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Marshall Characteristics of Quicklime and Portland Composite Cement (PCC) as Fillers in Asphalt Concrete Binder Course (AC-BC) Mixture

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ABSTRACT

Quicklime and Portland Composite Cement (PCC) were used in a concrete-asphalt mixture (C-AM) combination to compare quicklime and Portland Composite Cement (PCC). The Marshall characteristics test was used to discover the distinguishing characteristics of a hot asphalt mixture made of quicklime and Portland composite cement (PCC) to make asphalt-type Asphalt Concrete Binder Course (AC-BC). This study used petroleum bitumen with a 60/70 penetration and bitumen contents of 5.0%, 5.5%, 6.0%, 6.5%, and 7.0% created by combining quicklime and cement in a filler. In this study, quicklime and cement were used as fillers; both materials have been used to create concrete buildings and have demonstrated their strength. To determine values for stability and density, Marshall tests were run. The Marshall technique of 2 x 75 blows was used in this study to get the necessary road materials, which were obtained in the composition of asphalt concrete binder course, in accordance with the Indonesia 2018 General Specification and the Indonesia Requirement (in Indonesian). The results showed that the filler quicklime at the optimum bitumen content (OBC) 6.5% had stability Marshall 873.9 kg, VIM 3.9%, VFB 76.63%, flow 3:33 mm, Marshall Quetiont 262.16 kg/mm, and VMA 16,49%, whereas the filler cement had stability Marshall 905.5 kg, VIM 4.1%, and VFB 76.57%, Hot mix asphalt with cement filler works better than quicklime filler. for building using intermediate layers (asphalt-concrete binder course).

1. INTRODUCTION

Ground transportation is quite trustworthy, particularly over short to medium distances, along with the development in the number of automobiles. Regional or urban land use has an impact on how well current transportation assets are used. The requirement for movement through transportation facilities would increase due to residents' activities, particularly social activities. Also, cities that construct road infrastructure using a sizable portion of the city's land must strike a balance between this and the availability of public transportation, pedestrian facilities, and bicycle lanes. For roads to be strong and able to last their service life, this increase in growth must be offset by an improvement in pavement performance. Additionally, road development itself needs support and monitoring to produce the best results. Rigid pavement is one type of pavement that is frequently utilized [1, 2].

The binder course is the name given to this hard pavement. In between the base and wearing courses is a surface layer that includes the binder course. Relate studies of the intermediate layer's job is to lessen stress and endure the heaviest strain from traffic so that it has enough strength [3-6].

A specific grade and ratio of asphalt and aggregate are combined to create an asphalt-aggregate mixture. Filler, coarse aggregate, and fine aggregate are the three components of the aggregate mixture. Each ingredient in the mixture must adhere to certain requirements; for instance, if the filler is sourced from a different location or is made of a different substance, the asphalt aggregate stacking composition (volume) material must be corrected using the specific gravity of the substitute filler [7-9].

So far, rock dust has been used as a filler in the asphalt aggregate mixture. The issue that surfaces later is that providing stone dust for usage demands more time and money, therefore it's important to have a plan to obtain an alternate choice of other materials that are acceptable and simple to obtain. In light of this, quicklime was evaluated as a replacement (mineral filler) and contrasted with PCC filler.

In order to replace filler materials in asphalt concrete binder course (AC-BC) mixtures, quicklime with Portland Composite Cement (PCC) or a combination of the two was investigated. This was done by looking at the Marshall properties.

The stress conditions caused by wheel load on the pavement layer can be examined in the lab, although with several skewed variables. A number of simplified tests were developed to investigate various aspects of in-situ behavior. One of these methods is empirical testing utilizing the Marshall test; the Marshall characteristic tests are stability, flow, Marshall Quetiont (MQ), VIM (Void in Mix), VMA (Void in Mineral Aggregate), and VFB (Void Filled Bitumen) [10].

2. LITERATURE REVIEW

Aggregate is a common building material that plays a significant part in construction projects. Both rigid and rigid pavements employ aggregate as the primary building block for both flexible and rigid pavements. Aggregate makes up 90% to 95% of the mixture, which is what makes up the majority of the pavement's weight.

The quality of the materials must meet the set standards in order for the road pavement to last as long as it is intended to. The construction will have a low level of resistance and durability if the material quality does not fulfill the criteria. One of the earliest signs that the target design life has not been reached is damage that manifest. The result is that maintaining or fixing the construction is expensive.

