APPLICATION OF SPECIAL SPECIFICATIONS FOR ROCK MATERIAL AS ROAD EMBANKMENT IN THE PROBOLINGGO–BANYUWANGI TOLL ROAD PROJECT PACKAGE 3 STA 20+200 – STA 45+800: A SPECIAL SPECIFICATION ANALYSIS

Julius Ardo Lemambang[1], Muhammad Fadillah Rahman[2], Rikal Andani[3], Dani Hamdani[4]

[1,2,3,4] Program Studi Teknologi Konstruksi Jalan dan Jembatan, Politeknik Pekerjaan Umum Semarang, Jl. Soekarno Hatta No.100 Semarang 51066

Correspondence: fadilrahman898@gmail.com

Diterima: 31 Desember 2025, Disetujui: 1 Januari 2026

ABSTRACT

The Probolinggo–Banyuwangi Toll Road Project, Package 3 STA 20+200 – STA 45+800, is the first pilot project in Indonesia to use excavated rock as embankment material. This approach optimizes rock excavation volume, reduces external borrow needs, and lowers disposal costs. The study explains rock embankment works carried out in the field according to the Special Specifications, outlines the water replacement method for field density measurement, and evaluates rock material feasibility to ensure roadbed stability. Research methods include literature and specification review, technical interviews, and analysis of laboratory and field data. Tests conducted were Uniaxial Compressive Strength (UCS), Proctor compaction, proof rolling, and density measurement with the water replacement method. Results show the works complied with the Special Specifications, covering material testing, excavation, hauling, spreading in ≤60 cm layers, compaction, geotextile installation, and covering with Common Borrow Material (CBM). The water replacement method proved effective for coarse materials with results meeting requirements. The rock material used in the field has UCS ≥ 12.5 MPa, meeting the hard rock excavation criteria specified in the Special Specifications, confirming its suitability as an alternative embankment material for similar projects.

Keywords: *Rock Embankment, Special Specifications, Water Replacement Method, Probolinggo–Banyuwangi Toll Road Package 3*

ABSTRAK

Proyek Jalan Tol Probolinggo–Banyuwangi Paket 3 (STA 20+200 – STA 45+800) merupakan proyek percontohan pertama di Indonesia yang menggunakan hasil galian batu sebagai material timbunan. Pendekatan ini mengoptimalkan volume galian batu, mengurangi kebutuhan material timbunan dari luar (external borrow), dan menekan biaya pembuangan (disposal). Penelitian ini menjelaskan pekerjaan timbunan batu yang dilaksanakan di lapangan sesuai dengan Spesifikasi Khusus, menguraikan metode penggantian air (water replacement) untuk pengukuran kepadatan lapangan, serta mengevaluasi kelayakan material batu guna memastikan stabilitas badan jalan. Metode penelitian mencakup tinjauan literatur dan spesifikasi, wawancara teknis, serta analisis data laboratorium dan lapangan. Pengujian yang dilakukan meliputi Uniaxial Compressive Strength (UCS), pemadatan Proctor, proof rolling, dan pengukuran kepadatan dengan metode penggantian air. Hasil penelitian menunjukkan bahwa pekerjaan telah memenuhi Spesifikasi Khusus, yang mencakup pengujian material, penggalian, pengangkutan, penghamparan dalam lapisan ≤ 60 cm, pemadatan, pemasangan geotekstil, dan penutupan dengan Common Borrow Material (CBM). Metode penggantian air terbukti efektif untuk material berbutir kasar dengan hasil yang memenuhi persyaratan. Material batu yang digunakan di lapangan memiliki nilai UCS ≥ 12,5 MPa, sehingga memenuhi kriteria galian

DOI : 10.56911/jdk.v2i2.208

batu keras sesuai Spesifikasi Khusus. Hal ini mengonfirmasi kelayakannya sebagai material timbunan alternatif untuk proyek-proyek serupa.

