The Use of By Product-Waste Materials on Road Pavement Construction in Indonesia

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Abstract : One of efforts for sustainability in Road Pavement Materials agenda is reducing virgin material in road pavement construction and increasing the use of waste materials as alternative materials in road pavement materials without reducing quality of pavement structure. The objective of this paper is to discuss the use of product waste materials from industry for road pavement construction in Indonesia. Waste materials used in this study as additive materials on road construction are Residium Catalytic Cracking 15 (RCC-15), lignin, slag and tailing. RCC15 addition showed an increase of soil bearing capacity and reduce the level of expansion on soil on composition of 2% RCC and 2% PCC, the addition of 4% lignin by weight of dry soil can increase the unsoaked CBR, the use 100% of slag will provide a better mix characteristic than the natural aggregate mixture and the addition of 45% tailing in mix gave good effect on stability of base and sub-base layer and Generally, test laboratory results showed that road construction containing waste materials have higher performance than conventional road construction.

Key Words: *Waste Materials, Road Pavement Construction*

1. PREFACE

Every year, the development in road construction continues to increase. This year, total length of roads (national roads, highway, provincial roads, district roads and city roads) handled either by increasing or making of a new roads achieve 348.241 km. From the total, 90% of it are flexible pavement with asphalt and aggregate as basic materials.

Road damage that generally occurs in Indonesia are permanent deformation caused of the lack of carrying capacity of the lower layers of pavement structure and crack or plasticity deformation on asphalted layer. Besides handling and construction process, quality of used materials making a great contribution to the damage.
In other side, not all district have materials resources with desired quality. Importing material from other place will increase construction cost, so it's necessary to do the material engineering or diversification to increase the quality of pavement structure produced or the use of sub standard materials and waste materials to optimize the use of material source potential in areas.

This paper is trying to discuss about the use of by product waste materials, such as RCC-15, lignin, slag and tailing on road pavement construction.

2. BY PRODUCT-WASTE-MATERIALS AS ROAD PAVEMENT MATERIAL

2.1 Residual Catalytic Cracking 15 (RCC-15)

Residual Catalytic Cracking 15 (RCC-15) was a ex-refinery waste owned by Processing Unit (PU) VI Balongan PT. Pertamina which everyday can produce approximately 10 ton catalyst waste. The use of RCC as soil stabilization on road pavement subgrade construction based on RCC's characteristics in order to reduce cement percentage.

Chemicals and its compounds comparison on spent catalyst RCC-15 and Portland Composite Cement (PCC) as additive for soil stabilization which can be seen as follows:

Table 1 Compound comparison between RCC and PCC (Hendi Dhatri A. R., 2003)

Compound Composition	Percentage of PC (%)	Percentage of Spent Catalyst RCC-15 (%)
Silica (SiO_2)	23.25	63.93
Alumina (Al_2O_3)	6.34	20.11
Ferric Oxide (Fe_2O_3)	3.36	0.33
Calcium (CaO)	58.15	2.74
Magnesium Oxide (MgO)	2.02	1.07
Sulphur Trioxide (SO_3)	1.98	-
Insoluble Part (IR)	7.53	-
Free Calcium(F-CaO)	0.82	-
Total of Alkali	0.60	7.21

Stabilized soil with RCC-15 is Gedebage soil, Bandung which has lower bearing capacity and high potential swelling. Results of physical properties testing can be seen in Table 2.

Table 2 Technical Data of Gedebage Bandung Soil

No	Soil Characteristics	Value
1.	Passing No. 200 (%)	94,82
2.	Clay Fraction %	10,03
3.	Water Content (%)	56,73
4.	Liquid Limit (%)	60,15
5.	Plastic Limit (%)	25,38
6.	Shrinkage Limit (%)	11,82
7.	Plasticity Index (%)	34,77
8.	Activity (%)	6,91
9.	Specific Gravity / Gs	2,67
10.	Unit Weight/γ_k (gr/cm^3)	1.64
11	*Swelling* Potential (%)	6,12

The percentage use of RCC as binder material on soil stabilization are 0 %, 2 %, 4 %, 8% and PCC as much as 2 % on optimum water content condition. Laboratory test consist of existing soil and additive mixture such as soil index properties, modified proctor test, California bearing ratio test (CBR) and Unconfined Compression Strength (UCS).

a. RCC-15 Influence to Compaction Test

On Figure 1 can be seen, with additional 2% content RCC increasing Dry Density (γk) Gedebage Bandung clay soil from 1,44 gr/cm3 to 1,46 gr/cm3 then go down again to 1,44 gr/cm3 in additional 4% RCC of 4% and decliner in additional 8% RCC with Dry Density (γk) about 1,37 gr/cm3.

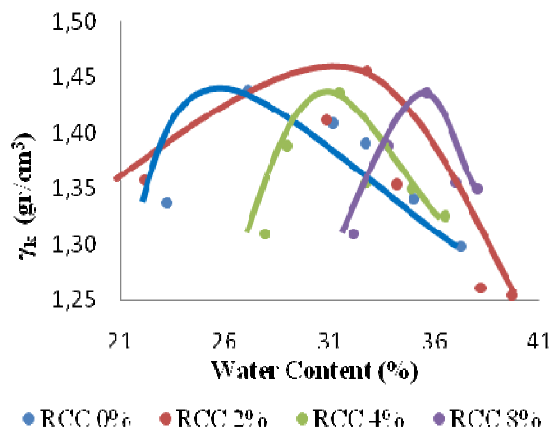


Figure 1 Compaction graphic with additional 2% PCC content and 2%, 4% and 8% RCC.

