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Field Soil Density Analysis Using the Sand Cone Method on the Segayam–Lebak Gedong Road Improvement Project, Ogan Ilir Regency

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Abstract: Road infrastructure is crucial for the economy's smooth functioning, but its current state is largely due to natural and human factors, leading to increased traffic. Quality control is essential in road construction planning, focusing on aggregates, subgrade, and subbase layers. Factors such as water content, soil type, and compacted soil can affect soil density. A dense sub-base layer provides good bearing capacity, strengthening road construction. Improving road infrastructure is essential for maintaining the economy's lifeblood, supporting people's movement and influencing distribution and logistics activities. With the development of cities and technological advancements, national roads have grown, passing through provincial capitals and regency/city capitals. The Ogan Ilir Regency Government, through the Public Works and Housing Office, is working to meet community needs in road infrastructure, particularly in rural areas. However, many road conditions in Ogan Ilir Regency still need repairs and improvements. Road improvement in Ogan Ilir Regency should be carried out using good methods and optimal supervision. The sand cone method, which employs Ottawa sand as a parameter for soil density, is used to inspect the field density of the compacted soil layer or pavement layer.

Keywords: Road, Soil Compaction, Sand Cone.

INTRODUCTION

The improvement of road infrastructure has become very important in maintaining the lifeblood of the economy. This is closely related to its role in supporting the movement of people and influencing distribution and logistics activities (Bowles, J.E, 1993). At this point, the availability of infrastructure is of great importance because it correlates with travel time and distribution costs that determine the progress of an area. Roads are basic infrastructure facilities needed by humans to move from one location to another in order to meet their needs

(Siregar, Ratna Dewi, 2015). The availability of roads becomes a pressing issue when the economic activities of the community experience significant growth.

With the development of cities and technological advancements, along with economic growth and societal needs, there has been growth on the national roads passing through cities— both provincial capitals and district/city capitals. The national road is a road that connects the provincial capital with roads of national strategic importance (Hadijah, Ida, 2015). National roads can also consist of transitional roads from provincial roads proposed to the central government to be managed as national roads (Sukirman. S, 1999). The improvement and rehabilitation of roads are also carried out in densely populated residential areas. With the improving road conditions, it increasingly triggers the spread of new residential pockets and the expansion of existing settlements so that the population is not concentrated only in the sprawling residential areas (Aashto, 1993). The spread of the population due to the improved road services can be seen with the emergence of new settlements following the upgraded roadways.

The Ogan Ilir Regency Government, through the Public Works and Housing Office, continues to strive to meet the community's needs in the field of road infrastructure, especially in the region. However, until now, many road conditions in Ogan Ilir Regency still need repairs and improvements (Sudarsono, 1979). Given these issues, it is necessary to carry out road improvements in Ogan Ilir Regency using good methods and optimal supervision. Soil compaction using the sand cone method employs Ottawa sand as a parameter for soil density, which has the properties of being dry, clean, hard, and free-flowing without any binding materials. The sand cone test aims to check the density in the field on the layer of soil or the layer of pavement that has been compacted (Braja, 1993). In compaction with different water contents, different density values will also be obtained (Sukirman. S, 1999). Thus, a certain moisture content will result in the densest state (the lowest void ratio). The moisture content at which the soil reaches its densest state is called the optimum moisture content. To determine the optimum moisture content, a graph is usually made showing the relationship between moisture content and dry bulk density (Craig, R.F, 1989). This dry bulk density is used to determine the optimum moisture content where it reaches the densest state.

The definition of infrastructure, according to the American Public Works Association, is the physical facilities developed or needed by public agencies for government functions in the provision of water, electricity, waste disposal, transportation, and similar services to facilitate social and economic goals (Terzaghi, K & Peck, R.B, 1987). Technically speaking, infrastructure is defined as physical assets built into a system to deliver crucial public services. Therefore, infrastructure consists of components in the form of facilities and infrastructure that are inseparable from one another and defined within a system. According to Craig, R.F (1989), infrastructure is a physical system that provides transportation, irrigation, drainage, buildings, and other public facilities that meet the basic needs of humans, both social and economic.

