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# THE USE OF STEEL SLAG WASTE AS A REPLACEMENT OF GRAVEL IN MADURA FOR PLANNING THE FOOTING LAYER

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## ABSTRACT

*Madura is one of the island that has a huge material potential. However, this island still use material from Java for road infrastructure development. Road pavement is needed to be as an infrastructure for social relationships, economic and culture. PT. Hanil Jaya Steel as the steel smelting factory is the one of industrial company around Surabaya that produce slag waste, the use of slag waste for minimalize buildup that brings negative effect in environment. Thus, this research is implemented the use slag steel waste as a replacement of Madura gravel, the gravel and sand will be taken from Bangkalan. This study aimed to investigate the gravel's influence of Bangkalan and slag characteristic on asphalt concrete mixture. Experimental method is conducted in this study by using the experiment to obtain the result, hence, the use of slag steel gravel on asphalt concrete construction can be various with slag levels; 0%, 10%, 20%, 30%, 40% and 50%. SNI procedure will be followed while checking Madura's aggregate, slag aggregate and the asphalt. The result of examination and analysis of asphalt concrete mixture characteristic using the variation level of slag steel gravel is shown performance improvement of asphalt concrete mixture. The **stability** result of asphalt level shows 6 % as the highest score, 5 % asphalt level of **durability** as the highest score, 5.5 % asphalt level of **Marshall Quotient** as the highest score. By using 40mm thickness and ± 3 mm tolerance as the footing layer.*

**Key words**: Steel slag, Gravel in Bangkalan, Stability, Durability, Footing Layer

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# 1. INTRODUCTION

Madura is one of the island in East Java that has a huge material potential. However, it is mostly used for concrete material rather than road pavement (highway structure). The color of aggregate from Madura is brownish and slightly white. Not only use that material, this research also use the waste from steel smelting as the gravel replacement from Madura. Nowadays, residual production or waste keep on increasing due to the industrial development, especially in Indonesia. Thus, facilitate and utilizing waste is needed for decreasing the negativity effect of the waste.

Steel slag is the result of steel smelting processes. Steel slag has characteristic like gravel with hollow surface, yet, the hollow doesn't connect to each other, and so, the toughness doesn't disappear until even the smallest particle when the slag is torn in the breaking process because slag aggregate has the highest toughness and this is useful for road pavement.

Abovementioned, this research is investigating the use of slag waste as coarse aggregate by mixing the material from Madura for asphalt concrete mixture in highway planning which used in footing layer planning. There are several previous study that has the exactly concern about the use of the steel slag. Those are;

**Wanga, G., Wanga, Y. H., & Gaob, Z. (2010)**. Use of steel slag as a granular material: volume expansion prediction and usability criteris. *Journal of Hazardous Materials*, *184*, 555-560.

The minimum (lowest) absorbable void volume is approximately 7.5%, which is unrelated to the free lime content. A usability criterion is then developed based on the volume expansion of steel slag (%) and the minimum percentage of the volume that can take the volume expansion of steel slag (%). Eventually the criterion (relationship) is established based on the free lime content, the specific gravity and bulk relative gravity of a specific steel slag sample. The criteria can be used as guidance and specification for the use of steel slag and other expansion-prone nonferrous slags, copper, nickel for instance as a granular material in highway construction.

**Behiry, A. E. A. E. M. (2013).** Evaluation of steel slag and crushed limestone mixtures as subbase material in flexible pavement. *Ain Shams Engineering Journal*, *4*(1), 43-53.

In general can be said that the use of steel slag especially at optimal ratio improved the subbase layer density, strength and failure resistance especially for horizontal distance of 60 cm from load center. Thus, this research recommends utilizing industrial by-products such as steel slag especially in developing countries to reduce the use of primary aggregate and thus minimize the cost of road construction.

## 1.1. Asphalt Concrete

Asphalt concrete layer which known as AC, is one of the types of paved pavement mixture layer. This type of pavement is using evenly mixed between aggregate and asphalt as a binder and heated at certain temperature. Stated by (*Spesifikasi Umum Bidang Jalan dan Jembatan, Divisi VI Perkerasan Aspal, Dep. PU*) asphalt concrete footing divided into 3 types, those are:

1. Asphalt concrete layer as the wear layer, known as AC – WC (Asphalt Concrete – Wearing Course) with the size of aggregate maximum19 mm and minimum thickness 4 cm.
2. Asphalt concrete layer as a between layer or known as AC – BC (Asphalt Concrete – Binder Course) with the size of aggregate maximum 25.4 mm minimum thickness 6 cm.
3. Asphalt concrete layer as a footing layer or known as AC-Base (Asphalt Concrete – Base) with the size of aggregate maximum 37.5 mm minimum thickness 7.5 cm.

The layer is used as a base or footing, even though this layer doesn't have correlation with the weather, yet, base layer has the high of stability level to carry the traffic load that is given by the previous layer.