Kata kunci: *Timbunan Batu, Spesifikasi Khusus, Metode Penggantian Air, Jalan Tol Probolinggo–Banyuwangi Paket 3*

DOI : 10.56911/jdk.v2i2.208

INTRODUCTION

The Probolinggo–Banyuwangi Toll Road Project, located in East Java Province, is part of the Trans-Java Toll Road network that connects Probolinggo, Situbondo, and Banyuwangi to Ketapang Port. The construction of Section 3 (STA 20+200 – STA 45+800) plays a strategic role in supporting national connectivity and improving the efficiency of logistics and regional development. A distinctive aspect of this project is the utilization of rock material as a main component for road embankment construction, which represents a new approach in Indonesia's toll road infrastructure works.

This innovation originated from the project's mass excavation plan, where a significant portion of the work involved rock excavation from mountainous areas. The excavated rock volume reached approximately six million cubic meters, creating both a technical and environmental challenge. Instead of disposing of the material, the project team optimized its use as embankment fill material. This approach reduced the need for borrow material from external sources and minimized disposal costs, aligning with sustainable construction principles.

However, at the initial design stage, no existing specification defined the technical requirements for using rock material as embankment fill. The Bill of Quantity (BoQ) listed "rock excavation for embankment," but the design drawings lacked details such as typical cross-sections and construction methods. Consequently, coordination between the project stakeholders and the Directorate General of Highways (Bina Marga), Ministry of Public Works and Housing (PUPR), was required. This collaboration resulted in the issuance of a Special Specification that regulates the technical aspects of rock embankment construction, including material classification, compaction methods, layer thickness, and geotextile installation.

As the first pilot project in Indonesia implementing rock embankment construction, this initiative represents a significant step toward resource optimization and sustainable infrastructure. Additionally, a novel field compaction test method, known as the water replacement method, was applied to measure the density of coarse-grained rock material accurately.

This study aims to describe the implementation of rock embankment construction according to the Special Specification, evaluate the application of the water replacement method for in-situ density measurement, and assess the suitability of rock material as an alternative fill material for future infrastructure projects with similar geological conditions.

METHODS

This study was conducted to analyze the implementation of the Special Specification on of Rock Embankment on the Probolinggo–Banyuwangi Toll Road Project Section 3 STA 20+200 – STA 45+800. The research method was descriptive, supported by literature study, technical interviews, and data analysis to obtain a comprehensive understanding of the field implementation and quality control process. The overall research process was arranged in a systematic flow as shown in the research flowchart.

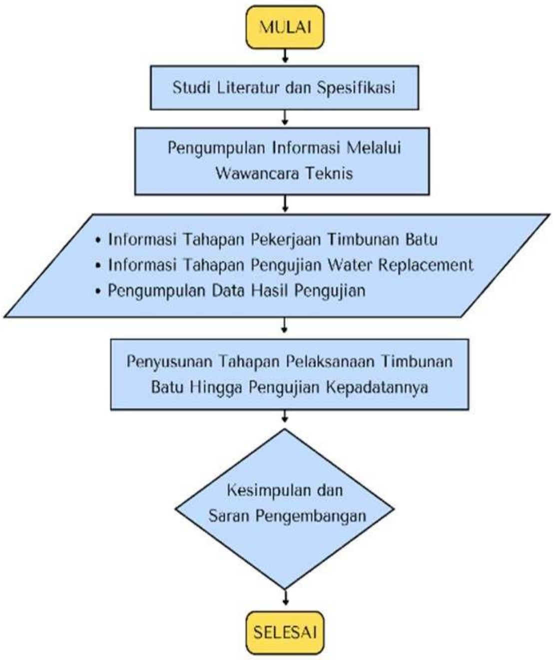


Figure 1. Research Flowchart of Rock Embankment Method
(Source: Personal Documentation, 2025)

The first step was a literature and specification study, carried out to review the applicable technical standards such as SNI, General Specifications, and the Special Specifications issued by the Directorate General of Highways. This stage aimed to build a theoretical foundation regarding testing methods, material criteria, and construction requirements for rock embankment work.

