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Research Article

The Utilisation of Waste Bamboo Shells as A Filler in The ACWC Mixture on Marshall Characteristics

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ABSTRACT

Roads as transportation system infrastructure that are routinely used to support human activities every day must have adequate quality. The increase in the number of public and private vehicles results in the use of roads that continue to increase to the potential road damage if they do not have adequate quality. One of the factors of the quality of road infrastructure is the road pavement. This study is to examine the effects of bamboo shell powder as Filler on the ac-WC hot asphalt mixture on the characteristic value of Marshall. In this study we used Marshall Testing. This research was carried out in laboratories, starting from literature studies, material collection, material testing, determination of mixed plan asphalt levels, preparation and manufacture of test objects and Marshall testing. This study found bamboo shells to be one of the mixed materials in the hot asphalt mixture so that it becomes an asset for residents in the future.

Keywords: bamboo shell powder, asphalt mixture, marshall, ac-WC hot asphalt mixture

Introduction

One of the obstacles that hinder the Indonesian economy is the slow pace of infrastructure development. This is indicated by the lack of quality and quantity of infrastructure or infrastructure.

Infrastructure development and macroeconomic development should have a reciprocal relationship because infrastructure development leads to economic expansion through a

multiplier effect. At the same time, the economic growth creates a need to expand existing infrastructure to absorb the increasing flow of goods and people circulating or circulating throughout the economy. However, suppose the infrastructure cannot absorb the increased economic activity (and not enough new infrastructure is developed). In that case, there will be problems -- similar to clogged arteries in the

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human body, which cause life-threatening conditions because the blood cannot flow.

The development of an area is very dependent on the availability of adequate transportation facilities and infrastructure. Such availabilities can support the development of the place, which will directly or indirectly increase regional revenue. For example, it does appear in Madura after the construction of the Suramadu Bridge (Asmaroni and Irwanto, 2019).

Madura is the name of the island, which is located in the north of East Java, and the area is 5,250 km². Administratively, Madura is the area of East Java Province divided into four districts, namely Bangkalan, Sampang, Pamekasan, and Sumenep. Island Madura is also surrounded by more islands small ones, namely Goat Island, Gili Raja, Tile, Puteran, Iyang, Sapudi, and Raas. Approximately, there is no definite data on population. In 2019, the population was estimated to be more than 19 million people, which spreads on the island of Madura alone. Some live next door east of East Java, from Pasuruan to north of Banyuwangi. This island is famous as a national salt supplier for Indonesia.

Madurese people in general work as fishermen. Bamboo clams/shells are easily obtained in large numbers, especially in the coastal area in the West Pademawu area of Pamekasan regency. Bamboo clams have another name, known as *lorjuk*. The shell itself is wasted. It actually has an essential benefit if we know how to maximise it.

This study found bamboo shells to be one of the mixed materials in the hot asphalt mixture so that it becomes an asset for residents in the future. Previously one type of shell examined by Widyaningsih and Hamzah (2019) and Agisman et al. (2018) can provide good stability value on asphalt compositions. Agisman et al. (2018) mentioned that using shells can give stability, flow, VIM, VMA and MQ values that meet the standards of general specifications of the Indonesian government about adequate transportation facilities and infrastructure. Another study conducted by Veranita and Chaira (2019) mentioned that bamboo shellfish contain Calcium Oxide (CaO) or lime content that reaches 98.23%, which has benefits as an adhesive in asphalt mixture.

This study is to examine the effects of bamboo shell powder as Filler on the ac-WC hot asphalt mixture on the characteristic value of Marshall (Andri and Pradani, 2012; Qodar, 2016). In this study we used Marshall Testing.

Literature review

Asphalt is the main ingredient in road pavement. Asphalt has several types, namely natural asphalt, hard asphalt, liquid asphalt, and modified asphalt. Asphalt has viscoelastic properties, for example the property to melt at high temperatures and solidify at low temperatures. The properties of asphalt are the main things that make asphalt the main ingredient in road pavement because it can bind road pavement mixing materials. There are several types of pavement used in Indonesia. The most widely used road pavement in Indonesia is asphalt concrete layer or Laston (AC/Asphalt Concrete). Asphalt concrete layer is widely used because this type of pavement has good stability and flexibility values.