## 1.2. The Basic Material of Asphalt Concrete Mixture

### *1.2.1. (Asphalt Cement, AC)*

Asphalt defines as black or dark brown material in a room temperature is solid until it is rather dense. Low penetration AC is used for hot area or high traffic volume while high penetration AC is used for cold area or low traffic volume. This study conducts penetration AC 60/70. The asphalt for asphalt concrete mixture has to be selected as the requirements stated in the table 1

**Table 1.** Rough Asphalt Requirements Pen 60/70

| Num. | Type of Testing | Method | Requirements (RSNI S-01-2003) |
|---|---|---|---|
| 1 | Penetration, 25 $^0$C; 100gr; 5 second, 0.1 mm | SNI 06-2456-1991 | 60 - 79 |
| 2 | Softening point, $^0$C | SNI 06-2434-1991 | 48 - 53 |
| 3 | Flash point | SNI 06-2433-1991 | Min 200 |
| 4 | Ductility, cm | SNI 06-2432-1991 | Min 100 |
| 5 | Mass | SNI 06-2441-1991 | Min 0.1 |
| 6 | Decreasing Mass (TFOT), % | SNI 06-2440-1991 | Max 1.0 |

(*Pd T-04-2005-B, Dep PU*)

### *1.2.2. Coarse Aggregate*

According to Spesifikasi Umum Bidang Jalan Dan Jembatan, Divisi VI untuk Campuran Beraspal Panas, Dep PU, Edisi November 2010, the requirements of coarse aggregate stated as in:

**Table 2.** The Requirements of Standard Coarse Aggregate

| Testing | Method | Requirements |
|---|---|---|
| Mass, Kg/m$^3$<br>Bulk<br>SSD<br>Apparent | SNI 03-1969-1990 | <br>Min 2.5<br>Min 2.5<br>Min 2.5 |
| Absorbent, % | SNI 03-1969-1990 | Max 3 |
| Abrasion with Los Angeles machine, % | SNI 03-2417-1991 | Max 40 |
| Conservation of the aggregate form with solutions of sodium or magnesium sulfate<br>, % | SNI 03-3407-1994 | Max 12 |
| Angularity, % (*) | SNI 03-3407-1994 | 95/90 |
| Flat and oval particles, % (**) | RSNI T-01-2005 | Max 10 |
| Stickiness to asphalt, % | SNI 03-2439-1991 | Min 95 |
| Material escapes #200, % | SNI 03-4142-1996 | Max 1 |

(*Pd T-04-2005-B, Dep PU*)

Notes:

(*****) 95/90 showed that 95 % coarse aggregate has the surface of the field break one or more; and 90 % coarse aggregate has the surface of field break two or more.

(******) Testing by the testing tools on shaft 1:5

### *1.2.3. Fine Aggregate*

Fine aggregate (sand) is the natural mineral that used as filled substitute in asphalt concrete mixture which has the particle size below 2.36 mm or escape filter num.8 and endure filter num.200.

Fine aggregate has to be fit in the requirements that designed by *Bina Marga.*

**Table 3.** The Requirements of Standard Fine Aggregate

| Testing | Method | Requirement |
|---|---|---|
| Mass, Kg/m$^3$<br>Bulk<br>SSD<br>Apparent | SNI 03-1979-1990 | <br>Min 2.5<br>Min 2.5<br>Min 2.5 |
| Sand Equivalent Value, % | SNI 03-4428-1997 | Min 50 |
| Material Sieve Escape No. 200, % | SNI 03-4142-1996 | Max 8 |
| Water absorbent, % | SNI 03-1979-1990 | Max 3 |

(*Pd T-04-2005-B, Dep PU*)

## 1.3. Steel SlagFlowing Waste

Slag is the result of residue of burning high furnace which produced by steel slag industrial and one of them is slag waste that physically more like coarse aggregate. There are two characteristics of steel slag waste, they are; chemistry and physical characteristic.

## Physical Characteristic

Testing of standard slag aggregate need to be done in order to know physical characteristic of slag aggregate to fit in the requirements in asphalt concrete mixture, the form of the slag aggregate physical characteristic testing is explaining below:

**Table 4.** Slag Aggregate Requirements

| Testing | Method | Requirements |
|---|---|---|
| Mass, Kg/m$^3$<br>Bulk<br>SSD<br>Apparent | SNI 03-1969-1990 | <br>Min 3.3<br>Min 3.3<br>Min 3.3 |
| absorbent, % | SNI 03-1969-1990 | Max 3 |
| Aggregate wear by using Los Angeles machine, % | SNI 03-2417-1991 | Max 40 |
| Conservation of the aggregate form with solutions of sodium or magnesium sulphate, % | SNI 03-3407-1994 | Max 12 |
| Stickiness to asphalt, % | SNI 03-2439-1991 | Min 95 |
| Material escape #200, % | SNI 03-4142-1996 | Max 1 |

(Pd T 04-2005-B, Dep PU)

### 1.4. The Requirements of Asphalt Concrete Mixture

The mixture of each aggregate fraction has to be firstly checked about the gradation and then combined by using several comparing methods like; rectangular method, trial method or triangular method which can produce the mixture aggregate that completed gradation specification.