DOI : 10.56911/jdk.v2i2.208

After establishing sufficient theoretical understanding, technical interviews were conducted with relevant parties including the engineering team, field supervisors, and quality control personnel. The interviews were intended to obtain detailed information on regarding construction procedures, work sequences, and testing methods used on-site, considering that the rock embankment and water replacement testing had been completed before the observation period began.

The collected information included descriptions of material testing, rock excavation and processing methods, hauling and spreading procedures, compaction stages, and in-situ density testing. Additional data were gathered directly from the project's quality control team, including the results of Uniaxial Compressive Strength (UCS) tests, density tests, proof rolling, and water replacement method tests. These data were used to evaluate the field compaction on quality and the suitability of the material as embankment fill.

Subsequently, the researcher compiled the sequence of field implementation from material excavation to density testing using the water replacement method. This synthesis was intended to provide a structured description of actual on-site procedures that could serve as a reference for similar projects.

The research was conducted over a 20-day period, from 1 July 2025 to 20 July 2025, at the Probolinggo–Banyuwangi Toll Road Project Sec on 3 STA 20+200 – STA 45+800, which is the only package utilizing rock as the main embankment material. Data processing was performed by organizing the collected information based on work stages and testing categories, then comparing the findings with relevant standards and project specifications such as SNI and the Special Specification for Rock Embankment.

All data were analyzed descriptively to assess the conformity of field implementation with technical standards and to determine the compaction quality achieved through the water replacement method.

RESULT AND DISCUSSION

Method of Stone Embankment Construction

The stone embankment work was carried out as the foundation for forming the road body along the toll road alignment. The implementation process begins with rock and subgrade testing, followed by gradual spreading and compaction of materials un l the final elevation is reached. Each stage follows technical procedures to ensure that the work meets the specifications.

The flowchart of the stone embankment implementation can be seen in **Figure 2**.

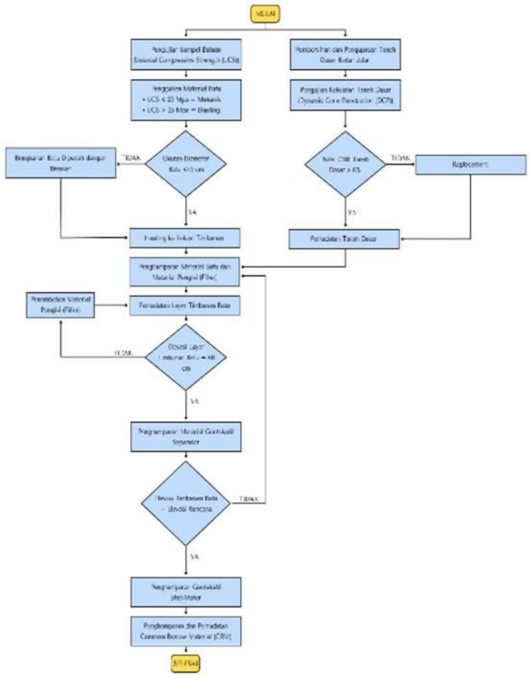


Figure 2. Flowchart of Rock Embankment Implementation
(Source: Personal Documentation, 2025)

Prior to construction, the subgrade preparation was conducted. The subgrade was first cleared of unnecessary materials such as grass, waste, and the humus layer. After cleaning, the subgrade was stripped to a depth of 30 cm, followed by a Dynamic Cone Penetration (DCP) test to determine the field CBR value. If the CBR value was less than 6%, the subgrade had to be further excavated to a depth of 1 m and replaced with Common Borrow Material (CBM). However, if the CBR value was greater than 6%, the subgrade was only compacted after the 30 cm stripping. Compaction was performed using a sheep foot roller and a vibro roller un l the subgrade was ready to receive the embankment layer.

The next stage was the Uniaxial Compressive Strength (UCS) test to classify the material. Materials with UCS <12.5 MPa were categorized as soft rock, while materials with UCS ≥12.5 MPa were classified as rock excavation. The

DOI : 10.56911/jdk.v2i2.208

excavation material used as the embankment for the road body in this project was categorized as rock excavation. The UCS test results also served as the basis for determining the excavation method. If the UCS value was ≤25 MPa, excavation could be carried out using a breaker, whereas if it exceeded 25 MPa, blasting was required because the breaker would not be effective in breaking the rock.