To determine the parameters of the hot asphalt mixture and to achieve stability and flow that can be measured immediately with a dial, Li et al. [10] examined the asphalt mixture using the Marshal method. Around the 1940s, Bruce Marshall of the Mississippi State Highway Department first popularized this technique. You will also receive values for VIM, VMA, asphalt mixture density, and Marshall quotient in addition to stability and flow parameters. The Marshall approach was utilized to construct the asphalt mixture that was employed in the elastic modulus investigation of asphalt concrete mixtures.

Regardless of the asphalt mix design method and aggregate type, Gul and Guler [11] claimed that compacted cylindrical specimens, which may be made from either superpave or marshall compaction equipment, can be used to study the permanent deformation properties of asphalt mixtures. According to Yan et al. [12], the Marshall approach was utilized while constructing asphalt mixtures to assess the crack characteristics of asphalt mixtures. The volumetric mix in the solid state, which consists of air spaces voids between aggregates in the mixture (VIM), and voids filled with bitumen, is significantly responsible for the asphalt mixture's performance (VFA).

The Marshall quotient (MQ), according to Ahmedzade and Yilmaz [13], is a feature of compressive strength modulus or stiffness. The MQ value is a measure of how resistant the asphalt mixture is to deformation; a high MQ value denotes a high stiffness in the asphalt mixture.

An asphalt mixture with a high MQ value is rigid, which means that it is sufficiently dense and stable. A low MQ indicates that the asphalt mixture is brittle and insufficiently stable, raising the possibility that it will crack on the surface and move horizontally in the direction of travel [14]. A high Marshall Quotient asphalt mixture is therefore less prone to crack as a result of persistent deformation.

Rutting, fatigue, and low-temperature cracking are the three main mechanical stresses that can result in cracking. In this study, it is hoped that by adding filler made of quicklime and Portland Composite Cement (PCC), the cracks in the asphalt mixtures will be decreased. Asphalt mixtures with high tensile strength will have greater resistance to cracking (PCC).

3. MATERIALS AND METHOD

3.1 Physical characteristics of aggregate

One has crushed stone sizes of 10-20 mm and the other has aggregate diameters of 5-10 mm were both employed as coarse aggregate fractions made from crushed river stone. River sand and stone dust created during the stone crushing operation were utilized as fine aggregate and filler, respectively. The Jeneberang River in Gowa served as the source of the aggregates that were employed as material components in the chilly mixture. Filler is defined in this study as material that passes through a 0.075-mm sieve. The characteristics of coarse aggregates, fine aggregates, and filler are shown in Tables 1-3, respectively.

Table 1. Characteristics of granular aggregate

Characteristics	Crushed Stone	
	0.05-0.01 m	0.01-0.02 mm
Water soaking up, %	1.98	1.77
Specific gravity of the bulk	1.93	1.73
Dry surface saturation specific gravity	1.99	1.78
Perceived specific gravity	2.79	2.79
Index of flakiness, %	19.12	9.67
Aggregate for abrasion, %	20.60	19.96

Table 2. Characteristics of fine aggregate

Water soaking up, %	2.88
Equal to sand, %	90.77
Specific gravity of the bulk	2.56
Dry surface saturation specific gravity	2.62
Perceived specific gravity	2.74

Table 3. Characteristics of mineral filler

Water soaking up, %	2.39
Equal to sand, %	79.78
Specific gravity of the bulk	2.68
Dry surface saturation specific gravity	2.56
Perceived specific gravity	2.89

3.2 Physical characteristics of crude oil bitumen

Table 4 displays the physical characteristics of the crude oil bitumen grades 60 and 70 used in this study. The results of the investigation into the characteristics of crude oil bitumen are shown in Table 4, This show that the asphalt used in this study satisfied with the Indonesian requirement (in Indonesian) for the necessary road materials as well as the General Specification of Indonesia 2018 [15, 16].

Table 4. Characteristics of crude oil bitumen

No.	Characteristics	Testing Result
1	Before weight loss, penetration, 0.1 mm	70.11
2	The breaking point, °C	58.95
3	Ductility (25°C, 5 cm/minute), cm	121.00
4	Bright point, °C	263.00
5	Fiery point, °C	260.00
6	Spesific gravity	1.21
7	Loss of weight, % weight	0.27
8	Penetration after a decrease of weight, % pure	90.00

3.3 Physical characteristics of quicklime

Table 5 lists the quicklime's physical characteristics.