Roads are land transportation infrastructure that includes all parts of the road, including supplementary buildings and their accessories intended for traffic, which are located on the surface of the ground, above the surface of the ground, below the surface of the ground and water, as well as above the surface of the water, except for railroads, truck roads, and cable roads (Murti, MS, 2007). Roads are classified into several types, namely:

1. Public road, which is a road designated for public traffic.
2. Special road, which is a road built by institutions, businesses, individuals, or community groups for their own interests.
3. Toll road, which is a public road that is part of the road network system and serves as a national road where users are required to pay a toll.

In Law No. 38 of 2004, public roads are classified based on the system, function, status, and class of the road. For the classification of public roads based on the system, they are divided into two: the primary and secondary road network systems. Meanwhile, public roads classified based on their function are divided into arterial roads, collector roads, local roads, and environmental roads (Kementerian Pekerjaan Umum (Indonesia), 1987). For public roads, according to their status, they are classified into national roads, provincial roads, district roads, city roads, and village roads. Public roads are classified according to their class as toll, arterial, collector, and local roads.

The road structure consists of various structural layers, starting with the aggregate base layer (classes A and B), AC-BC, AC-WC, and so on. Each structural layer has its own function, and the implementation methods also vary. The aggregate base layers of classes A, B, and S do not use asphalt material because these structures fall into the category of road foundations. The aggregate base layer is a structural layer located above the soil/subgrade that functions to provide load-bearing capacity to the road, ensuring that the road surface remains stable (Djatmiko & Edy, 1993). The foundation plays an important role in the durability of a road. Most of the damage to road asphalt is caused by the aggregate base layer being weak and unstable (Hendarsin, S.L, 2000). Class B Aggregate Base Layer is an aggregate base layer that is located above the subgrade. The subgrade soil beneath the LPB can be either natural soil or fill and excavation soil. The class B aggregate base layer is a mixture of various aggregate fractions. The composition of the class B aggregate mixture depends on the job mix formula that has been created. The creation of the JMF begins with various aggregate material tests, including specific gravity tests, CBR, rock hardness tests (abrasion), and so on. An example of the aggregate composition for class B resulting from the JMF is as follows:

1. Fraction 1 (37.5 – 50 mm) = 15%
2. Fraction 2 (0 – 37.5 mm) = 53%
3. Fraction 3 (sand) = 32%

The implementation of class B aggregate is carried out after the subgrade is ready. The steps for the class B aggregate work are as follows:

1. Subgrade preparation work by taking measurements using measuring instruments such as total stations, theodolites, or waterpasses.
2. The process of crushing stones into the desired fractions using a stone crusher.
3. Blending the material starting from fractions 1, 2, and 3 according to the JMF composition. Blending can use a blending plant, if not available, blending can use an excavator or a wheel loader.
4. The process of transporting to the spreading location uses a dump truck.
5. Spreading of aggregate using a motor grader with a maximum aggregate layer thickness of 20 cm.
6. The compaction process uses a vibro roller. During compaction, the moisture content needs to be maintained. Therefore, watering using a water tank truck is necessary.
7. Testing the thickness of LPB or spit test.
8. Testing the density of aggregates using the sand cone method. The density level reaches up to 100%.
9. Field CBR testing and laboratory CBR testing with a minimum CBR value of 60%.

One way to determine soil density in the field is through the sand cone test. In principle, this method (sand cone) is only used to determine the volume of soil excavated in the pavement layer. Meanwhile, the weight and moisture content in the soil sample can be determined by weighing and drying it (Endrayana, MR, 2008). Sand cone is a field density test using Ottawa sand as the soil density parameter, which is dry, clean, hard, and free of binding materials, allowing it to flow freely (Indrawahyuni, H et al., 2009). The Ottawa sand used is passed through a No. 10 sieve and retained on a No. 200 sieve. For the examination of soil density in the field on the layer of soil or pavement that is compacted. The test described involves soil and rock particles with a diameter of no more than 5 cm. The one that corresponds to field density is the dry unit weight (SNI 03-2828, 1992).The result of the sand cone test is the dry unit weight of the soil or base layer material, which is the field density of the soil or base layer being examined and aims to evaluate the compaction work results in the field expressed in the degree of compaction, which is the ratio between the field dry density (δd) and the laboratory dry density (δd).Field testing to determine the local soil density can be either destructive or non-destructive. Soil density can be determined by driving a cylinder into the ground to obtain a soil sample with a known volume. What is usually done is digging a hole; this method is called "soil displacement." The method of soil displacement is as follows:

1. Digging a hole in the ground surface.
2. Measuring the volume of the excavated soil.
3. Determining its water content.
4. Calculating the wet volume weight.