From figure 1 can be seen the connection between dry weight and additional RCC content, dry density in additional 2% content increased, and then decline in 4% RCC content and keep decline in 8% RCC content.

b. RCC-15 influence to Unconfined Compression Value and Swelling

From Figure 2 can be seen the connection between swelling with qu (t/m2) value, the most significant during 1 day treatment, there are an additional RCC content about 2,62 % which swelling still happen about 60%, during 7 days and 14 days treatment, there are raising qu (t/m2) value, the greatest happened in additional RCC optimum content that is 2,45% which the swelling still happened about 30% during 7 days treatment, whereas during 14 days treatment, the swelling about 26%. Whereas during 28 days treatment, greatest qu (t/m2) value obtained in optimum RCC content that is 2,6% where there are no more swelling.

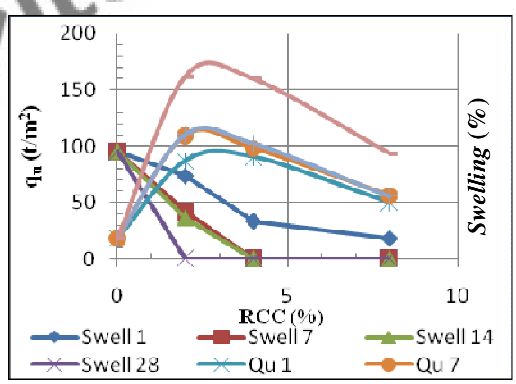


Figure 2 Graph of relationship between swelling and qu value

c. RCC-15 influence to CBR value and Swelling

In Figure 3 can be seen the relationship between swelling and CBR unsoaked value with the most value on 1 day treatment in additional 2,1% RCC content where the swelling happened about 74%. During 7 days treatment, the biggest CBR unsoaked value obtained in optimum RCC content that is 2,15% which swelling still happen about 44%. During 14 days treatment, there are additional optimum RCC content about 2,2%. During 28 days treatment, the biggest

CBR unsoaked value obtained in optimum RCC content that is 2,4% where there no more swelling.

In Figure 4 can be seen the relationship between swelling and the biggest CBR soaked value, during 1 day treatment obtained optimum RCC content that is 2,2% with 70% swelling. The biggest CBR soaked value during 7 days treatment, obtained in optimum RCC content that is 2,5% with 30% swelling.

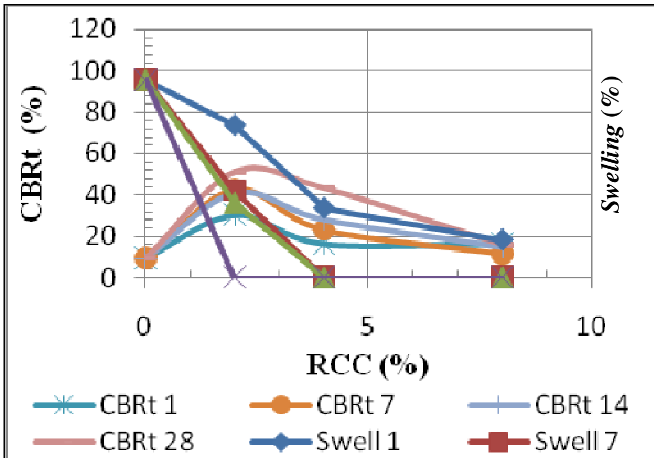


Figure 3 Graph of relationship between swelling and CBR unsoaked value

During 14 days treatment, the biggest connection between swelling and CBR soaked value obtained in optimum RCC content, that is 2,5% with 24% swelling. Whereas during 28 days treatment, the biggest connection between swelling and CBR soaked value obtained in optimum RCC content that is 2,3% where there are no more swelling.

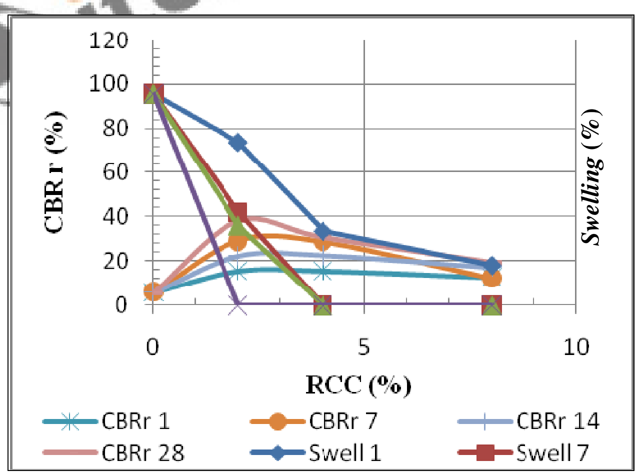


Figure 4 Graph of the relationship between swelling and soaked CBR values

2.2 Lignin

Lignin is a waste material from paper mills which are physically a liquid that has a specific gravity of 1.017. Lignin doesn't contain hazardous materials and harmless to the respiratory. Because lignin is derived from cellulose, lignin many contain sulphonat. Lignin molecule is an active component with large molecular structure and complex with hydroxide and carbon clusters that have the ability to bind soil particles, especially silica. Besides, lignin can also used as clay dispersion so that the clay more plastic and can increase the density. Because of that characteristic, lignin can be categorized as non-bituminous materials stabilizer.

