (Revisi 2).* Kementerian Pekerjaan Umum dan Perumahan Rakyat. Jakarta.

[6] Bowles, Joseph E. (1997). *Foundation Analysis and Design Fifth Edition,* Teh McGraw-Hill Companies,Inc. Singapore.

[7] Das, Braja M., (1995). *Mekanika Tanah (Prinsip – Prinsip Rekayasa Geoteknis), Terjemahan oleh Noor Endah & Indrasurya B. Mochtar, Jilid I*. Erlangga. Jakarta.
[8] Hardiyatmo, G. C. (2002). *Mekanika Tanah Jilid 1*. Gajah Mada University Press. Yogyakarta.
[9] Hardiyatmo, Hary Christady (2022). *Stabillisasi Tanah Untuk Perkerasan Jalan.* Universitas Gadjah Mada. Yogyakarta.
[10] Rangkuti, Rahmadsyah (2024). *Stabillisasi Tanah dengan Kapur Untuk Memperbaiki Sifat Fisis dan Mekanis Tanah Sebagai Bahan Timbunan (Studi Kasus: Ruas Jalan Trengguli – Bts. Kab Demak/Kudus).* Institut Teknologi Sepuluh Nopember. Surabaya.
[11] Soehardi, Fitridawati, et al., (2017). *Stabilisasi Tanah dengan Variasi Penambahan Kapur dan Waktu Pemeraman*. Universitas Lancang Kuning. Pekanbaru.
[12] Sormin, Prince Joy (2024). *Penentuan Persentase Bahan Stabilisasi Kapur Ca(OH)2 Untuk Tanah Weathered Clay Shale Sebagai Tanah Dasar (Subgrade) Jalan Tol Serang Panimbang Seksi III Sta 57+200*. Institut Teknologi Sepuluh Nopember, Surabaya.
[13] Yanuar, Mohammad Iqbal (2024). *Analisis Perilaku dan Stabilisasi Kimiawi Timbunan yang Menggunakan Tanah Galian Setempat Berplastisitas Tinggi Pada Proyek Jalan Tol IKN Segmen 3A Karangjoang – KKT Kariangau*. Institut Teknologi Sepuluh Nopember. Surabaya.