Table 5. Physical properties of quicklime

No.	Characteristics	Testing result
1	Spesific gravity	2.80
2	Sieve analysis	> 40% pass sieve No. 200

3.4 Marshall stability test

According to SNI 06-2489-1991 [17], samples of the Asphalt Concrete Binder Course (AC-BC)-mixture were tested for stability using the Marshall method. Figure 1 depicts the Marshall stability test equipment.

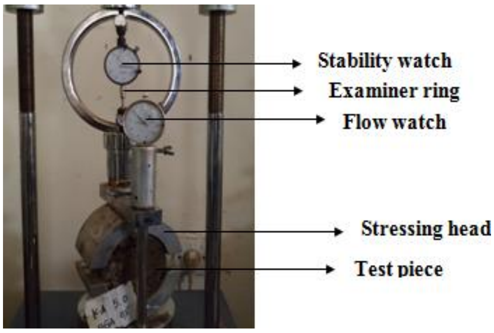

Figure 1. Equipment for Marshall stability tests

3.5 Combined aggregate gradation and mixture proportion of asphalt

The aggregate gradation of mixtures was chosen as the midway of the control limits used in the design of densely graded asphalt concrete binder courses. Figure 2 provides the design constraints and gradation applied in this investigation. For all mixes, the combined aggregate gradation was maintained. Each and every blend was created in a lab. The percentage of asphalt in combinations is displayed in Table 6.

The components were blended and tightly pressed into a cylindrical mold with a capacity of 1,200 grams and a diameter of 101.6 mm. All specimens were compressed using the Marshall method with a compactive effort of 75 blows per side. At a temperature of 27°C, the blending and compacting processes were completed in the lab. Prior to completing Marshal stability tests, samples were put through the following curing procedure after compaction.

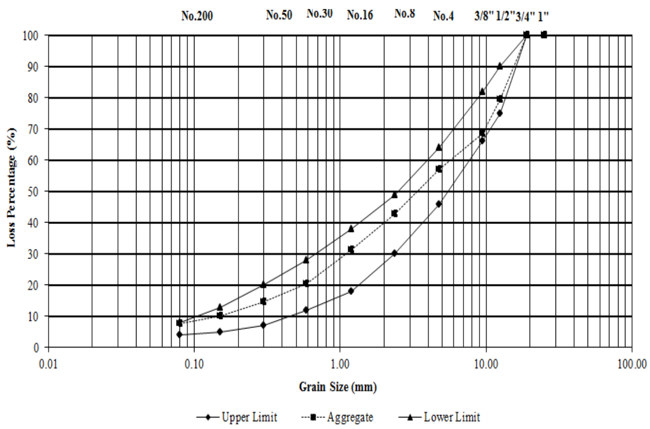

Figure 2. Combined aggregate gradation

Table 6. Proportion of the mixture's asphalt

No.	Contains asphalt (%)	The volume of asphalt (gr)
1	5.0	64.18
2	5.5	70.74
3	6.0	78.70
4	6.5	84.51
5	7.0	91.42

4. RESULTS AND DISCUSSION

4.1 Void in mix (VIM)

VIM, which is expressed as a proportion of the pavement's overall volume, is the total amount of air that exists between the aggregate pieces of an asphalt-covered pavement (cavities in the mixture). The VIM value was calculated based on the outcomes of the laboratory tests, as illustrated in Figure 3. According to Indonesia's requirements for the necessary road materials, which are stated in Indonesian, according to the VIM by General Specification of Indonesia 2018, the minimum is 3.5% and the highest is 5.5%. The VIM value for cement in the asphalt concrete binder course mixture was achieved for a concentration of 5.0–6.0% asphalt, but levels of 6.5%–7.0% asphalt had met the requirements.

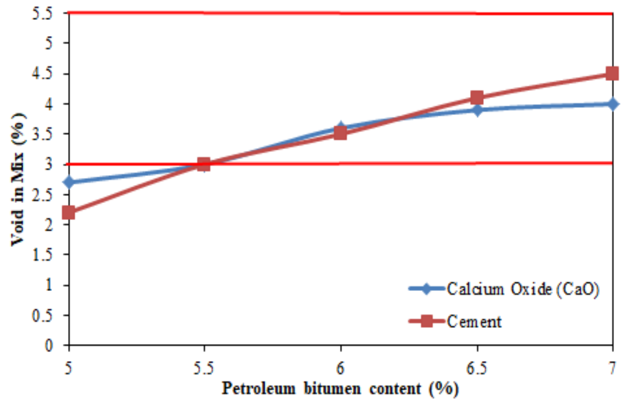

Figure 3. Asphalt content and VIM: A relationship

4.2 Void filled btumen (VFB)

The volume of bitumen with asphalt in it (VFB), excluding asphalt absorbed by the aggregate, that fills the voids between the component parts of the mixture. As a result, the aggregate grains found in the pores of solid concrete asphalt are hidden by the asphalt used to fill the VFB. Based on the VFB by General Specification of Indonesia, the Indonesian requirement (in Indonesian) for the necessary road materials has a minimum value of 63% (2018) (Figure 4).

