Design and properties of asphalt concrete with various plastic waste in dry processed

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Abstract. Plastic is a waste that cannot be decomposed easily, plastic need about a ten to hundreds years to be decomposed perfectly depends on the plastic type. According to CNN, Indonesia is the second largest plastic waste contributor after China with more than 1 million in a minute, 50 percent are just single use then throw away and 5 percent are the truly recycle plastic waste. Along with the current development, there are a lot of innovations to the all things, one of them is substitute the aggregate with plastic, in this thing, plastic will substitute the aggregate pass the ¾ aggregate filters and strained the number 4 aggregate filter substitute with LDPE, PP and PET Plastic each. This research is aimed for evaluating and comparing the effect of adding or substitute the aggregate with LDPE, PP and PET plastics type for designing asphalt concrete. There are four test that related to strength and durability of Asphalt Concrete: Unconfined Compressive Strength (UCS), Indirect Tensile Strength (ITS) test, Cantabro test, and Permeability test, each of them has a value and each of test will be comparing the specimen test whose aggregate is substitute on LDPE, PP and PET. The result of this research show that in the UCS test PP mixture specimen test can hold the vertical pressure 253.41% stronger than PET and 399.12% stronger than LDPE. In ITS test PP mix object 56.29% stronger than PET and 396.90% stronger than LDPE. In the Cantabro test PP has durability 1.33% better than PET and 1.60% better than LDPE and in the Permeability test PP has a better classification to be the Asphalt Concrete Wearing Course with Practically Impervious classification.

1. Introduction
Plastic is a waste that is very difficult to decompose, plastic requires decades or even hundreds of years to decompose completely depending on the type of plastic. Indonesia is the second largest contributor to plastic waste in the world after China with a total of 187.20 million tons. More than one million plastic bags are used every minute, and 50 per cent of the plastic bags are used only once and immediately discarded, only five per cent are completely recycled. Asphalt and aggregates are the main material that must exist in a pavement, asphalt as an aggregate adhesion media that compiles into a flexible pavement that is comfortable to use. Quality improvement needs to be carried out in terms of resilience and stability, reducing asphalt material or adding additional materials or substitute materials on aggregates can also be an option to improve the quality of this pavement. Along with the development of time, innovation in all things also exist, one of them is innovation on highway
hardness. This innovation can be a bridge for quality improvement in pavement. Innovation of substitute materials on pavement can be in the form of plastic, fuel oil or resin. In this study polymer or plastic materials were used. Plastics are one type of commercial product or waste that is widely available in Indonesia. There are also many types of plastic types, namely PETE or PET (Polyethylene terephthalate) [1,2,3], HDPE (High Density Polyethylene), PVC (Polyvinyl chloride), LDPE (Low Density Polyethylene) [4,5], PP (Polypropylene), PS (Polystyrene). In this study, PP seeds and PET plastic seeds will be used from the plastic processing plant CV. Flamboyant Plastic which is located in Mojosongo. Polyethylene is a soft, transparent and flexible film has good impact strength and tear strength. PET has a low absorption of water vapour, as well as absorption of water. PP contains versatile ingredients because it is hard and strong but still has flexibility. PP also provides strong chemical resistance[6]. This platinum PET and PP type is expected to be a substitute for 100% aggregate and make bitumen more resistant to water. This study aims to evaluate and compare the effect of addition or substitute of aggregate with PETE or PET type and PP type plastic on permeability test [7], Unconfined Compressive Strength test using UCS tool, tensile strength test using ITS (Indirect Tensile Strength) , and the Cantabro test to evaluate the resistance to disintegration on asphalt mixture[8].