In Table 3 and Figure 5 showed the influence additional lignin in two kinds of clay soil Atterberg limit such as Sumedang clay and Garut lake. From this table can be seen that Sumedang clay soil is extremely plastic with 41,1% IP value, which according to “Unified Soil Classification, USC” this soil include OH kind (organic clay with medium or high plasticity, organic silt) or MH (inorganic silt, soft sandy or silty soil contains mika or diatoma, elasticity silt). Garut clay soil has low plasticity and classified in OL group (organic silt and organic silt-clay with low plasticity) or ML (inorganic silt and very soft sand, rock flour, silty or clay soft sand with low plasticity. But according to “AASHTO System” these two kinds soil include in same group that is A-7-5.

a. Lignin Influence to Soil Physical Properties

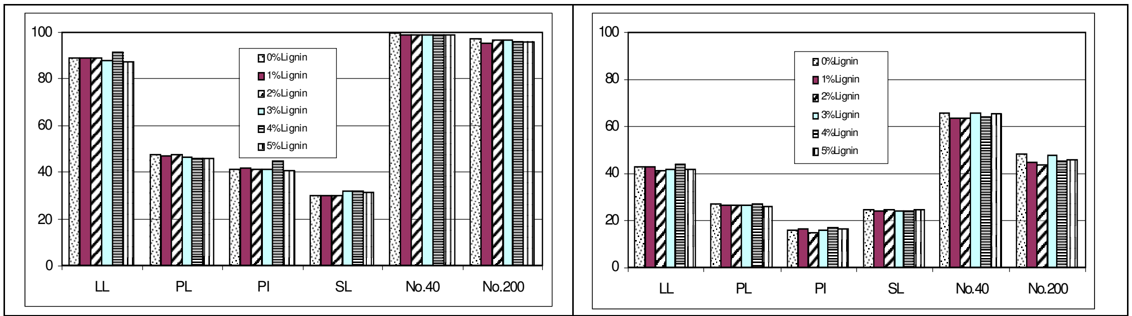
From these Table 3 and Figure 5 can be seen that additional lignin doesn’t show any light change Atterberg limit (liquid limit, plastic limit, plastic index). Likewise with its soil gradation (represented by grain weight of the sieve No.40 and 200), not affected significantly by lignin addition. This means that the lignin give less bond on grain soil, especially on Sumedang clay and Garut silt.

Table 3 Lignin influence to soil physical properties after 1 day aging

Soil Characteristics	Location											
	Sumedang Soil						Garut Soil					
	Percentage of Lignin Addition											
	0%	1%	2%	3%	4%	5%	0%	1%	2%	3%	4%	5%
1. Liquid Limit (%)	89.0	89.0	89.0	88.0	91.0	87.0	43.0	43.00	41.0	42.0	44.0	42.0
2. Plastic Limit (%)	47.9	47.1	47.5	46.7	46.0	45.2	27.3	26.50	26.6	26.4	26.8	25.7
3. Pasticity Index (%)	41.1	41.8	41.4	41.2	44.9	41.6	15.7	16.50	14.4	15.6	17.2	16.2
4. Clasification - AASHTO - USCS	A-7-5 OH/MH						A-7-5 OL/ML					
5. Shrinkage Limit (%)	30.4	30.2	30.2	32.1	31.8	31.2	24.4	24.3	24.5	23.9	23.9	24.5
6. Passing No.40 (%)	99.2	99.0	98.8	99.0	98.8	98.9	65.9	63.4	63.7	65.8	63.9	65.5
7. Passing No.200 (%)	96.8	95.4	96.2	96.3	96.1	96.1	48.0	44.5	43.6	47.8	45.5	46.0
8. Optimum Water Content (%)	49.5	46.9	47.1	47.1	49.0	48.1	27.2	26.4	26.1	26.0	25.0	24.
9. Maximum Dry Density (gr/cm^3)	1.1	1.1	1.1	1.1	1.1	1.1	1.4	1.4	1.4	1.4	1.4	1.4
10. Specific Gravity	2.6	2.6	2.6	2.6	2.6	2.6	2.8	2.7	2.8	2.8	28	2.8

b. Lignin influence to Soil Chemical Properties

Lignin addition doesn’t make meaningful changes in properties and soil chemical composition as shows in Table 4 and Figure 5. Thus it can be said that relatively no chemical reactions happened between soil and lignin or that the reaction can’t be showed by the testing that has been done.



a. Soil from Sumedang	b.Soil from Garut

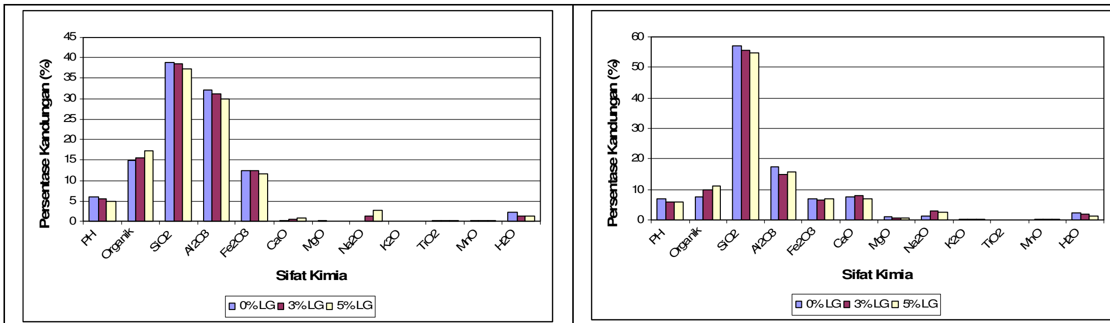
Figure 5. Additional Lignin Influences in Atterberg Limit, Shrinkage Limit and Soil Gradation After 1 Day Aging