Prior studies examine this topical issues by green mussel shells that contain higher levels of calcium carbonate (CaCO₃) when compared to limestone, eggshell, ceramic or other materials (e.g. Putra et al. 2020). This can be seen from the level of hardness of the shells. The harder the shell, the higher the calcium carbonate content. Green mussel waste production per hectare per year itself can reach ± 200-300 tons of whole shellfish or about 60-100 tons of mussel meat. The initial examination of green mussel shells is sand equivalent of 93.34%. The apparent density is 2.73 and 100% passes filter no. 3/8. 99.6% passed the No. sieve. 4. 95.40% passed the No. sieve. 8. 27.40% passed the No. sieve. 30. 2.07% passed the No. sieve. 200. Thus the green mussel shells qualify as fine aggregates in the Latasir class B mixture.

Coarse aggregate, fine aggregate, medium aggregate filler and asphalt are ingredients for mixing asphalt concrete layers. These mixing materials must have characteristics that are in accordance with existing requirements so that the asphalt concrete pavement has good stability and flexibility. Testing with the Marshall tool is carried out in accordance with the procedure to determine the characteristics of the

mixture, determine the resistance or stability to the plastic melt of the pure asphalt mixture.

Methods

This research was carried out in laboratories, starting from literature studies, material collection, material testing, determination of mixed plan asphalt levels, preparation and manufacture of test objects and Marshall testing. This method have been applied by prior studies (Sari, 2021; Widyaningsih and Hamzah, 2019).

As previously mentioned, before conducting research, we reviewed the literature study. It is done by looking for written sources, either in the form of books, archives, articles and journals, or documents relevant to the current study's concerns. So, information obtained from this literature study is used as a reference to strengthen the arguments of study.

The material used in this study is 60/70 penetrating asphalt, bamboo shell fillers from the pamekasan pedemawu area, and broken stone from Pasrepan village, Pasuruan Regency East Java. The types of materials taken are coarse aggregates (CA), medium aggregates (MA), fine aggregates (FA) and fillers (FF) which are bamboo shells.

Before being used as a paved mixed material, we performed aggregate or material testing to determine the physical and mechanical characteristics. Aggregate or material testing consists of gradation, type weight, content weight and air cavity (Air Void).

Manufacture of Test Objects

This stage is the stage of making test objects or asphalt concrete briquettes based on aggregate proportions and variations in asphalt levels that have been obtained from the stage of the manufacturing plan. The implementation steps are as follows:

- Aggregates are weighed according to percentage based on the desired gradation for each test object with a mixed weight of 1200 gr.
- The aggregates and asphalt are heated in separate heating places until they reach a temperature of 150 °C, the asphalt is mixed with aggregates and stirred evenly.

- The hot mix inserted into a mould that has been smeared with oil and the bottom of the mould is given a piece of paper that has been cut according to the diameter of the mould, pierced with a spatula as much as 15 times at the edge and 10 times in the middle.
- Compaction is done manually with the number of collisions as 75 times on each side (up and down).
- After the compaction process is completed, the test object is silenced so that the temperature drops. After that, the test object is removed with *an injector* aid and given a code.
- The test object is ready to be used.

Marshall Testing

Marshall testing is a test that is intended to obtain Optimum Asphalt Levels and to know the characteristic values of the mixture of the manufacturing plans. The processes at this stage include:

- Test objects are cleaned of dirt that sticks.
- Test objects are soaked in water for 10 to 24 hours so that they are saturated. After saturated the test object is weighed in water.
- Test objects are removed from the water and dried with a cloth on the surface so that the dry condition of the saturated surface, then weighed.
- The test object is soaked in a soaking tub at a temperature of 60 °C for 30 minutes, for the stability of the rest of the test object soaked for 24 hours with a temperature of 60 °C.
- The inside of the pressure head surface is cleaned and lubricated so that the test object is easily removed after testing.
- The test object is removed from the sinking tub, then placed right in the middle of the pressure head then place the top of the pressure head by inserting through the guiding rod. After that put the whole thing in the testing machine.
- The flow *meter* installed on the stand on one of the guiding rods.
- The pressure head is raised to touch the top of the tester ring, then set the position of the pressure watch needle and the *flow* watch on the number.

i. The test object is given loading at a fixed speed of 50.8 mm per minute until the maximum correcting is reached or the loading decreases as indicated by the press watch needle. At that time, a reading of the maximum value or stabilisation of marshall and exhaust (flow) was also carried out.

Results

Material Testing

Wear/Abrasion Testing

Abrasion testing is performed on aggregate sizes (10 – 15) and (05 – 10). Calculation of Abrasion values as follows; see Table 1.