Comparing the dry bulk density (laboratory) with the maximum dry bulk density obtained in the field, calculating the relative soil density. The relative density obtained is at least 80%, but it is recommended to be between 90% and 100%.

METHOD

The research design was created in accordance with the chosen research topic of this research, which was how the results of field soil density analysis using the sand cone method. The sand cone test was conducted at 20 (twenty) points at STA.0+000, STA.0+050, STA.1+250, STA.1+900, STA.2+050, STA.2+750, STA.3+050, STA.3+750, STA.4+050, STA.4+900, STA.5+100, STA.5+600, STA.6+150, STA.7+050, STA.8+200, STA.9+350, STA.10+100, STA.10+200, STA.10+400, and STA.12+050. In conducting soil compaction, several stages must be carried out, starting with the literature review used in writing and research, the fieldwork stage, and the laboratory work stage. In the fieldwork, soil samples were taken. Then continued with laboratory testing and analysis in the form of testing the physical properties of the soil and the mechanical properties of the soil. To regulate the implementation of planning, a good and correct methodology was necessary, as methodology serves as a reference to determine the steps that need to be taken in planning, such as location surveys to obtain a general overview of the study area's conditions to achieve optimal results. Data processing to search and evaluate soil compaction results based on literature studies is necessary as a reference to support this research, which can be achieved using several international regulations, such as ASTM. As for national regulations, the SNI regulations are used, namely:

1. Sand cone test (ASTM D-1556)
2. Soil specific gravity test (ASTM D-854-02)
3. Density testing (glass vibration)

RESULT AND DISCUSSION

In the Segayam-Lebak Gedong Road Improvement Project, Ogan Ilir Regency, South Sumatra.For earthworks, the contractor is required to achieve a density of at least 88% of the maximum dry weight volume of the soil.

Table 1. Field Density Degree

No	STA	Degree of Density Field (%)

1	0+000	95.56
2	0+050	94.49
3	1+250	97.60
4	1+900	99.68
5	2+050	93.91
6	2+750	95.34
7	3+050	95.54
8	3+750	85.51
9	4+050	95.79
10	4+900	96.27
11	5+100	97.30
12	5+600	91.33
13	6+150	90.58
14	7+050	90.90
15	8+200	89.77
16	9+350	96.68
17	10+100	95.45
18	10+200	88.72
19	14+400	95.61
20	12+050	95.25

During the compaction process, it is necessary to determine whether the specified bulk density can be achieved or not. The standard procedure for determining the field bulk density due to compaction is the sand cone method (Bowles, J.E, 1993).

This moisture content test uses class B aggregates from a direct location taken for laboratory testing. The aggregate data that serves as the source location for this research is class B aggregate tested in the laboratory. The initial moisture content test before compaction yielded the following data:

Table 2. Calculation of Moisture Content

Water Content					
Krus No	**J1**	**10**	**A**	**6**	**A1**
Wet Soil Weight + Cross	602.20	685.70	726.20	751.50	760.20
Dry Soil Weight + Cross	586.40	670.70	706.60	728.00	736.00
Crucible Weight	90.50	78.90	97.40	80.60	98.80
Water Weight	15.80	15.00	19.60	23.50	24.20
Dry Soil Weight	495.90	591.80	609.20	647.40	637.20
% Water Content (W)	3.19	2.53	3.22	3.63	3.80

This moisture content test uses class B aggregates from a direct location taken for laboratory testing. The aggregate data that serves as the source location for this research is class B aggregate tested in the laboratory. The initial moisture content test before compaction yielded the following data:

Specific Gravity testing, type of Class B Aggregate is obtained as follows:

Table 3. Specific Gravity Test

COARSE AGGREGATE (RETAINED NO. 4) / SNI 03 - 1969 - 1990					
Oven Dry Sample Weight (%)			Gr	5,295	5,295
Saturated Surface Dry Sample Weight (Ssd)			Gr	5,441	5,441
Sample Weight In Water			Gr	3,415	3,415
Bulk	2.614	2.614	Ssd Specific Gravity	2.686	2.686