After the UCS test results were obtained, the next stage was rock excavation. The excavation process was carried out according to the predetermined method, either by using a breaker or blasting. Excavated material that met dimensional requirements was then loaded into dump trucks. If rocks larger than 45 cm were found, they were broken down to meet specifications. The loaded material was then transported to the embankment site through designated haul routes. The excavation material naturally consisted of large rock fragments mixed with smaller materials, either stone fragments or fine particles such as soil, referred to as filler. Filler served to fill the voids between rocks, making the embankment layer denser and more stable. Since the excavation process could not separate large rock from filler, both were automatically mixed and transported together to the embankment site.

Upon arrival at the site, the material was dumped gradually to avoid accumulation at a single point and then spread using a bulldozer with a maximum thickness of 60 cm per layer. Because the excavated material was a mixture of large rocks and filler, both were automatically spread together during placement. If oversized rocks were found, a breaker available on-site was used to reduce their size to specification.

After spreading was completed and the surface was considered level, the compaction process was carried out. Initial compaction was performed using a sheep foot roller with vibration to press and knead the rock material so that the particles interlocked and formed a more stable embankment structure. Subsequently, surface compaction was performed using a vibro roller. Before compaction with the vibro roller, an inspection was carried out to ensure that the equipment met the required technical standards, including the specified vibration frequency. Compaction was then conducted with a minimum of six passes, a drum vibration on force of at least 50 kN/m, a vibration frequency of at least 16 Hz, and a rolling speed not exceeding 1 meter per 3 seconds. If, after compaction, the layer thickness was less than 60 cm, filler was added to adjust the elevation to the design level, followed by re-compaction un l the required thickness was achieved.

On each compacted layer, a geotextile separator was placed to prevent mixing between layers. On the uppermost layer, a combination of geotex le separator and geotex le stabilizer was applied sequentially, with the separator at the bottom and the stabilizer on top, to enhance embankment stability. Finally, a cover layer of Common Borrow Material (CBM) was placed with an initial thickness greater than 20 cm to an cipate se lement due to compaction, and then compacted to a final thickness of 20 cm. This process was repeated un l three layers were formed, with each layer controlled through elevating stakes to ensure that the thickness and final elevation conformed to the design specifications.

Method of Water Replacement Test Implementation

The Water Replacement method is one of the field soil density testing methods used to determine the dry density of compacted soil. The basic principle of this method is to replace the volume of excavated soil with water so that the volume of the hole can be accurately measured. By knowing the volume of soil excavated and its wet mass, the dry density value can be calculated. In principle, this method has a similar concept to the Sand Cone method, which both aim to determine soil density through measurement of the excavated hole volume. The difference lies in the filling medium and hole size, where the Sand Cone method uses quartz sand, while the Water Replacement method uses water and is applied to larger holes.

The stages of this testing procedure can be seen in **Figure 3**.

DOI : 10.56911/jdk.v2i2.208

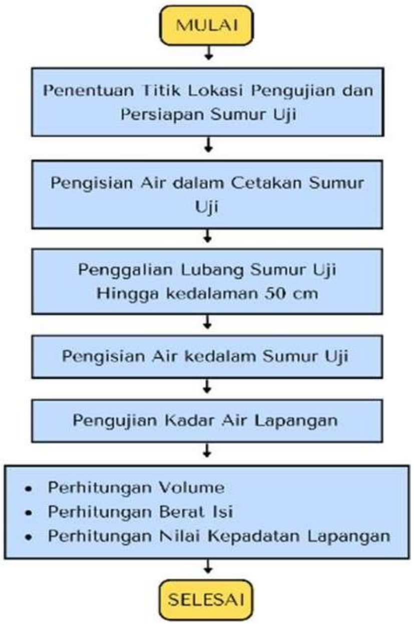


Figure 3. Flowchart of Water Replacement Testing Procedure
(Source: Personal Documentation, 2025)

The test begins with site preparation and construction of the test pit. The test location is selected in a representative area, and the surface is cleaned of loose materials such as gravel, small stones, or organic debris to avoid interference during the test. A metal plate with a diameter of about 1.2 m is then placed on the soil surface and leveled using a water pass to ensure it is completely flat. The inside of the plate is lined with a double plastic sheet to prevent water from seeping into the soil. Water is poured into the mold until it reaches the reference point, and the mass of water used is recorded as the initial volume.