**Table 5.** The Requirements of Asphalt Concrete Mixture

| Mixture Characteristics | | Concrete Layer | | |
|---|---|---|---|---|
| | | WC | BC | Base |
| Asphalt absorbent, (%) | Max | 1.7 | | |
| Number of collisions per field | | 75 | | 112 |
| Void in the mixture , VIM, (%) | Min | 3.5 | | |
| | Max | 5.5 | | |
| Void in the aggregate , VMA, (%) | Min | 15 | 14 | 13 |
| Void filled in asphalt , VFB, (%) | Min | 65 | 63 | 60 |
| Marshall Stability, (kg) | Min | 800 | | 1500 |
| | Max | - | | - |
| Flow, (mm) | Min | 3 | | 5 |
| Marshall Quotient, (Kg/mm) | Min | 250 | | 300 |
| Marshall stability left (%) after immersion in 24 hours, 60 $^0$C | Min | 75 | | |
| Void in mixture (%) on bald thickness (refusal) | Min | 2.5 | | |

(Pd T-04-2005-B, Dep PU)

## 2. DATA COLLECTION

This study is about the use of steel slag waste as gravel replacement of Madura for pavement road as the foundation layer. The data needed in this study are collected in the laboratory such as; the analysis of filter, mass and absorbent, abrasion for coarse and fine aggregate while asphalt testing is for penetration, mass, flash point and ductility.

Filter analysis is used to know the particle gradation of coarse and fine aggregate, slag aggregate, mass is used to know about SSD mass and absorbent mass of coarse and fine aggregate, slag and abrasion that it used to know conservation of both coarse and fine aggregate because the pavement road materials can be used to endure the transportation volume.

Asphalt penetration is used to know asphalt thickness in certain temperature ($^0$c), penetration also defines to investigate the pavement of low, medium or high traffic volume. Softening and flash point is used to know the limit of the asphalt in certain temperature ($^0$c) while ductility is used to know the limit of asphalt elasticity using in pavement road whether it can stick to the coarse and fine aggregate.

The characteristic of coarse and fine aggregate has to be filled in the requirements, then, mixture design of the aggregate will be the next step to define the percentage of the aggregate mixture needed. The mass of coarse gravel aggregate and the slag percentage counted as 0%, 10%, 20%, 30%, 40% and 50%. Defining the optimum level of asphalt and the considering the composition of the mixture by making the testing tool as much as the slag percentage and based

on 5 different asphalt level (3tools), then, Marshall testing should be done to know the influence of the slag over the characteristic stability, durability and flexibility, and the requirement will be obtained as the result to foundation layer in the pavement road in Madura Island.

# 3. RESULTS AND DISCUSSION

## 3.1. Heavy Planning for Each Fraction

The composition of each aggregate and the asphalt level is explaining below:

**Table 6.** Comparing table for combining the aggregate

| % Passing | | Aggregate Proportion of 4-way- mixture | | Total Gradation | % 4- way-mixture Aggregate | Spec. | Forbidden Zone | Notes | Mid Spec. | % Mid spec. Aggregate |
|---|---|---|---|---|---|---|---|---|---|---|
| F1 | F2 | F1 = 45% | F2 = 55% | | | | | | | |
| 0 | 0 | | | | | - | | | | |
| 100 | 100 | 34 | 62 | 100 | | 100 | | OK | 100 | |
| 88,978 | 100 | 30,252 | 62 | 95,04 | 3,748 | 90 – 100 | | OK | 95 | 5 |
| 69,689 | 99 | 23,694 | 62 | 85,81 | 6,558 | Maks 90 | | OK | 81 | 14 |
| 26,473 | 86 | 9,001 | 62 | 59,213 | 14,693 | - | | OK | 61,5 | 19,5 |
| 1,558 | 72,2 | 0,53 | 52,339 | 40,411 | 18,148 | 28 – 58 | 39,1 | OK | 48,55 | 12,95 |
| 1,003 | 60,32 | 0,341 | 33,128 | 33,627 | 19,563 | - | 25.6-31.6 | OK | 35,8 | 12,75 |
| 0,919 | 46,68 | 0,313 | 24,945 | 26,088 | 9,757 | - | 19.1-23.1 | OK | 26,55 | 9,25 |
| 0,848 | 37,84 | 0,288 | 17,506 | 21,194 | 9,522 | - | 15,5 | OK | 18,75 | 7,8 |
| 0,768 | 20,57 | 0,261 | 11,482 | 11,659 | 6,248 | - | | OK | 12,25 | 6,5 |
| 0,593 | 9,84 | 0,202 | 4,815 | 5,679 | 6,743 | 4 - 10' | | OK | 7 | 5,25 |
| - | - | | | | 5,679 | | | | | 7 |