Table 4.1. Aggregate Abrasion Value

| No. | Testing | Type of Material | Test Results | Unit | Requirement |
|-----|----------|------------------------|--------------|------|-------------|
| 1 | Abrasion | Aggregate (10 - 15) mm | 21.34 | % | Max. 40 % |
| | | Aggregate (05 - 10) mm | 21.97 | % | Max. 40 % |

The results of calculations in Table 1 obtained the aggregate abrasion value of size (10 - 15) mm by 21.34 %, while the abrasion value (05 - 10) mm by 21.97 %. These data have met the requirements of the Indonesian government about adequate transportation

facilities and infrastructure, where the maximum value of abrasion test is about 40%.

Aggregate Gradation Testing

Gradation testing is performed on aggregate material sizes (10 – 15) mm, (05 – 10), (00 – 05) and *Filler* mm with results as in table 3.

Table 3. Filter Analysis

| No. | Testing | Type of Material | Test Results | Unit | Requirement |
|-----|-----------------|-------------------------------|--|------|--|
| 1 | Filter Analysis | Coarse Aggregate (10 – 15) mm | 0 | % | Maximum pass filter No. 200 by 1%. |
| | | Aggregate Medium (05 – 10) mm | 0 | % | Maximum pass filter No. 200 by 1%. |
| | | Fine Aggregate (05 – 10) mm | No. 4 was obtained by 99.12 and passed No. 200 of 8.07 | % | minimum pass no. 4 at least 50% and pass no. 200 maximum 10% |
| | | Filler | pass filter No. 200 79.73% | % | pass filter No. 200 Minimum 75% |
| | | | | | |

Aggregate Type Weight Testing and Absorption

Aggregate type weight testing is conducted on coarse aggregates, fine aggregates and

fillers, i.e. on aggregate sizes (00 – 05) mm, (05 – 10) mm and (10 – 15) mm with results as in table 4 below.

Table 4. Type Weight Testing.

| No. | Testing | Type of Material | Test Results | Unit | Requirement |
|-----|-------------------------------------|-------------------------------|--------------|------|-------------|
| 1 | Bulk Type Weight (Specific Gravity) | Coarse Aggregate (10 – 15) mm | 2.689 | | 2.5 |
| | | Aggregate Medium (05 – 10) mm | 2.679 | | 2.5 |
| | | Fine Aggregate (05 – 10) mm | 2.604 | | 2.5 |
| | | Filler | 2.630 | | 2.5 |
| 2 | Weight Dry Type Saturated Surface | Coarse Aggregate (10 – 15) mm | 2.720 | | 2.5 |
| | | Aggregate Medium (05 – 10) mm | 2.709 | | 2.5 |
| | | Fine Aggregate (05 – 10) mm | 2.628 | | 2.5 |

| No. | Testing | Type of Material | Test Results | Unit | Requirement |
|-----|-------------------------------|-------------------------------|--------------|------|-------------|
| 3 | Pseudo-Type Weight (Apparent) | Coarse Aggregate (10 – 15) mm | 2.775 | | 2.5 |
| | | Aggregate Medium (05 – 10) mm | 2.761 | | 2.5 |
| | | Fine Aggregate (05 – 10) mm | 2.669 | | 2.5 |
| 4 | Absorption | Coarse Aggregate (10 – 15) mm | 1.148 | % | - |
| | | Aggregate Medium (05 – 10) mm | 1.103 | % | - |
| | | Fine Aggregate (05 – 10) mm | 0.932 | % | - |

Table 4 reported the results of testing type weight, dry type weight saturated surface, pseudo-type weight and absorption in aggregates (10 - 15) mm, aggregate medium (05 - 10) mm, fine Aggregate (05 - 10) mm and *Filler*. From the data, it can be concluded that the testing of type weight on Aggregate have met the General Specification of adequate transportation facilities and infrastructure from the Indonesian government.

Test Object Testing Results

Stability

Stability values for filler levels of 0%, 2%, 4% and 6% can be seen in Table 5.