Table 4 Lignin Influence to Soil Chemical Properties, 1 day Aging

Chemical Compound	Addittion Percentage of Lignin					
	Sumedang Clay					
	0%		0%		0%	
PH	6.00	PH	6.00	PH	6.00	PH
Organic	14.84	Organic	14.84	Organic	14.84	Organic
SiO_2	38.83	SiO_2	38.83	SiO_2	38.83	SiO_2
Al_2O_3	32.22	Al_2O_3	32.22	Al_2O_3	32.22	Al_2O_3
Fe_2O_3	12.38	Fe_2O_3	12.38	Fe_2O_3	12.38	Fe_2O_3
CaO	0.34	CaO	0.34	CaO	0.34	CaO
MgO	0.24	MgO	0.24	MgO	0.24	MgO
Na_2O	0.02	Na_2O	0.02	Na_2O	0.02	Na_2O
K_2O	0.06	K_2O	0.06	K_2O	0.06	K_2O
TiO_2	0.15	TiO_2	0.15	TiO_2	0.15	TiO_2
MnO	0.26	MnO	0.26	MnO	0.26	MnO
H_2O	2.22	H_2O	2.22	H_2O	2.22	H_2O

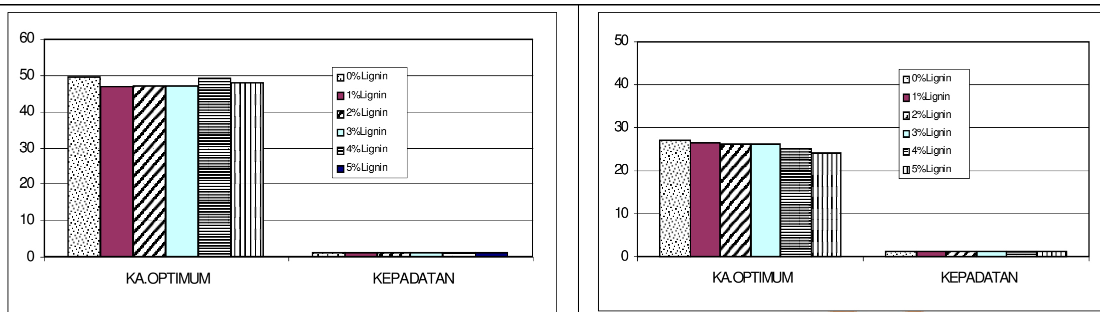
c. Optimum Water Content and Maximum Dry Density

Besides showed in Table 3, optimum water content and maximum dry density of Standard Proctor Compaction test are also showed in Figure 7. For Sumedang soil, maximum dry density happened in 1% and 5% additional lignin that is about 1,13 gr/cm3 with optimum water content about 47%. While the soil from Garut, the dry density obtained in 2%, 3% and 4% additional lignin, that is 1,44 gr/cm3 with about 26% optimum water content. Nevertheless, as shown in Table 3 and Figure 8, lignin addition doesn't significantly effect soil maximum dry weight and optimum water content.



a. Soil from Sumedang | b.Soil from Garut

Figure 6 Lignin influence to soil chemical properties, 1 Day Aging



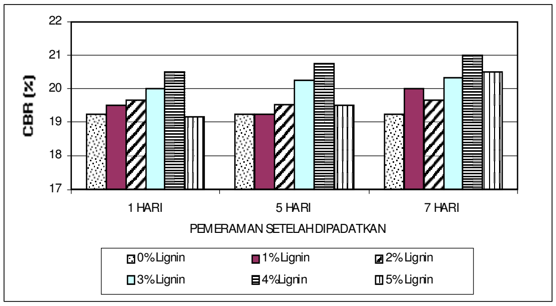
b. Soil from Sumedang | b.Soil from Garut

Figure 7 Lignin addition influence, optimum water content, dry density with standard proctor test

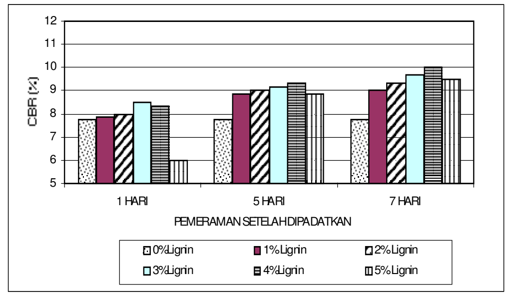
d. Lignin influence to CBR value

Lignin addition influences to CBR value that showed in Figure 8 and Figure 9. From these two figures can be seen some tendency of CBR soaked and unsoaked value because of lignin addition and aging after compaction are as follows:

– After adding lignin, CBR value for two kinds of soil (Sumedang clay and Garut silt) doesn't show a meaningful raising. Even so, there are indications that certain doses of lignin produces maximum CBR value.
– Both types of soil CBR values increased according to the length of curing time after the soil compacted, although with a small improvement. In fact, there is a possibility that the finished compacted soil in the field, the longer become stronger.
– Due to the addition of 4% lignin and curing time after compaction for 7 days, an increase of CBR to CBR existing soil is approximately 109% for Sumedang clay and about 120% for Garut silty soil. As for the CBR soaked, the increasing of CBR existing Sumedang clay value is approximately 120% and about 170% for Garut silty soil.
– From the trend of above can be concluded that the highest increase in CBR occurs in soil that has a small plastic index value. This phenomenon indicates that the smaller soil plasticity index value the higher effectiveness of the use of lignin.