The next step is the excavation of the test pit. The hole is dug in a cylindrical shape according to the diameter of the mold to a depth of 50 cm. At locations with hard material, a jackhammer is used to break rocks, as most of the embankment consists of large-sized material. The excavated material is separated into control frac on, consisting of fine to medium materials such as soil or small stones, and oversize, consisting of large boulders. Both fractions are collected and weighed separately for calculation purposes. The pit is then relined with plastic and refilled with water up to the reference level. The mass of water used is recorded, and the difference from the initial volume indicates the volume of excavated soil.

Field moisture content testing is carried out on the control fraction using a Speedy Moisture Tester. This device works on the principle of a chemical reaction between the soil sample and calcium carbide (CaC_2) inside a sealed chamber, which produces gas pressure that is read on a manometer. The measured moisture content value is then used to calculate the dry unit weight of the soil.

The next step is the volume calculation. The volume of water used to fill the pit is determined from the difference in water mass before and after filling, then converted into volume units. From this total volume, the oversize volume—obtained from the oversize mass divided by the specific gravity of the rock—is subtracted. The result is the volume of the control frac on. The wet unit weight is obtained by dividing the mass of the control fraction by its volume, and then corrected for the field moisture content to determine the dry unit weight.

The field density value is calculated by comparing the dry unit weight from the test with the Maximum Dry Density (MDD) from laboratory compaction tests, multiplied by 100 percent. If the result is ≥95%, the embankment is considered to have been compacted properly according to technical specifications.

Test Results

This section presents the test results of the rock material used and the evaluation of embankment work carried out in the field. Testing was conducted in stages, starting from rock characterization tests such as compressive strength (UCS) and specific gravity, density tests of filler material, inspection of embankment compaction results through proof rolling, up to field density tests using the water replacement method. These results serve as the basis for assessing the quality of materials and the stability of the constructed embankment.

Uniaxial Compressive Strength (UCS) Test of Rock

The Uniaxial Compressive Strength (UCS) test was carried out using a Compression Machine with a capacity of 3000 kN on rock samples taken directly from the field in their natural condition.

The test results are shown in **Table 1**.

DOI : 10.56911/jdk.v2i2.208

Table 1. Uniaxial Compressive Strength (UCS) Test Results of Rock at STA 27+800

No	Parameter	Result
1	Rock Color	Dark Gray
2	Dimension	Height (H) = 119.2 mm; Diameter (D) = 55.12 mm; Ratio (H/D) = 2.16 (SNI Ratio 2–2.5)
3	Cross-sectional Area (A)	2385.00 mm^2
4	Volume (V)	284.292 mm^3
5	Sample Weight	685.50 g
6	Unit Weight	2.41 g/mm^3
7	Failure Load	93 kN
8	Compressive Strength (before correction)	38.99 MPa
9	Compressive Strength (after correction)	39.35 MPa

(Source: PT. PP (Persero), Tbk, 2025)

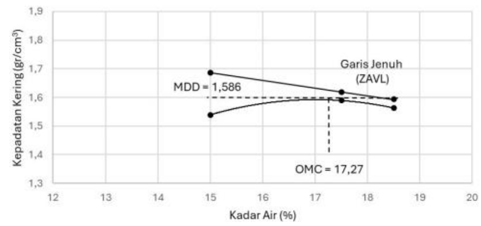
The test results show a UCS value of 39.35 MPa. This indicates that the rock belongs to the category of rock excavation (>12.5 MPa) with hard rock characteristics. With a value greater than 25 MPa, breaker methods are not effective; therefore, blasting was applied in this area. Bulk Density Test for Filler Material

Bulk density test of filler material to determine the relationship between water content and dry unit weight.