**Table 7.** Hot Mix Design Data by using Marshall way

| Asphalt Level | Slag Level | Dry Mass (gram) | SSD Mass (gram) | Mass in water (gram) | Density (gr/cm$^3$) | VMA (%) | VFB (%) | VIM (%) | Stability (Kg) | Flow (mm) | MQ (Kg/mm) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 5% | 0% | 1187 | 1193 | 685 | 2.33 | 17.39 | 66.98 | 6.148 | 1198 | 3.10 | 386 |
| | 10% | 1190 | 1195 | 704 | 2.45 | 16.87 | 67.33 | 5.175 | 1456 | 3.13 | 464 |
| | 20% | 1192 | 1194 | 713 | 2.49 | 18.54 | 66.59 | 6.624 | 1601 | 3.33 | 480 |
| | 30% | 1189 | 1195 | 723 | 2.5 | 19.64 | 64.19 | 7.470 | 1927 | 3.53 | 545 |
| | 40% | 1187 | 1196 | 724 | 2.51 | 20.57 | 65.29 | 7.322 | 1932 | 3.56 | 536 |
| | 50% | 1186 | 1195 | 729 | 2.53 | 21.86 | 58.31 | 9.557 | 1951 | 3.63 | 537 |
| 5.50% | 0% | 1182 | 1189 | 683 | 2.34 | 17.51 | 73.50 | 5.088 | 1304 | 3.28 | 397 |
| | 10% | 1185 | 1191 | 703 | 2.44 | 16.98 | 78.82 | 4.062 | 1613 | 3.53 | 456 |
| | 20% | 1188 | 1192 | 711 | 2.48 | 18.89 | 71.96 | 5.771 | 1862 | 3.80 | 490 |
| | 30% | 1189 | 1194 | 723 | 2.53 | 19.82 | 70.16 | 6.397 | 2293 | 4.03 | 538 |
| | 40% | 1185 | 1193 | 720 | 2.55 | 21.68 | 73.23 | 6.887 | 2319 | 4.17 | 543 |
| | 50% | 1186 | 1192 | 728 | 2.56 | 22.04 | 63.82 | 8.464 | 2325 | 4.23 | 549 |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 6 % | 0% | 1181 | 1187 | 679 | 2.31 | 18.46 | 75.58 | 4.992 | 1503 | 3.77 | 399 |
| | 10% | 1186 | 1189 | 701 | 2.44 | 17.45 | 83.66 | 3.359 | 1723 | 3.97 | 434 |
| | 20% | 1185 | 1188 | 710 | 2.47 | 19.10 | 77.83 | 4.753 | 2049 | 4.47 | 458 |
| | 30% | 1187 | 1190 | 721 | 2.52 | 20.17 | 75.27 | 5.516 | 2487 | 4.57 | 486 |
| | 40% | 1186 | 1189 | 724 | 2.54 | 21.81 | 73.33 | 6.445 | 2479 | 4.81 | 513 |
| | 50% | 1185 | 1191 | 726 | 2.57 | 22.44 | 68.41 | 7.622 | 2483 | 4.97 | 544 |
| 6.5% | 0% | 1180 | 1185 | 675 | 2.33 | 19.17 | 78.57 | 4.631 | 1282 | 4.20 | 305 |
| | 10% | 1182 | 1185 | 698 | 2.39 | 17.97 | 87.87 | 2.728 | 1426 | 4.47 | 319 |
| | 20% | 1183 | 1184 | 705 | 2.42 | 19.82 | 81.02 | 4.318 | 1870 | 4.98 | 375 |
| | 30% | 1185 | 1186 | 718 | 2.49 | 20.77 | 79.05 | 4.922 | 2024 | 4.95 | 384 |
| | 40% | 1185 | 1187 | 719 | 2.52 | 21.25 | 75.04 | 5.118 | 2049 | 5.65 | 399 |
| | 50% | 1183 | 1186 | 722 | 2.55 | 22.96 | 72.33 | 6.929 | 2056 | 5.35 | 402 |
| 7 % | 0% | 1176 | 1177 | 672 | 2.31 | 19.17 | 85.12 | 3.416 | 1227 | 4.70 | 261 |
| | 10% | 1178 | 1180 | 694 | 2.40 | 18.60 | 91.26 | 2.215 | 1369 | 5.17 | 265 |
| | 20% | 1180 | 1181 | 700 | 2.40 | 20.72 | 82.97 | 4.126 | 1517 | 5.57 | 272 |
| | 30% | 1182 | 1182 | 709 | 2.48 | 22.04 | 79.34 | 5.162 | 1775 | 5.60 | 291 |
| | 40% | 1174 | 1180 | 713 | 2.51 | 22.88 | 76.86 | 5.782 | 1833 | 5.92 | 294 |
| | 50% | 1177 | 1178 | 716 | 2.54 | 23653 | 75.31 | 6.458 | 1775 | 6.10 | 296 |

## 3.2. The Result of the Asphalt Concrete Mixture Specification

### Density

The table below provide the result of the density form the steel slag level variety