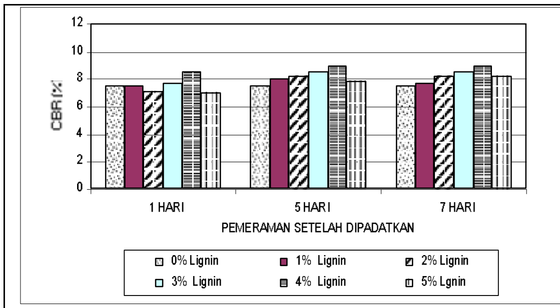


c. Soil From Sumedang

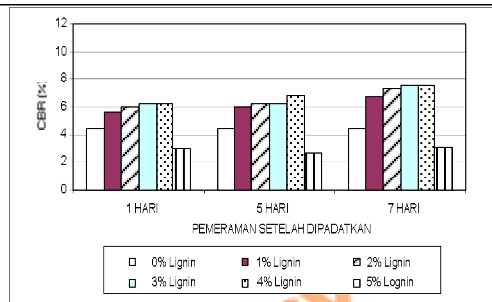


b.Soil From Garut

Figure 8 Influence of lignin additions on unsokaed CBR



a. Soil from Sumedang

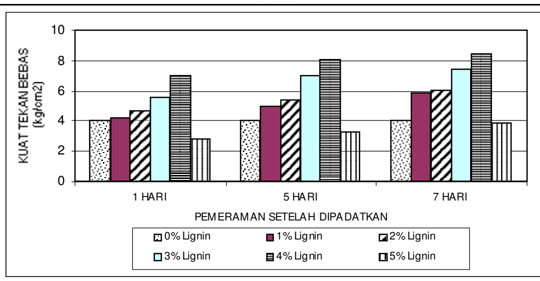


b.Soil from Garut

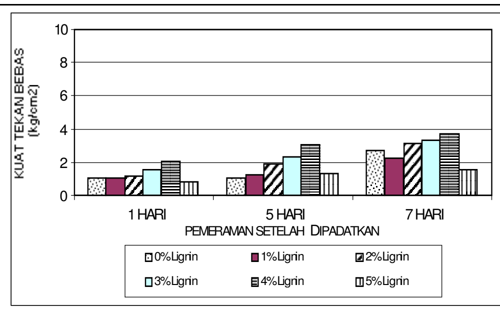
Figure 9 Influence of lignin additions on soaked CBR

e. Lignin impact to Unconfined Compression

The tendency of the soil unconfined compression strength due to the addition of lignin and curing time after compaction is similar to the trend of CBR value on Figure 10. For clay soil, due to the addition of 4% lignin and curing for 7 days after the compacted, raising the unconfined compression strength to unconfined compression strength of existing soil is approximately 209% and approximately 138% to Garut silty soil.



a. Soil from Sumedang



b. Soil from Garut

Figure 10 The influence of lignin additions to unconfined compression strength

2.3. Slag

Slag is a by product of steel industry formed from the combination of iron with limestone flux. Slag granular form with varying sizes from coarse to fine. Based on the cooling process, there are three kinds of slag that can be generated by the steel industry (ASA, 2002), the Blast-Furnace Slag (BF-Slag), Basic Oxygen Steel Slag (BOS-Slag) and Electric Arc Steel Slag (EAF- slag).

Based on the shape, there are five types of slag are included in the group BF-slag, which is rock slag, granulated slag, ground granulated slag, pelletized slag, and expanded slag or slag light weight (ASA, 2002). Although many types of slag can be produced, but because most of the slag produced by the steel industry, gained through air cooled process, so most of slag produced in the form of lumps or rock slag (Sherwood, 1995). Thus, the slag divided process is needed so slag can be used further.

Rock slag that obtained through air cooled process called air-cooled slag. This type of slag produced by slowly cooling the liquid metal in the open air. Slag produced from this process in the form of lumps. In order to use the slag, slag lumps should be divided again by using the stone crusher. A broken slag is cubical or angular shaped, as shown in Figure 12, with a high density (> 3 ton/m3) and typical worn-out value of Los Angeles (LAAV) at 20 to 35%. In Indonesia, 150-ton air-cooled-slag is produced each day by PT. Krakatau Steel industry, Cilegon, Banten.

In many countries, the slag has been widely used as an aggregate substitute for asphalt mixture, for concrete as well as materials for pavement foundation (ASA, 2002). In America, slag mixed with gravel and hydrated lime has been widely used. In addition, the slag also has begun to be used to inhibit crack expansion. Slag used for this purpose was made in the form of ready mix gravel-slag and pre-crushed granulated slag mixture (Heeckett, 2001).