The results are shown in **Table 2.**

Table 2. Bulk Density Test Results for Filler Material

Unit	Mold + Soil Weight (g)	Mold Weight (g)	Soil Weight (g)	Mold Volume (cm^3)	Bulk Density (g/cm^3)	Water Content (%)	Dry Density (g/cm^3)	ZAV
1	9873.2	6257.1	3716.1	2099	1.770	15.0	1.539	1.687
2	10075.9	6157.1	3918.8	2099	1.867	17.5	1.589	1.619
3	10045.2	6157.1	3888.1	2099	1.852	18.5	1.563	1.593



(Source: PT. PP (Persero), Tbk, 2025)

The results show that the maximum dry density was 1.586 g/cm^3 at an optimum moisture content (OMC) of 17.27%. This value was then used as a reference in the evaluation of field density.

Specific Gravity Test

A specific gravity test was also carried out to determine the physical characteristics of the rock.

The results are presented in **Table 3.**

Table 3. Specific Gravity Test Results of Rock

Parameter	Sample 1	Sample 2	Average
Bulk Specific Gravity (Dry)	**2.209**	**2.309**	**2.259**
Bulk Specific Gravity (SSD)	**2.331**	**2.389**	**2.360**
Apparent Specific Gravity	**2.516**	**2.510**	**2.513**
Water Absorption	**0.055**	**0.035**	**0.045**

(Source: PT. PP (Persero), Tbk, 2025)

The average apparent specific gravity value obtained was 2.513. This value was later used in the calculation of oversize volume in the water replacement method.

Inspection of Rock Embankment Compaction Results and Proof Rolling Test

Field compaction inspection and proof rolling were carried out to verify compliance with specifications.

The results are presented in **Table 4.**

DOI : 10.56911/jdk.v2i2.208

Table 4. Field Compaction Inspection and Proof Rolling Test

No	Inspection Item	Result	Spesification	Status
1	Material Size	45 cm	Max. 45 cm (75% of 60 cm layer)	OK
2	Layer Thickness	60 cm	Max. 60 cm	OK
3	Sheep Foot Passing	7	Min. 6	OK
4	Vibro Roller Passing	8	Min. 6	OK
5	Roller Weight	50 kN/m	Min. 50 kN/m	OK
6	Vibration Frequency	18 Hz	Min. 16 Hz	OK
7	Speed	1 m/3 sec	Max. 1 m/3 sec	OK
8	Proof Rolling (40 tons)	No deform	-	OK

(Source: PT. PP (Persero), Tbk, 2025)

The inspection showed that all parameters met the required specifications. Proof rolling using a 40-ton truck showed no deformation on the embankment surface, indicating that the embankment was stable.

Field Density Test Using the Water Replacement Method

The final test was the field density determination using the water replacement method.

The results are presented in **Table 5.**

Table 5. Water Replacement Test Results

Parameter	Value
MDD	1.586 t/m^3
OMC	17.27%
Layer Thickness	60 cm
Test Pit Depth	50 cm
Water Volume	0.320 m^3
Oversize Volume	0.102 m^3
Control Fraction Volume	0.218 m^3
Wet Unit Weight	1.843 t/m^3
Dry Unit Weight	1.591 t/m^3
Field Density	100.31%

(Source: PT. PP (Persero), Tbk, 2025)

The field density test showed a value of 100.31% compared to the maximum dry density (MDD), which exceeds the minimum requirement of 95%. Therefore, the embankment construction was declared to have met the required quality standards.