Table 5: Filler level stability values 0%, 2%, 4% and 6%

| No. | Filler Levels | Asphalt Rate (%) | Stability |
|----------------|---------------|------------------|-----------|
| 1 | 0% | 5.2 | 887.54 |
| | | 5.7 | 839.68 |
| | | 6.2 | 761.37 |
| 2 | 2% | 5.2 | 939.74 |
| | | 5.7 | 813.57 |
| | | 6.2 | 817.93 |
| 3 | 4% | 5.3 | 691.76 |
| | | 5.8 | 613.44 |
| | | 6.3 | 665.65 |
| 4 | 6% | 6.0 | 770.07 |
| | | 6.5 | 770.07 |
| | | 7.0 | 791.82 |
| Specifications | | | > 800 |

Table 5 shows stability values for filler levels of 0%, 2%, 4% and 6%. They do not meet the requirements, namely filler levels of 0% with asphalt levels of 6.2% with a value of 761.37, filler levels of 4% of the three asphalt levels used and the use of filler levels of 6% of the three asphalt levels used based on the

Mixed Plan Determination

Calculation of asphalt level plan and mixed composition used data from filter analysis. It is also to search the composition of each Aggregate with reference specifications of each no. filter. According to the calculations, we obtained the value of asphalt levels of the plan and the composition of the mixture, see Table 5.

standards of general specifications of the Indonesian government about adequate transportation facilities and infrastructure.

Plastic (Flow)

Plastics (Flow) values for *filler* levels of 0%, 2%, 4% and 6% can be seen in table 6.

Table 6: Plastic (Flow) filler grades 0%, 2%, 4% and 6%

| No. | Filler Levels | Asphalt Rate (%) | Flow |
|----------------|---------------|------------------|-------|
| 1 | 0% | 5.2 | 2.97 |
| | | 5.7 | 3.37 |
| | | 6.2 | 2.73 |
| 2 | 2% | 5.2 | 3.27 |
| | | 5.7 | 3.20 |
| | | 6.2 | 3.10 |
| 3 | 4% | 5.3 | 4.00 |
| | | 5.8 | 3.33 |
| | | 6.3 | 3.33 |
| 4 | 6% | 6.0 | 3.93 |
| | | 6.5 | 3.93 |
| | | 7.0 | 3.40 |
| Specifications | | | 2 - 4 |

Plastic exhaust values (Flow) meet all requirements for *filler* use of 0%, 2%, 4% and 6% with each asphalt level used, which refers to the standards of general specifications of the Indonesian government about adequate transportation facilities and infrastructure.

Marshall Share Results (MQ)

Marshall's Share Results values for filler levels of 0%, 2%, 4% and 6% can be seen in table 7.

Table 7 Marshall Share Values filler levels 0%, 2%, 4% and 6%

| No. | Filler Levels | Asphalt Rate (%) | MQ (Kg/mm) |
|----------------|---------------|------------------|------------|
| 1 | 0% | 5.2 | 299.17 |
| | | 5.7 | 249.41 |
| | | 6.2 | 278.55 |
| 2 | 2% | 5.2 | 287.68 |
| | | 5.7 | 254.24 |
| | | 6.2 | 263.85 |
| 3 | 4% | 5.3 | 172.94 |
| | | 5.8 | 184.03 |
| | | 6.3 | 199.70 |
| 4 | 6% | 6.0 | 195.78 |
| | | 6.5 | 195.78 |
| | | 7.0 | 232.89 |
| Specifications | | | > 250 |

The value of the results for marshall as shown by Table 7 each *filler* level of 0% with asphalt level of 5.7 does not meet the requirements, while for filler level 2% already meets the requirements of the three asphalt levels

used. The use of 4% and 6% fillers with asphalt levels do not meet the requirements under the standards of general specifications of the Indonesian government about adequate transportation facilities and infrastructure.

Cavities in the Mixture

Cavity values in the Mixture (VIM) for *filler* levels of 0%, 2%, 4% and 6% can be seen in table 8.

Table 8 Cavity Values in a Mixture (VIM) filler levels 0%, 2%, 4% and 6%

| No. | Filler Levels | Asphalt Rate (%) | VIM (%) |
|----------------|---------------|------------------|---------|
| 1 | 0% | 5.2 | 12.74 |
| | | 5.7 | 13.42 |
| | | 6.2 | 10.78 |
| 2 | 2% | 5.2 | 4.26 |
| | | 5.7 | 4.55 |
| | | 6.2 | 4.02 |
| 3 | 4% | 5.3 | 7.70 |
| | | 5.8 | 11.54 |
| | | 6.3 | 8.58 |
| 4 | 6% | 6.0 | 9.21 |
| | | 6.5 | 7.93 |
| | | 7.0 | 12.31 |
| Specifications | | | 3 ~ 5 |

Based on Table 8, Cavity values that only meet the requirements are on the use of *fillers* 2%. While in the use of fillers, 0%, 4% and 6% do not meet the criteria. That exceeds more than 5% for the value of cavities in the mixture.