Figure 11 Slag grain form

In its use, slag is often regarded as an aggregate (aggregate-like material) and therefore, the physical requirements of slag are usually considered equal to the physical requirements for the aggregate. However, because slag has different chemical properties with natural aggregates so there are other requirements for slag in order to use it as a substitute for natural aggregates. According to BS 1047 (1983) the requirements are durability (soundness) and sulphate content contained in the slag. According to that requirement, the sulphur content (S) in the slag is not more than 2% and sulphate on SiO3 not more than 0.75%. While the durability of slag can be seen from the bigness contents of CaO and MgO in the slag, good slag when the weight percentage:

$$CaO + 0{,}8\ MgO < 1{,}2SiO_2 + 0{,}4Al_2O_3 + 1{,}75\ S$$

or

$$CaO < 0{,}9\ SiO_2 + 0{,}6\ Al_2O_3 + 1{,}75\ S$$

The potential using PT. Karakatau Steel slag, the study results of using aggregate substitute in asphalt mixture and binder bitumen 60/70 pen oil and asphalt rubber (3% latex KKK-60), as follows

Table 5 Aggregate and slag characteristic

Test	Test Results		Specification
	Aggregate	Slag	
- Specific Gravity			
-Bulk	2,603 – 2,640	3,359 – 3,481	>2,5
-SSD	2,664 – 2,700	3,534 – 3,409	>2,5
-Apparent	2,772 – 2,803	3,533 – 3,678	>2,5
- Absorption	2,120 – 2,333	1,461 – 1, 460	>3,0
- Disintegration	14,4 – 19,2	16,31	<40
- Affinity	95+	95+	95+
- Impact Value	14,7	13,91	<30
- Sand Patch	54,11	55,18	>50
- Flakiness Index	14,16 – 23,2	8,72	<25

Table 6 Thypical chemical content of Karakatau steel BF-slag

Chemical Compound	Symbol	Content (% Weight)
Calcium Oxide	CaO	41
Free Calcium	-	0
Silica Oxide	SiO_2	35
Ferro Oxide	Fe_2O_3	0,7
Magnesium Oxide	MgO	6,5
Mangan Oxide	MnO	0,45
Aluminium Oxide	Al_2O_3	14
Titanium Oxide	TiO_2	1
Potassium Oxide	K_2O	0,3
Chromium Oxide	Cr_2O_3	< 0,005
Vanadium Oxide	V_2O_3	< 0,05
Sulphur	S	0,6

Source : ASA, 2002

From Table 5 can be seen that the slag has properties which satisfy the required properties for natural aggregate as material for asphalt mixture. Compared with the properties of natural aggregate, slag has better properties. This is indicated by the higher density of slag, higher strength and lower levels of absorption. Slag also has other enough physical properties such as form of cubical granules as shown in Figure 11, the value of SE and high viscosity of the asphalt, where all of these three properties are rarely met by the aggregate sub-standard nature.

Besides, from Table 6 can be seen that the slag produced by PT. Karakatau steel also has good durability level indicated by the small content of CaO + 0.8 MgO, that is 46.2%, of 1,2SiO2 + 0,4Al2O3 + 1,75 S, which is 48.65%, and low level of sulphate content contained in the slag (<2%).

Only by splitting up processes, slag can be as an aggregate for asphalt mixture. This is demonstrated by completing the Bina Marga, gradation requirements by merger of CS, MS and FS in proportion not by sieve and the fulfilment of the mixture properties. So that the asphalt mixture with slag as an aggregate can be produced in the AMP.

From Figure 12 can be seen that the asphalt mixture which is made of slag with 60 pen bitumen binder (mixture B) has a volumetric properties near the volumetric properties of asphalt mixture of natural aggregate standard (mixture A), but a mixture B has better mechanical properties which indicated by high levels of density, stability and its Marshall value comparison. Because the slag absorption rate is lower than the natural aggregate so for the same type of asphalt, optimum asphalt content (OAC) of mixture B is lower than the OBC mixture A, as shown in Table 7. From this table also show that the OBC mixture C, the mixture containing slag with asphalt rubber as a fastening, is equal to the OBC mixture A, this is caused due to the addition of latex into the asphalt.