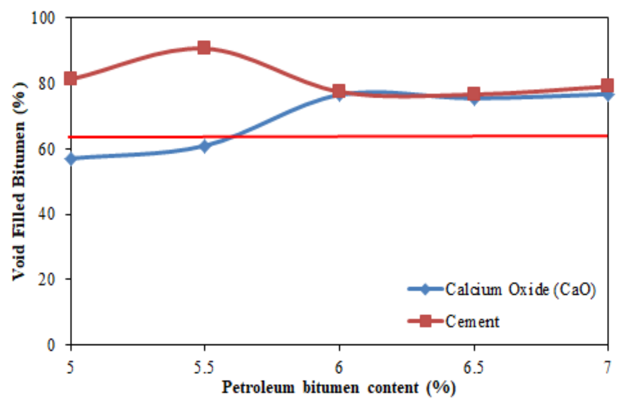

Figure 4. Asphalt content and VFB: A relationship

At an asphalt percentage of 5.0% to 7.0%, the asphalt concrete binder course mixture's VFB value was within acceptable range. The VFB value obtained for the asphalt concrete binder course mixture meets the required parameters for an asphalt percentage of 5.0%-7.0%.

4.3 Void in mineral aggregate (VMA)

VMA stands for volume of cavities, which includes the volume of the air cavity and the volume of the actual asphalt material (cavities in the aggregate), that exist between the aggregate grains of a solid asphalt mixture, represented as a percentage of the specimen's overall volume. According to these findings, asphalt levels of 6% to 7% are in compliance with the General Specification of Indonesia 2018 whereas those of 5.0% to 5.5% are not. The asphalt concrete binder course mixture's minimum VMA content is 14%, and the needed standard takes the value obtained by laboratory test results into account. When measured against the requirements of the General Specification of Indonesia 2018 the asphalt content of 5.0% to 5.5% in filler cement does not meet the requirements, whereas the asphalt content of 6% to 7% complies. The value obtained from the results of the laboratory tests is in accordance with the necessary norm (Figure 5).