VMAs

VMAs values for filler levels of 0%, 2%, 4% and 6% can be seen in Table 9.

Table 9: Filler grade vMA values 0%, 2%, 4% and 6%

| No. | Filler Levels | Asphalt Rate (%) | VMAs (%) |
|----------------|---------------|------------------|----------|
| 1 | 0% | 5.2 | 21.98 |
| | | 5.7 | 23.56 |
| | | 6.2 | 22.22 |
| 2 | 2% | 5.2 | 15.06 |
| | | 5.7 | 15.42 |
| | | 6.2 | 16.98 |
| 3 | 4% | 5.3 | 18.34 |
| | | 5.8 | 22.73 |
| | | 6.3 | 21.14 |
| 4 | 6% | 6.0 | 21.11 |
| | | 6.5 | 21.00 |
| | | 7.0 | 22.84 |
| Specifications | | | > 15 |

Based on Table 9, it can be concluded that for the results of VMA testing on filler use, 0%, 2%, 4%, and 6% meet the requirements. They are more than 15% as required in the standards of

general specifications of the Indonesian government about adequate transportation facilities and infrastructure.

VFB

VFB values for filler levels of 0%, 2%, 4% and 6% can be seen in table 10.

Table 10: VFB filler grades 0%, 2%, 4% and 6%

| No. | Filler Levels | Asphalt Rate (%) | VFB(%) |
|----------------|---------------|------------------|--------|
| 1 | 0% | 5.2 | 42.03 |
| | | 5.7 | 43.05 |
| | | 6.2 | 51.48 |
| 2 | 2% | 5.2 | 71.75 |
| | | 5.7 | 70.48 |
| | | 6.2 | 76.34 |
| 3 | 4% | 5.3 | 58.04 |
| | | 5.8 | 49.22 |
| | | 6.3 | 59.43 |
| 4 | 6% | 6.0 | 56.37 |
| | | 6.5 | 62.25 |
| | | 7.0 | 46.09 |
| Specifications | | | > 65 |

Based on Table 10, it can be concluded that for VFB testing results on filler use, 0%, 4%, and 6% do not meet the requirements below 65%. In comparison, filler use of 2% meets the value as required by the standards of general specifications of the Indonesian government

about adequate transportation facilities and infrastructure.

Absorption

Absorption values for filler levels of 0%, 2%, 4% and 6% can be seen in Table 11.

Table 11 Filler absorption values 0%, 2%, 4% and 6%

| No. | Filler Levels | Asphalt Rate (%) | Absorption (%) |
|----------------|---------------|------------------|----------------|
| 1 | 0% | 5.2 | 0.54 |
| | | 5.7 | 0.54 |
| | | 6.2 | 0.54 |
| 2 | 2% | 5.2 | 0.52 |
| | | 5.7 | 0.52 |
| | | 6.2 | 0.52 |
| 3 | 4% | 5.3 | 0.52 |
| | | 5.8 | 0.52 |
| | | 6.3 | 0.52 |
| 4 | 6% | 6.0 | 0.51 |
| | | 6.5 | 0.51 |
| | | 7.0 | 0.51 |
| Specifications | | | < 1.2 |

Referring to Table 10, the value is obtained for absorption test results on filler use 0%, 2%, 4% and 6% meet the requirements that are less than 1.2% as required in the standards of gen-

eral specifications of the Indonesian government of adequate transportation facilities and infrastructure.

Conclusion and Suggestions

Conclusion

The conclusions obtained from the research on the effect of the use of bamboo shell powder *fillers* on the characteristic value of marshall's on ac-wc hot asphalt mixture are as follows:

- a. In the use of bamboo shell powder *fillers* as much as 2% are able to produce a good stability value as required in the standards of general specifications of the Indonesian government of adequate transportation facilities and infrastructure. However, in the addition of bamboo shell powder fillers, between 4% and 6% experienced a decrease in the stability value.
- b. The increase in the amount of bamboo shell powder *filler* by 2%, 4%, and 6% can increase the flow value or fatigue. The most considerable flow value is found in the addition of bamboo shell powder filler by 4% with a 5.3% asphalt variation of 4 mm.
- c. VIM values that meet the standards of general specifications of the Indonesian government of adequate transportation facilities and infrastructure in this study are in the use of bamboo shell powder *fillers* by 2% with asphalt levels of 5.2% by 4.25%, 5.7% by 4.55% and 6.2% by 4.02%.
- d. The addition of bamboo shell powder fillers by 2%, 4% and 6% can reduce the value of VMAs. It is because of increasing the number of filler levels that can cover the cavity between the aggregate materials.
- e. VFA values that meet the standards of general specifications of the Indonesian government of adequate transportation facilities and infrastructure in this study are in the use of *fillers* of 2% with asphalt levels of 5.2%, 5.7% and 6.2%, which are 71.75%, 70.48 and 76.34%.
- f. The addition of bamboo shell powder fillers by 2%, 4% and 6% can reduce the value of MQ. In this study, the value of MQ that meets the general specification is contained in the addition of bamboo shell powder fillers by 2% with asphalt variations of 5.2%, 5.7% and 62%, which is