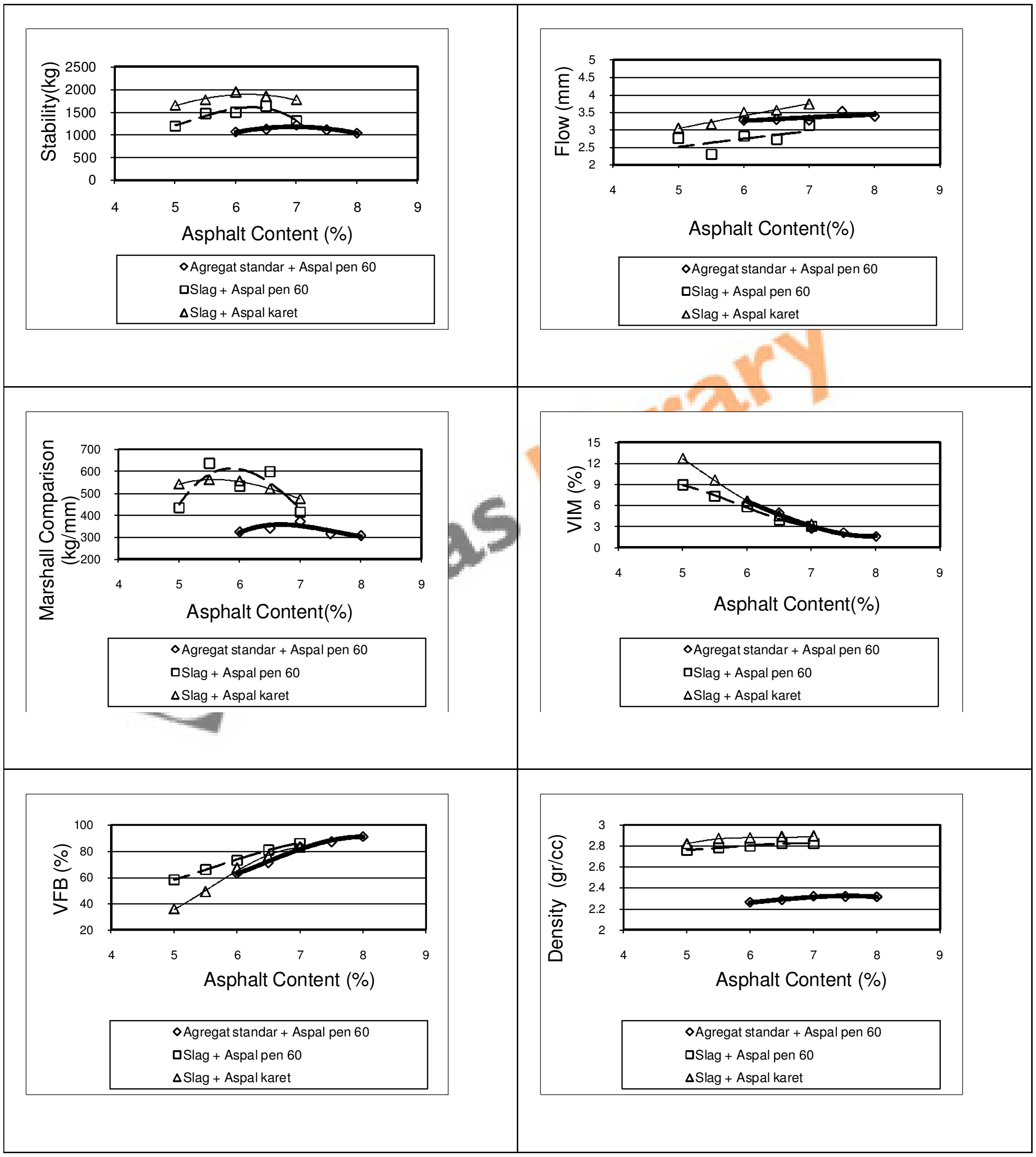


Figure 12. The Relation Between Asphalt Content and Marshall's Parameters

In terms of strength and stiffness levels of the mixture, on its OBC mixture B has better properties than mixture A, but mixture B has lower stability than mixture A, although its value still meets the specification limits. This weakness can be overcome by using asphalt rubber as a binder. From Table 7 can be seen that the use of asphalt rubber in asphalt mixtures using slag (mixture C) will increase the stability of the mix. In addition, the use of rubber asphalt will also lower the level of the mixture stiffness (its MQ). However this value is still outside the range of specified requirement. In order to make containing slag more flexible, so that more resistant to crack then the value of its MQ parameter must be lowered. Therefore, if this slag can give nature a better asphalt mixture it needed to conduct further research using other binder which is more elastomeric than the asphalt rubber.

Table 7 Mixture characteristic at optimum asphalt content

No.	Testing	Test Results			Specification
		A	B	C	
1	Optimum Asphalt Content	6,8	6,4	6,8	-
2	Density	2,302	2,819	2,890	-
3	VMA	16,61	20,94	19,27	>16 %
4	VIM	3,77	4,31	3,94	3 – 5 %
5	VFB	77,45	79,42	79,61	> 65%
6	Stability	1168,9	1605,1	1810	> 800Kg
7	Flow	3,29	2,75	3,37	> 2 mm
8	Marshall Quotient (MQ)	356,4	583,7	531,6	200-500 Kg/mm
9	Residual Stability	79,2	78,1	93	>75%

Note: A = Standard Aggregate + Asphalt pen 6
B = Slag + Asphalt pen 60
C = Slag + Rubber Asphal

2.4 Tailing

Tailing is a waste from the process of mining gold and copper in size as the sand. This tailing materials has resistance to good weather where the Soundness test shows a value of about 2% - 8% (maximum limit is 10%).

In Indonesia, numerous tailing can be found in Timika, Mimika regency, West Papua Province. In this area tailing is a waste from PT Freeport Indonesia (PT-FI) as a result of waste materials from the mining of gold and copper ore. These wastes have been generated since the 70's with a total production of around 80,000 – 100,000 tons per day, and it continues to increase every year and now has reach 300,000 tons per day, flowed through Aghawagon and Ajkwa river. Tailings in the area has a maximum grain size of about 2.38 mm to 0.149 mm fine grain, and have non-plastic or loose characteristic that has no ties between the grain itself. Its chemical composition as shown in Table 8

Table 8 Chemical composition of PT. Freeport Tailing

Chemical Compound	Test Results (%)	
	PUSTRAN	
SiO_2	65	SiO_2
Al_2O_3	11	Al_2O_3
CaO	8	CaO
Other Oxides	16	Other Oxides

If viewed from grading, the size of the tailings can be categorized as, medium fraction (pass sieve # 4 caught sieve # 8), and fine fraction (pass sieve # 8 and caught sieve # 200). From the results of the sieve test, from some tailing samples taken from several locations, the gradation of the tailing is shown in Table 9. Based on the results, tailings have saturated surface dry density ranges from 2.48 to 2.86 with loose density ranging from 1.23 to 1.79 ton/m^3 (Affandi el al. 2004)

By considering the origin of the tailing formation and the results of physical and chemical analysis so tailing is categorized as puzzolanic material SiO2 and CaO high enough yield, where this material could be used for civil construction material in particulate composite or mortar form with specific matrix binding system that is using cement matrix type V or a matrix combination of cement - polymer.