**Table 7**. The Density of the steel slag level

| Asphalt Level | The variety level of slag gravel (%) | | | | | |
|---|---|---|---|---|---|---|
| % | 0 | 10 | 20 | 30 | 40 | 50 |
| 5 | 2.33 | 2.45 | 2.49 | 2.5 | 2.51 | 2.53 |
| 5.5 | 2.34 | 2.44 | 2.48 | 2.53 | 2.55 | 2.56 |
| 6 | 2.31 | 2.44 | 2.47 | 2.52 | 2.54 | 2.57 |
| 6.5 | 2.33 | 2.39 | 2.42 | 2.49 | 2.52 | 2.55 |
| 7 | 2.31 | 2.40 | 2.40 | 2.48 | 2.51 | 2.54 |

The testing is shown the result of the density completed the specification from *Pd T-04-2005-B, Dep PU*and can be seen in table 7. There is tendency to density improvement as the slag level increase, the highest density obtained by the sla level on 50% with the value on 2.57

#### *3.2.1. Void in Mineral Aggregate*

VMA value is the void percentage between aggregate particles that involve in the asphalt concrete mixture which named in (%).

**Table 8.** VMA Value with Steel Slag Level

| Asphalt Level | The variety level of slag gravel (%) | | | | | |
|---|---|---|---|---|---|---|
| % | 0 | 10 | 20 | 30 | 40 | 50 |
| 5 | 17.39 | 16.87 | 18.54 | 19.64 | 20.57 | 21.86 |
| 5.5 | 17.51 | 16.98 | 18.89 | 19.82 | 21.68 | 22.04 |
| 6 | 18.46 | 17.45 | 19.11 | 20.17 | 21.81 | 22.44 |
| 6.5 | 19.17 | 17.97 | 19.82 | 20.77 | 21.25 | 22.96 |
| 7 | 19.16 | 18.60 | 20.72 | 22.04 | 22.88 | 23.65 |

Table 8 is showed that VMA value fulfilled the specification, can be seen form the improvement of the value as the gravel slag level increasing in the mixture. The reason beyond this result is because the more slag level, the less aggregate particles and slag void getting bigger that can make available room for keeping asphalt volume and the need of void volume becomes wider.

### *3.2.2. Void Filled in Asphalt*

VFB is the void that filled in the asphalt while the mixture and become dense which stated in (%) toward the void in aggregate particle (VMA).

**Table 9**. VFB Value with Steel Slag Level

| Asphalt Level | The variety level of slag gravel (%) | | | | | |
|---|---|---|---|---|---|---|
| % | 0 | 10 | 20 | 30 | 40 | 50 |
| 5 | 66.98 | 67.33 | 66.59 | 64.19 | 65.29 | 58.31 |
| 5.5 | 73.49 | 78.82 | 71.96 | 70.16 | 73.23 | 63.82 |
| 6 | 75.58 | 83.66 | 77.83 | 75.27 | 73.33 | 68.41 |
| 6.5 | 78.57 | 87.87 | 81.02 | 79.05 | 75.05 | 72.33 |
| 7 | 85.12 | 91.26 | 82.96 | 79.34 | 76.86 | 75.31 |

The table is identified VMA value is decreasing as the more of gravel level in the mixture.

### *3.2.3. Flow*

The flow is the implementation from flexibility mixture characteristic, the value of the flow influenced by asphalt level and aggregate distribution.

**Table 10.** Flow Value with Steel Slag Level

| Asphalt Level | The variety level of slag gravel (%) | | | | | |
|---|---|---|---|---|---|---|
| % | 0 | 10 | 20 | 30 | 40 | 50 |
| 5 | 3.10 | 3.13 | 3.33 | 3.53 | 3.56 | 3.63 |
| 5.5 | 3.28 | 3.53 | 3.80 | 4.03 | 4.17 | 4.23 |
| 6 | 3.77 | 3.97 | 4.47 | 4.57 | 4.81 | 4.97 |
| 6.5 | 4.20 | 4.47 | 4.98 | 4.95 | 5.65 | 5.35 |
| 7 | 4.70 | 5.17 | 5.57 | 5.60 | 5.92 | 6.10 |

Table 10 stated that the more steel slag level in the asphalt concrete mixture, the more also value of the flow. This is occurred because the amount of aggregate particels decreased as the slag level percentage in the mixture is increasing which caused the deformation because of load improvement.

## 3.3. The Result of Slag Influence on Mixture Characteristic (Stability, Durability and Flexibility)

### *3.3.1. Slag Influence on the Stability Mixture*

Stability is an ability of pavement layer to carry the traffic load without any permanent deformation like; wave, flow, or bleeding.

**Table 11.** Stability Value with Steel Slag Level

| Asphalt Level | The variety level of slag gravel (%) | | | | | |
|---|---|---|---|---|---|---|
| % | 0 | 10 | 20 | 30 | 40 | 50 |
| 5 | 1198 | 1456 | 1601 | 1927 | 1932 | 1951 |
| 5.5 | 1304 | 1613 | 1862 | 2293 | 2319 | 2325 |
| 6 | 1503 | 1723 | 2049 | 2487 | 2479 | 2483 |
| 6.5 | 1282 | 1426 | 1870 | 2024 | 2049 | 2056 |
| 7 | 1227 | 1369 | 1517 | 1775 | 1833 | 1775 |

Table 11 showed that every stability value fulfilled the requirements. Stability has increased up to the optimum limit; 30% slag, with the asphalt level 6% on 2487 kg.