CONCLUSION

Based on the study of the u liza on of rock material as embankment fill in the Probolinggo–Banyuwangi Toll Road Construction Project, Package 3 STA 20+200 – STA 45+800, the following conclusions can be drawn:

- The application of rock embankment works in this project was carried out in compliance with the applicable Special Specifications. The construction stages included initial testing of the rock material (Uniaxial Compressive Strength), excavation with methods adapted to the rock strength, hauling, spreading in layers of a maximum thickness of 60 cm, compaction using vibro rollers and sheep foot rollers, installation of geotextile separator and stabilizer, and final covering with Common Borrow Material (CBM).

- The field density measurement of the embankment was conducted using the water replacement method in accordance with SNI 6872:2015. This method was selected due to the large particle size of the embankment material, which cannot be tested using the sand cone method. The test results showed that the achieved density met the technical specification requirements.

- The suitability of rock material as embankment fill has been verified. The rock material fulfilled the requirement of compressive strength ≥12.5 MPa, proof rolling tests confirmed stability under heavy vehicle loads, and density tests demonstrated op mal filling of voids between particles. These results indicate that the embankment is stable and feasible for application in similar projects.

Suggestions

Based on the findings and analysis, several suggestions are proposed for consideration in the implementation of rock embankment works in future projects:

DOI : 10.56911/jdk.v2i2.208

- Continuous studies and evaluations of rock embankment construction methods are recommended, with particular focus on identifying new techniques or equipment that can improve work efficiency and reduce construction me.

- Since this project serves as a pilot project and an important case study, it is strongly recommended to encourage the formulation or further refinement of national technical standards related to rock embankment works.

- The excavation process for water replacement testing requires a significant amount of me, particularly due to the difficulty of excavating hard rock with dimensions up to 45 cm using jack hammers. Therefore, further studies should be conducted to identify alternative techniques or equipment that may improve efficiency and reduce the me required for test pit excavation.

THANK-YOU NOTE

The author would like to sincerely thank PT. PP (Persero), Tbk for the support and facilities provided during the implementation of this research. Appreciation is also extended to the Department of Civil Engineering, [Your University Name], for academic guidance and resources.

Special thanks are given to the advisors and examiners who have provided valuable insights, constructive feedback, and continuous encouragement throughout the preparation of this thesis.

Finally, the author expresses heartfelt gratitude to family and colleagues for their unwavering moral support during the completion of this study.

BIBLIOGRAPHY

[1] Badan Standardisasi Nasional, SNI 1743:2008 – Cara Uji Kepadatan Berat Untuk Tanah. Jakarta: Badan Standardisasi Nasional, 2008.

[2] Badan Standardisasi Nasional, SNI 1969:2008 – Cara Uji Berat Jenis dan Penyerapan Air Agregat Kasar. Jakarta: Badan Standardisasi Nasional, 2008.

[3] Badan Standardisasi Nasional, SNI 2825:2008 – Cara Uji Kuat Tekan Batu Uniaxial. Jakarta: Badan Standardisasi Nasional, 2008.

[4] Badan Standardisasi Nasional, SNI 6872:2015 – Metode Uji Kepadatan Tanah dan Batuan di Lapangan dengan Cara Penggantian Air pada Sumur Uji. Jakarta: Badan Standardisasi Nasional, 2015.

[5] Kementerian Pekerjaan Umum dan Perumahan Rakyat, Spesi ikasi Umum 2018 untuk Pekerjaan Konstruksi Jalan dan Jembatan (Revisi 2). Jakarta: Direktorat Jenderal Bina Marga, 2020.

[6] Kementerian Pekerjaan Umum dan Perumahan Rakyat, Spesi ikasi Umum untuk Jalan Bebas Hambatan dan Jalan Tol. Jakarta: Direktorat Jenderal Bina Marga, 2020.

[7] Kementerian Pekerjaan Umum dan Perumahan Rakyat, Spesi ikasi Khusus Proyek Pembangunan Jalan Tol Probolinggo– Banyuwangi. Jakarta: Direktorat Jenderal Bina Marga, 2024.

[8] F. I. Kresnandi and W. Herijanto, “Perencanaan Gerbang Tol Probolinggo–Banyuwangi,” Jurnal Teknik ITS, vol. W, 2021, E162.

DOI : 10.56911/jdk.v2i2.208