Apparent	2.816	2.816	Absorption (%)	2.757	2.757
COARSE AGGREGATE (RETAINED NO. 4) / SNI 03 - 1969 - 1990					
Oven Dry Sample Weight (%)			Gr	500.0	500.0
Saturated Surface Dry Sample Weight (Ssd)			Gr	493.7	492.5
Sample Weight In Water			Gr	669.0	657.5
			Gr	975.2	966.6
Bulk	2.547	2.564	Ssd Specific Gravity	2.580	2.600
	2.580			2.619	
Apparent	2.633	2.659	Absorption (%)	1.276	1.399
	2.685			1.523	
AVERAGE SPECIFIC GRAVITY					
Percentage of Retained Example No. 4			68.76		
Sample Pass Percentage			31.24		
Bulk		2.598	Ssd Specific Gravity		2.658
Apparent		2.765	Absorption (%)		2.116

From the results of laboratory testing, the specific gravity was 2.765.

Atterberg limits testing through laboratory testing with class B aggregate samples of the Segayam-Lebak Gedong Road Improvement Project, Ogan Ilir Regency, South Sumatra as follows.

Tabel 4. Batas *Atterberg*

Atterberg Limit	
Liquid Limit (Ll)	19.87%
PLASTIC LIMIT (PL)	16.86%
Plastic Index (Pi)	3.02%
Symbol From Plasticity Chart (Aashto M - 145 - 87)	A - 1 - A

The liquid limit test of class B aggregate obtained a liquid limit value of 19.87%. The data is shown as below.

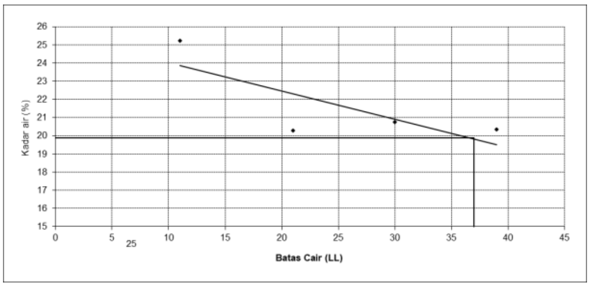


Figure 1. Graph of the relationship between water content and the number of taps

The plastic limit test of class B aggregate obtained a plastic limit value of 16.86%. The Plastic Index (IP) can be calculated using the formula:

$$IP = LL - PL = 19.87\% - 16.85\% = 3.02\%$$

The liquid limit test of class B aggregate obtained a liquid limit value of 26.24%. The data is shown below:

Table 5. Abrasion Test

Aggregate Base Class B			
Tested Gradation			A
Weight of Tested Sample	Gr	A	5,000
Sample Weight Retained on Sieve No. 12	Gr	B $\frac{A-B}{A} x100$	3,688
Wear Example	%		26.24

Testing of grain size distribution using hydrometer (sedimentation) and the following data from the calculation of grain size distribution testing. Found below, testing using (ASTM D-422-63 & D-1140-54) including:

Table 6. Sieve Analysis Graffic Commulative

Sieve Size	***Cumulative***			***Spec Limit***		
	Wt. Ret	**% Ret**	**% Pass**			
2"	0	0.00	100	100	-	100
1 1/2"	403	13.56	90	88	-	95
1"	765	25.77	74	70	-	85
3/8"	1,555	52.39	48	30	-	65
# 4	1,987	66.95	33	25	-	55
# 8						
# 10	2,350	79.18	21	15	-	40
# 16						
# 40	2,597	87.50	13	8	-	20
# 200	2,871	96.73	3	2	-	8

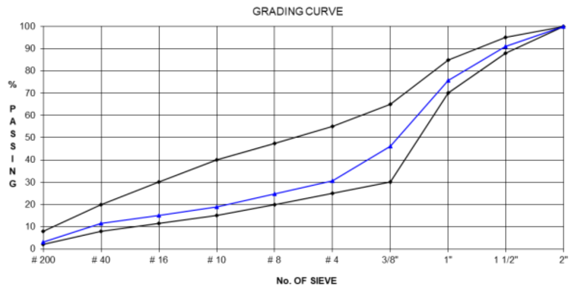
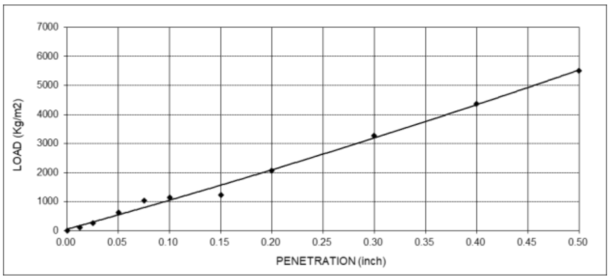