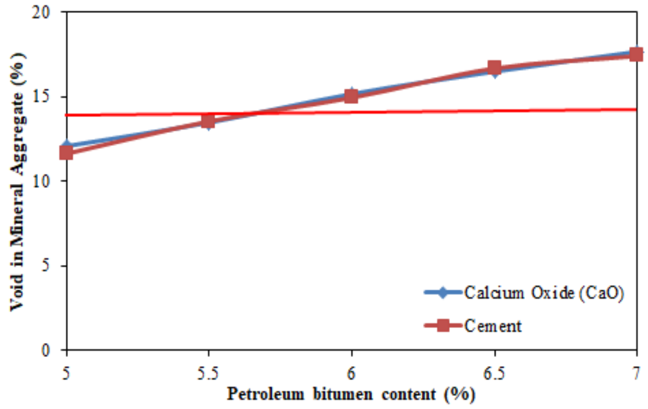

Figure 5. Asphalt content and VMA: A relationship

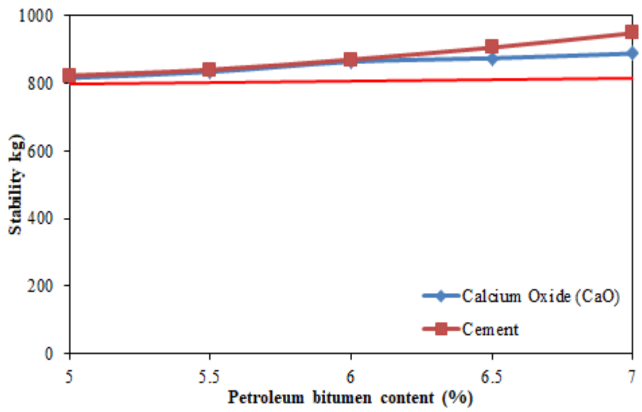

Figure 6. Asphalt content and stability: A relationship

4.4 Stability

Stability, which was measured in weight units, is a mixture's capacity or strength to absorb or sustain traffic loads or pressures without changing shape or forming a buildup of asphalt on the pavement surface can cause waves, grooves, or bleeding (kilograms). According to the General Specification of Indonesia 2018 standard, the minimum stability value for Indonesia is 800 kg, yet the value determined by laboratory test results vary. Quicklimeand cement are used as fillers to achieve the specification's stability value of 5.0%-7.0%. Up to a certain point, the asphalt will adequately cover and bind the aggregate, providing optimum stability, however if more asphalt is poured, the asphalt membrane on the surface of the aggregate would be damage thickens, increasing the distance between the aggregates and weakening the lock between them as well as the stability of the structure (Figure 6).

4.5 Flow

When a load reaches its limit of collapse, a plastic shape change in an asphalt mixture specimen occurs that is measured in units of length as flow (mm). According to the General Standard of Indonesia 2018, the minimum value is 3.0 mm. While 6% to 7% are mentioned in the specification, these standards are not met by flow values of quicklime and cement used as filler that are more than 5% to 5.5%. If you carefully consider the flow value above, you will notice that it fluctuates significantly. If we take a closer look, we will see that the flow value increases as the asphalt content rises, as does the thickness of the asphalt membrane or blanket covering the aggregate surface (Figure 7).

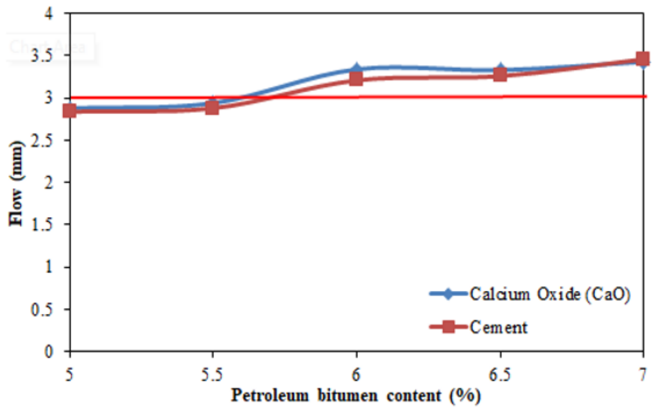

Figure 7. Asphalt content and flow: A relationship

4.6 Marshall quetiont (MQ)

MQ measures how resistant something is and is the stability to flow ratio, around one millimeter of the mixture is loaded. Although the MQ value above is higher, the results for the MQ value reveal a broad variation, using a 5% to 7% asphalt percentage, which meets with the standards. The Indonesian standard and the General Specification of Indonesia 2018 were used to compute the MQ value for traffic with a minimum weight of 250 kg/mm (in Indonesian) (Figure 8).

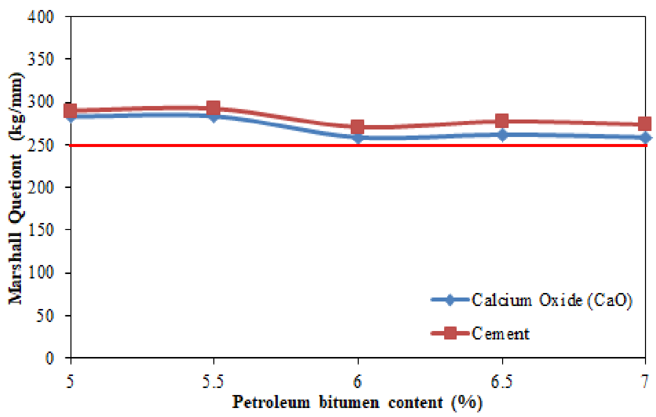

Figure 8. Asphalt content and MQ: A relationship

5. CONCLUSIONS

The Marshall value is 98.690% when cement is tested in the asphalt concrete binder course mixture (satisfies), for intermediate construction, what is superior to quicklime filler, (Asphalt Concrete Binder Course Mixture-AC-BC). The Marshall value for the quicklime hot mix test is 98.472%.

The results of this study can be used to support the use of locally accessible materials from Indonesia, such as Portland Composite Cement (PCC) and Quicklime, as filler materials. Because cement filler has been used in every road work package in Indonesian territory, this can also reduce the cost of building roads.