### *3.3.2. The Result of Slag Influence on Durability Mixture Characteristic*

VIM value influence the durability of the asphalt concrete mixture.

**Table 12.** VIM Value with the Steel Slag Level

| Asphalt Level | The variety level of slag gravel (%) | | | | | |
|---|---|---|---|---|---|---|
| % | 0 | 10 | 20 | 30 | 40 | 50 |
| 5 | 6.14 | 5.175 | 6.624 | 7.470 | 7.322 | 9.557 |
| 5.5 | 5.088 | 4.062 | 5.771 | 6.397 | 6.887 | 8.464 |
| 6 | 4.992 | 3.359 | 4.753 | 5.516 | 6.445 | 7.622 |
| 6.5 | 4.631 | 2.728 | 4.318 | 4.922 | 5.118 | 6.929 |
| 7 | 3.416 | 2.215 | 4.126 | 5.126 | 5.782 | 6.458 |

Table 12 identified the fulfilled slag level that met the requirements is 0% with the asphalt level 5.5% - 7%, 10% slag with asphalt level 5 – 5.5%, 20% slag with asphalt level 6% - 7%, 30% slag with asphalt level 6% – 7%, 40% slag with asphalt level 6.5%then on the level50% slag all of the VIM value failed to meet the requirements.

### *3.3.3. The Result of the Slag Influence on Flexibility Mixture*

Marshall Quotient (MQ) is the divided result between stability and flow. MQ value is shown that the more MQ value, the mixture becomes dense and if it does, the mixture is tend to break, yet, if the mixture is too elastic, it becomes unstable.

**Table 13**. MQ Value with Steel Slag Level

| Asphalt Level | The variety level of slag gravel (%) | | | | | |
|---|---|---|---|---|---|---|
| % | 0 | 10 | 20 | 30 | 40 | 50 |
| 5 | 386 | 464 | 480 | 545 | 536 | 537 |
| 5.5 | 397 | 456 | 490 | 538 | 543 | 549 |
| 6 | 399 | 434 | 458 | 486 | 513 | 544 |
| 6.5 | 305 | 319 | 375 | 384 | 399 | 402 |
| 7 | 261 | 265 | 272 | 291 | 294 | 296 |

Table 13 stated the slag level 0% - 50% has fulfilled the specification from MQ requirements and from this table, MQ value increased as the steel slag level has improvement. However, MQ value decreased after the slag level reach the optimum value; 30% and will keep on decreasing until50%.

The use of Madura's gravel to footing layer on pavement road.

### 3.4. The Result of Footing Layer

**Table 14**. The Requirements of Footing Layer Planning

| Mixture Characteristics | | Concrete Layer | Testing Result |
|---|---|---|---|
| | | WC | AC – WC |
| Void in mixture, VIM, (%) | Min | 3.5 | 3.4 |
| | Max | 5.5 | 7.6 |
| Void in aggregate, VMA, (%) | Min | 15 | 16.98 |
| Void in bitumen, VFB, (%) | Min | 65 | 65.19 |
| Marshall Stability, (kg) | Min | 800 | 1198.77 |
| | Max | - | |
| Flow, (mm) | Min | 3 | 5.6 |
| Marshall Quotient, (Kg/mm) | Min | 250 | 261 |

Marshall test result met the requirements to plan the footing layer on pavement road BASED ON pavement road Manual (revision on June, 2017) Number 04/SE/Db/2017 footing layer thickness 40 mm with tolerance thickness ± 3 mm.

## 4. CONCLUSION

The result of testing and analysing the asphalt concrete mixture characteristic by using the variety of slag gravel level is shown there is improvement on the asphalt concrete mixture which can be explained through the characteristics below:

### 4.1. Stability

Mixture stability which used steel slag gravel has improved up to optimum limit;30%, then, has decreased up to 50% level. The highest stability on asphalt level is on 6 % with the slag optimum level on30%

### 4.2. Fleksibility

Flexibility mixture value stated with Marshall Quotient (MQ). It showed that the value has increased as the slag gravel level has improved in the asphalt concrete mixture up to the highest limit;30% with the asphalt level; 5%, and will be decreased after.

### 4.3. Durability

Durability or preservation cope such a large field; durability correlate with the void in the mixture (VIM) and abrasion value from coarse aggregate mixture, VIM value in this study has increased as the slag gravel level is improved in the mixture, the optimum of durability value occurred on slag gravel level; 30% with the asphalt level 6%.

Marshall's result and mixture composition fulfilled the specification on pavement elastic planning for footing layer.