Figure 2. Sieve Analysis Graph

Laboratory CBR testing of class B aggregate obtained a liquid limit value of 69.50 where the CBR value requirements for class B aggregate must have a minimum CBR value of 60%. The data is shown as below:



Gambar 3. CBR Laboratorium

CONCLUSION

The results of this test provide an overview of the results of the field soil density analysis using the sand cone method on the road improvement project as follows:

1. From the test results, the density degree obtained an average density of 94.06%.
2. A good density degree meets the requirements for a soil density degree of 95% - 100%.
3. Based on the average density degree obtained, it is concluded that it is necessary to add water content and compaction at several stations.
4. Field testing must be carried out by considering field conditions in order to obtain more optimal results.
5. Further studies are needed regarding the relationship between the process in the laboratory and its implementation in the field, whether everything that is tested with different situations and conditions can be obtained in the field according to what is planned in the laboratory
6. It is better to clean the tools or machines before conducting tests in the laboratory, this is because it will affect the results obtained.
7. Accuracy is needed when ovening in water content testing, in order to obtain more accurate results. Testing accuracy is often compromised due to frequent power outages.

REFERENCES

Aashto. (1993). *Guide for Design of Pavement Structure*. The American Association of State Highway and Transportation Officials.

Bowles, J.E. (1993). *Sifat-Sifat Fisis dan Geoteknis Tanah*. Erlangga.

Braja. (1993). *Mekanika Tanah* (1st ed.). Erlangga.

Craig, R.F. (1989). *Mekanika Tanah* (4th ed.). Erlangga.

Djatmiko, & Edy. (1993). *Mekanika Tanah I* (1st ed.). Kanisius.

Endrayana, MR. (2008). *Pengaruh Geotekstil terhadap Kuat Geser Pada Tanah Lempung Lunak Dengan Uji Triaksial Terkonsolidasi Tak Terdrainasi* [Thesis]. Universitas Indonesia.

Hadijah, Ida. (2015). *Analisis Kepadatan Lapangan Dengan Sand Cone Pada Kegiatan Peningkatan Struktur Jalan Tegineneng –Batas Kota Metro* [Thesis]. Universitas Muhammadiyah Metro.

Hendarsin, S.L. (2000). *Penuntun Praktis Perencanaan Teknik Jalan Raya*. Gramedia.

Indrawahyuni, H, Munawir, A, & Damayanti, I. (2009). Pengaruh variasi kepadatan pada permodelan menggunakan tanah pasir berlempung terhadap stabilitas lereng. *Jurnal Rekayasa Sipil*, *3*(3), 192–308.

Kementerian Pekerjaan Umum (Indonesia). (1987). *Petunjuk Perencanaan Tebal Perkerasan Bahu Jalan*. Kementerian Pekerjaan Umum (Indonesia).

Murti, MS. (2007). *Undang-Undang Republik Indonesia Nomor 17 Tahun 2007 tentang Rencana Pembangunan Jangka Panjang Nasional Tahun 2005-2025*. Biro Peraturan Perundang-undangan Bidang Perekonomian dan Industri, Jakarta.

Siregar, Ratna Dewi. (2015). *Analisa Kepadatan Tanah Menggunakan Metode Sand Cone Pada Pembangunan Relokasi Jalan Bendungan Lau Simeme Paket Ii Kab. Deli Serdang Sumatera Utara*. Universitas Islam Sumatera Utara.

SNI 03-2828. (1992). *Pengujian Kepadatan di Lapangan Menggunakan Alat Konus Pasir (Sand Cone)*. Pusat Penelitian dan Pengembangan Pekerjaan Umum, Bandung.

Sudarsono. (1979). *Konstruksi Jalan Raya*. Yayasan Badan Penerbitan Pekerjaan Umum.

Sukirman. S. (1999). *Perkerasan Lentur Jalan Raya*. Nova.

Terzaghi, K & Peck, R.B. (1987). *Mekanika Tanah dalam Praktek Rekayasa* (2nd ed.). Erlangga.