287.68 kg / mm, 254.24 kg / mm and 263.85 kg / mm.

- g. Three types of mixtures meet the requirements against *Marshall's* characteristic value, namely in the use of *fillers* 2% asphalt variation 5.2%, 5.7% and *Filler* 6.2%.
- h. Optimum Asphalt levels in this study were found in *mixtures* with a total of filler additions of 2% asphalt levels of 5.2% obtained density value of 2.37, stability value of 940 kg, flow value of 3.27 mm, VIM value of 4.26%, MQ value of 287.68 kg / mm, VMA value of 15.06%, and VFA of 71.75%.

Suggestions

The results of the research recommended to:

- a. Continue research using bamboo shell powder *fillers* with *fillers* values around 1%, 3% and 5%.
- b. Research by replacing aggregates with other aggregates for instance using local broken stone, which is currently widely used as an aggregate in reinforced concrete mixtures.

References

Agisman F, Malik A dan Wibisono G (2018). Penggunaan Abu Kulit Kerang Sebagai Bahan Pengisi (*Filler*) Dalam Campuran Aspal Jenis AC-WC Dengan Pengujian marshall. *Jurnal online mahasiswa*, 5(2), 1-12

Andri, S, A, dan Pradani, N (2012). Pengaruh penggunaan kapur sebagai bahan pengisi (*Filler*) terhadap karakteristik campuran beton aspal lapis aus (AC-WC). *Jurnal Rekayasa Dan Manajemen Transportasi*, 2(2), 87-104.

Asmaroni, D, and Irwanto, T.J (2019). Pemanfaatan Material Lokal Dan Produk Samping Industri Sebagai Agregat Batu Pecah Dan *Filler* terhadap Kinerja Marshall pada Campuran Panas Aspal Beton Lapis Permukaan Aus (ACWC). *Ge-STRAM: Jurnal Perencanaan dan Rekayasa Sipil*, 2(1),

Kementerian Pekerjaan Umum. 2018. Spesifikasi Umum 2018 untuk Pekerjaan Konstruksi Jalan dan Jembatan Revisi 2 Yayasan Penerbit Pekerjaan Umum, Jakarta. Avalaible at:
https://binamarga.pu.go.id/v3/assets/files/NSPK/pembangunan_jalan/2018_Spesifikasi%20Umum%202018%20TERKEN-DALI%20FINAL.pdf

Qodar, T (2016). Pengaruh penggunaan serbuk batu kapur putih madura sebagai filler pada campuran aspal panas (hotmix) asphalt concrete wearing course (acwc) terhadap karakteristik marshall. *Jurusan Teknik Sipil Fakultas Teknik Universitas Madura*,

Putra, A., Mulyono, T., & Chrisnawati, Y. (2020). Kajian parameter marshall dengan menggunakan limbah serbuk kerang hijau sebagai filler campuran lapis aspal beton. *Menara: Jurnal Teknik Sipil*, 15(1), 1-8.

Sari, K. I. (2021). Pengaruh Serbuk Abu Cangkang Kerang Sebagai Bahan Pengganti Filler Pada Campuran Aspal. *Journal of civil engineering building and transportation*, 5(2), 132-142.

Veranita, V., & Chaira, C. (2019). Pengaruh Pemberian Filler Abu Cangkang Lokan Terhadap Parameter Marshall Pada Campuran Aspal Beton. *Jurnal Teknik Sipil dan Teknologi Konstruksi*, 5(1), 72-81.

Widyaningsih, N., & Hamzah, F. F. (2019). Pengaruh Variasi Kadar Filler Abu Cangkang Kerang Terhadap Parameter Marshall Di Lapisan Laston Ac-Wc. *Teknika*, 14(1), 22.