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| 133 | IJCIET_10_01_133 | IMPLEMENTING SUSTAINABILITY IN EXISTING BUILDING THROUGH RETROFITTING MEASURES | S.M. Che Husin , N.I. Mohd Zaki , M.K. Abu Husain | 1450-1471 |
| 134 | IJCIET_10_01_134 | INCREASING THE EXISTENCE OF SMES IN BANYUWANGI DIGITAL COMMERCE THROUGH DESIGNING DECISION SUPPORT SYSTEM (DSS) FOR BANYUWANGI MALL SITE | A. A. Gde Satia Utama , Izzato Millati , Deddy Kurniawansyah , Pending Puji Dwi Astuti , Yashinta Setyowati | 1472-1481 |

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| 139 | IJCIET_10_01_139 | ANALYSIS OF THE USE OF LAND VALUE ZONE APPLICATIONS (ZNT) FOR MOBILEBASED DATA COLLECTION, WEB-BASED CALCULATION AND REPORTING ON IMPROVING THE PERFORMANCE OF REGIONAL INCOME STAFF | Hafiz Muhammad Noer , Muhammad Arya Priastama Putra , Dicky Kusdian , Sfenrianto | 1515-1522 |
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| 141 | IJCIET_10_01_141 | DYNAMIC ANALYSIS OF 4-LEGGED STEEL TELECOMMUNICATION TOWER | Shwetha Shetty M R , Anusha M , Ashwini A , Rajiv T | 1535-1550 |
| 142 | IJCIET_10_01_142 | ASCERTAINMENT OF THE CHANGE OF THE DUCTILITY IN CORRODED STEEL SPECIMENS BY EXPERIMENT | Antonio Shopov , Borislav Bonev | 1551-1560 |
| 143 | IJCIET_10_01_143 | MODELLING INSTRUMENTS IN RISK MANAGEMENT | Gayvoronska Inna , Bondarenko Svitlana , Bodenchuk Liliya , Krynytska Oksana | 1561-1568 |
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| 155 | IJCIET_10_01_155 | THE EFFECT OF WORKPLACE SPIRITUALITY ON SCHOOL IMPROVEMENT IN CONTEXT SCHOOL CULTURE THROUGH THE WORKAHOLISM | Al Amin Mydin , Abdul Ghani Kanesan Abdullah , Samah Ali Mohsen Mofreh , Aziah Ismail , Muhammad Zuhair Zainal | 1694-1703 |
| 156 | IJCIET_10_01_156 | LINGUISTICS ELEMENTS OF ARABIC LANGUAGE APPLIED BY IMAM SHAFI'I IN ISLAMIC JURISPRUDENCE | Wan Zulkifli Wan Hassan , Nabilah Abdullah , Nazri Muslim , Jamsari Alias , Azizi Umar , Rozmel Abdul Latiff , Nani Rahayu Sallihuddin , Zulkifli Mohamad , Aminuddin Basir , Nasaruddin Yunus | 1704-1711 |
| 157 | IJCIET_10_01_157 | A SOURCE OF LOCAL RADIATION POLLUTION OF NATURAL ENVIRONMENT | V.Z. Burlaenko , L.N. Skipin , E.V. Zaharova , V.S. Petuhova , A.V. Kryzhanovskaya , O.V. Derevianko , Liliya Mukhametova | 1712-1717 |
| 158 | IJCIET_10_01_158 | IMPACT OF MECHANICAL ACTIVATION ON THE PREBIOTIC PROPERTIES OF PLANT BIOLOGICAL RESOURCES | Natalia S. Rodionova , Evgeny S. Popov , Vyacheslav Yu. Kustov , Aleksandr A. Rodionov , Ekaterina A. Pozhidaeva , Natalia A. Rodionova , Andrey A. Dyakov | 1718-1730 |
| 159 | IJCIET_10_01_159 | PREDICTION OF ENGINEERING PROPERTIES OF BASALTIC ROCKS IN JORDAN | Abdulla A. Sharo , Mohammad S. Al-Tawaha | 1731-1739 |
| 160 | IJCIET_10_01_160 | ACCIDENTS AND EMERGENCY FIRST AID FOR SOUTH KOREAN INFANT AND CHILDREN | Min Hyang Park RN | 1740-1744 |
| 161 | IJCIET_10_01_161 | A WRAPPER BASED FEATURE SELECTION APPROACH USING BEES ALGORITHM FOR EXTREME RAINFALL PREDICTION VIA WEATHER PATTERN RECOGNITION THROUGH SVM CLASSIFIER | V. Karunakaran , S. Iwin Joseph , Ravi Teja , M. Suganthi , V. Rajasekar | 1745-1750 |
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| 172 | IJCIET_10_01_172 | MATHEMATICAL COMPUTATION OF WATER QUALITY INDEX FOR THE ASSESSMENT OF AL-HILLA RIVER ECOSYSTEM | I. A. Al-Ani | 1862-1869 |
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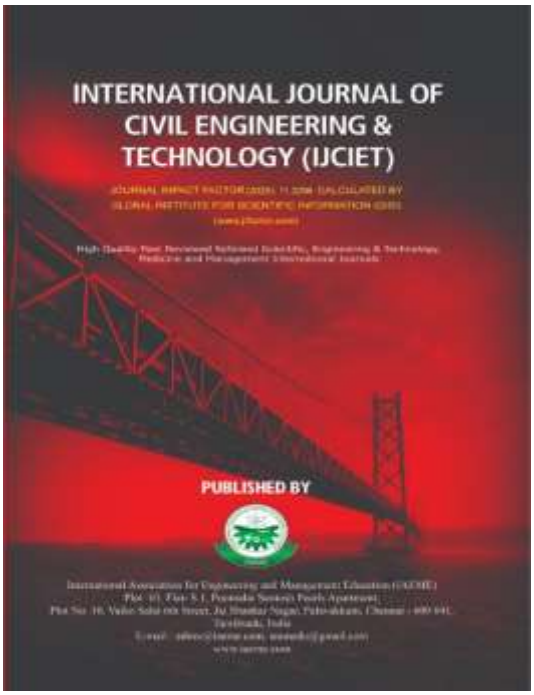