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REFERENCES

[1] Tumpu, M., Parung, H. (2021). Volumetric characteristics of HRS-WC mixed using petroleum bitumen grade 60/70 as binder. In IOP Conference Series: Earth and Environmental Science, 921(1): 012069. https://doi.org/10.1088/1755-1315/921/1/012069

[2] Rangan, P.R., Tumpu, M., Caroles, L. (2021). Compressive strength of high-strength concrete with cornice adhesive as a partial replacement for cement. IOP Conference Series: Earth and Environmental Science, 871(1): 012006. https://doi.org/10.1088/1755-1315/871/1/012006

[3] Tumpu, M., Tjaronge, M.W., Djamaluddin, A.R., Amiruddin, A.A., One, L. (2020). Effect of limestone and buton granular asphalt (BGA) on density of asphalt concrete wearing course (AC-WC) mixture. IOP Conference Series: Earth and Environmental Science, 419(1): 012029. https://doi.org/10.1088/1755-1315/419/1/012029

[4] Tumpu, M., Tjaronge, M.W., Djamaluddin, A.R. (2020). Prediction of long-term volumetric parameters of asphalt concrete binder course mixture using artificial ageing test. IOP Conference Series: Earth and Environmental Science, 419(1): 012058. https://doi.org/10.1088/1755-1315/419/1/012058

[5] Rangan, P.R., Irmawaty, R., Tjaronge, M.W., Amiruddin, A.A., Bakri, B., Tumpu, M. (2021). The effect of curing on compressive strength of geo-polymer mortar made rice straw ash, fly ash, and laterite soil. IOP Conference Series: Earth and Environmental Science, 921(1): 012009. https://doi.org/10.1088/1755-1315/921/1/012009

[6] Tumpu, M., Mabui, D.S. (2021). Influence of number of collisions towards asphalt emulsion mixture stability using marshall method (SNI 06-2489-1991). IOP Conference Series: Earth and Environmental Science, 921(1): 012017. https://doi.org/10.1088/1755-1315/921/1/012017

[7] Mabui, D.S., Tumpu, M. (2022). Influence of sea water immersion asphalt concrete wearing course mixed toward Marshall characteristics containing Doyo local aggregate of Jayapura district. AIP Conference Proceedings, 2391(1): 070004. https://doi.org/10.1063/5.0086704

[8] Tumpu, M., Mabui, D.S. (2022). Effect of hydrated lime (Ca (OH) 2) to compressive strength of geopolymer concrete. AIP Conference Proceedings, 2391(1): 070011. https://doi.org/10.1063/5.0086702

[9] Kabo, D.R.G., Tumpu, M., Parung, H. (2021). Influence of water immersion on stability of AC-WC mixed with gondorukem additional material. In IOP Conference Series: Earth and Environmental Science, 921(1): 012067. https://doi.org/10.1088/1755-1315/921/1/012067

[10] Li, G., Li, Y., Metcalf, J.B., Pang, S.S. (1999). Elastic modulus prediction of asphalt concrete. Journal of Materials in Civil Engineering, 11(3): 236-241. https://doi.org/10.1061/(ASCE)0899-1561(1999)11:3(236)

[11] Gul, W.A., Guler, M. (2014). Rutting susceptibility of asphalt concrete with recycled concrete aggregate using revised Marshall procedure. Construction and Building Materials, 55: 341-349. https://doi.org/10.1016/j.conbuildmat.2014.01.043

[12] Yan, J., Ni, F., Tao, Z., Jia, J. (2009). Development of asphalt emulsion cold in-place recycling specifications. In 2009 GeoHunan International Conference, Changsha, China, pp. 49-55. https://doi.org/10.1061/41042(349)7

[13] Ahmedzade, P., Yilmaz, M. (2008). Effect of polyester resin additive on the properties of asphalt binders and mixtures. Construction and Building Materials, 22(4): 481-486. https://doi.org/10.1016/j.conbuildmat.2006.11.015

[14] Tayfur, S., Ozen, H., Aksoy, A. (2007). Investigation of rutting performance of asphalt mixtures containing polymer modifiers. Construction and Building Materials, 21(2): 328-337. https://doi.org/10.1016/j.conbuildmat.2005.08.014

[15] Bitumen, S. (1990). The Shell bitumen handbook. Shell Bitumen UK.

[16] General Spesification of Indonesia. (2018). Indonesia Requirement.

[17] Standard National of Indonesia. Standard Test Method of Asphalt Mix with Marshall Test. SNI 06-2489-1991.