Tabel 9 Tailing gradation varies from some sources

Aggregate Gradation	Sieves	Passing
Middle	# 4 (4,75 mm)	100
	# 8 (2,36 mm)	95 – 100
Fines	# 16 (1,19 mm)	90 – 98
	# 30 (0,595 mm)	75 – 95
	# 50 (0,279 mm)	22 – 60
	# 100 (0,149 mm)	15 – 39

Bandung Institute of Technology in cooperation with PT. Free Port Indonesia has conducted field trials in Timika to make highways and simple span bridges using concrete mixed with tailings. Concrete mixture that is used both for highway and bridge is a mixture of tailings, cement, polymer and water with a ratio of 70%, 30%, 15% (weight of polymer to cement weight). Road experiment with concrete pavement using these tailings have been conducted with a total length of road approximately 525 meters by 6 meters wide and 9 meters with a thickness of concrete slab 15 cm and 20 cm, which was held in February 2001. This road traffic included in heavy traffic category that many mining trucks passed by. Concrete bridge experiment using tailings material has been done on a simple bridge (simple span) in Kaoga river in March 2001, also in Timika with span 12 meters and 9 meters wide. Both of theses construction, according to observations made by Bandung Institute of Technology team in July 2003 still in good condition.

To see the effect of additional tailings in the crushed stone material that will be used for layer of road foundation, Neni et al. (2004) has conducted studies to see the effect of additional to for layer of road foundation. The additional tailing which is made with variations ranging from 5% to 20%, with every 5% interval. Limitation of additional tailings as much as 20% good for sub-base and for base because the addition of a percentage in excess of 20% for sub-base and base will produce a mixture gradation that comes out of the required limits.

From the density and optimum water content result test with various additional tailings between 5% to 20%, for both base and sub-base mix, it is known that the addition of tailings relatively less effect on density and water content value at both the base and sub-base. However, CBR for base and sub-base values will increase along with increasing use of % tailings in the mixture. The increase that occurred between base mixture using 20% tailings with none tailing approximately 78.5%, about 53% sub-base, as shown in Figure 13.

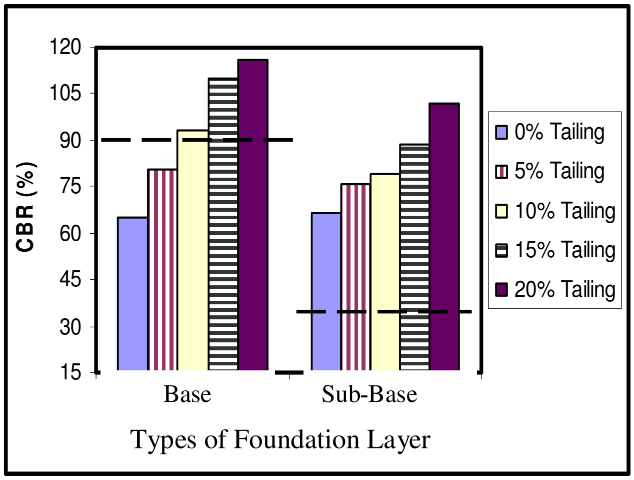


Figure 13 Effect of tailing addition on CBR value at base and bub-base (Neni et al. 2004)

3. CONCLUSION AND SUGGESTION

According to the investigation above, several conclusions can be drawn as follows:

a. RCC 15 Conclusion

RCC15 addition showed an increase of dry weight of 1.37% on the levels of 2% RCC and 2% PCC. The results of UCS tests showed an increase in the qu value with the most significant is the addition of 2% levels of RCC to 2.62% and 2% PCC with 28 days treatment time which is equal to 143.88 t/m2 to 172.5 t/m2 or approximately 89.68% of the original soil. CBR unsoaked test showed an increase of the highest unsoaked CBR value at 2% to 2.4% levels of RCC in the 28-day treatment period with the CBR value increased by 43.33% to 52.2%. From the soaked CBR test results showed an increase of the most significant CBR value of 31.11% to 39.5% with the addition 2% to 2.4% of RCC levels during 28 days treatment. Longer treatment time shows an increase of the most significant soil bearing capacity and reduce the level of expansion on soil.

b. Lignin Conclusion

Lignin addition did not show significant effects, both on the soil chemical composition and other soil physical characteristic, eg, Atterberg limits, shrinkage limit, gradation. Indications that shows the optimum lignin content was not seen clearly that it is difficult to determine the optimum percentage addition of lignin. Despite that, due to 7 days curing time after compaction, the addition of 4% lignin by weight of dry soil can increase the unsoaked CBR Sumedang clay and Garut silt each about 109% and 130% and increase soaked CBR about 120% and 170% of the CBR original soil. While the UCS increasing value was 209% and 138% of the original soil. Moreover, the addition of lignin can decrease the permeability quite real both on clay and silt soil.

c. Slag Conclusion

For the same type of asphalt, 100% use of slag from the PT. Karakatau Steel in the asphalt mixture will provide a better mix characteristic than the natural aggregate mixture, except in stability value and the remaining is below the stability of natural aggregate mixture, but still above the minimum required.

d. Tailing Conclusion

Tailing addition on base material and sub-base material give good effect on CBR values along with increasing use of 45 % tailing.

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