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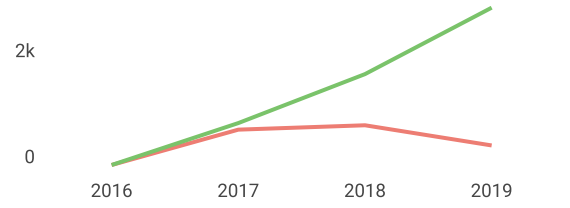


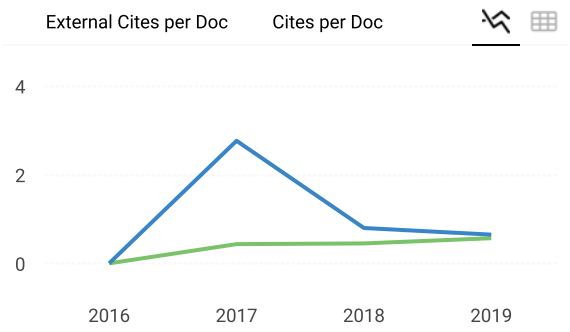


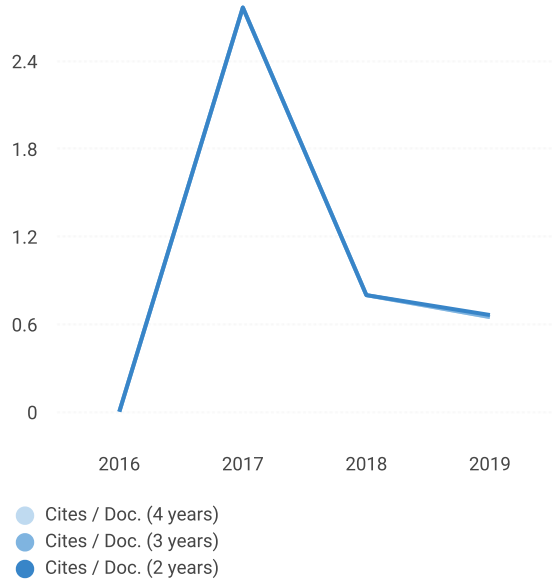


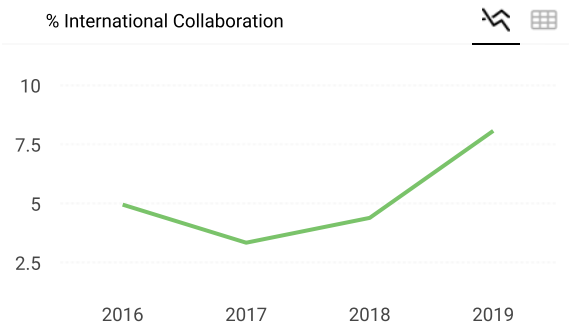


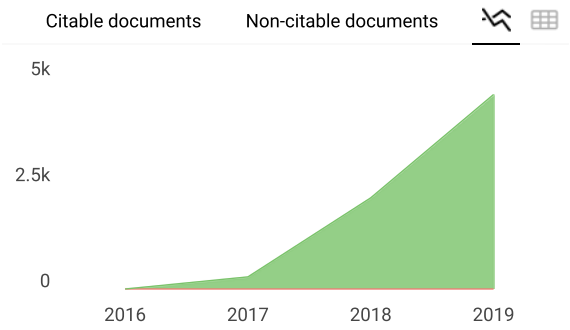


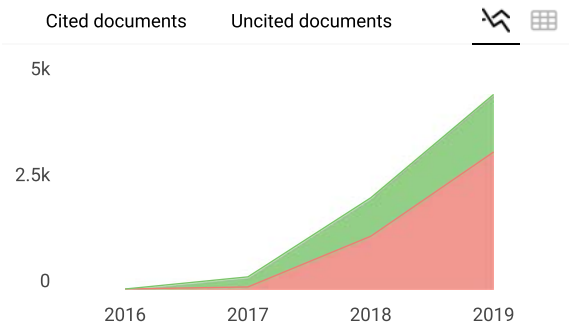



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