2. Experimental
The research method used was an experimental method conducted at the Sebelas Maret University Civil Engineering Study Highway Laboratory. The type of data used are primary and secondary data. The tests were performed to the samples that have been produced at optimum bitumen content. Three types of asphalt concrete modified with plastic.
- PP Mixtures with 4.5% bitumen content and 100% replacement of fine aggregates.
- PET Mixture with 5% bitumen content and 100% replacement of fine aggregates
- On plastic waste LDPE plastic only as added by 6% of bitumen content on the pavement mixture was taken from the application of asphalt plastic on the UNS dormitory road carried out by the Center for Research and Development of Roads and Bridges (Pusjatan), Research and Development Agency (Balitbang) and Ministry of Public Works and Public Housing (PUPR).

The samples required for this experiment are presented in Table 1.

| No | Testing                  | AC with PP | AC with PET | AC with LDPE |
|----|--------------------------|------------|-------------|--------------|
| 1  | Indirect Tensile Test    | 3          | 3           | 3            |
| 2  | UCS                      | 3          | 3           | 3            |
| 3  | Cantabro                 | 3          | 3           | 3            |
| 4  | Permeability             | 3          | 3           | 3            |
|    | Total                    | 12         | 12          | 12           |

2.1. Indirect Tensile Test
This test uses the Marshall loading principle with 12.5 mm wide concave loading strip. The loaded cylindrical specimen is then connected in parallel along the diameter plane vertically. This results in a tensile stress perpendicular to the direction of loading and along the vertical plane of diameter, which automatically causes the test object to fail / be damaged along the vertical diameter.

2.2. Unconfined Compressive Strength
The Compressive strength is the ability of the pavement layer to hold the load vertically, expressed in kg or lb. The amount of vehicle load that is channeled through the wheels of the vehicle is the
compressive load received by the pavement, while the loading takes place in various temperature variations due to changes in weather and time. This temperature change will affect the viscosity of asphalt as a binder so that it also affects the compressive strength of the pavement.

2.3. Cantabrian Test
Test cantabro aims to determine the resistance of the pavement mixture to wear using a Los Angeles machine. The specimens which are allowed to stand for 48 hours at room temperature and at least 6 (six) hours before temperature testing must be kept at room temperature. Before the specimen was inserted into the Los Angeles machine drum, it was first weighed to get the weight before being abrasive. Then the specimen was inserted into the Los Angeles machine drum one by one without a steel ball. Los Angeles machines run with speeds between 30-33 rpm as many as 300 rounds. Then the test object is removed and weighed to get the weight after abrasion.

2.4. Permeability test
Permeability is the ability of porous media to drain liquid. Any material that has an empty space between them is called porous, and if the empty space is interconnected, the material will have permeability properties. The size of permeability is denoted as K (cm²) and the permeability coefficient is denoted as s (cm/second).

3. Results and Discussion
This research has the purpose to find out and analyze the results of the UCS, ITS, Cantabro and Permeability tests on a mixture of Asphalt Concrete with the replacement of aggregate through the 1/2 filter and suspended filter no. 4 was replaced with LDPE, PP and PET plastic waste respectively. Of the 4 tests each Asphalt Concrete mixture with the replacement of aggregate with plastic waste compared for each test to find out which plastic waste is the best and can be applied

3.1. Indirect Tensile Test
This test aims to determine the indirect tensile strength of the results of the emphasis on the specimens with kg units using ITS test equipment, after that, it is calculated to find out the strength of ITS with the KPa unit. This test is carried out at room temperature of 25 °C with a speed of 51mm per minute. Table 2 presents the calculations of ITS on asphalt concrete modified plastic mixed specimens. The properties were then illustrated in Figure 1.

| Type of mixtures | ITS (KPa) | Strain (micro strain) | Static Modulus Elasticity (KPa) |
|------------------|-----------|-----------------------|-------------------------------|
| LDPE             | 1,204.21  | 0.0023                | 525,409.297                   |
| PET              | 3,828.70  | 0.01073               | 468,543.70                    |
| PP               | 5,983.74  | 0.00315               | 2,428.40                      |

Figure 1. The ITS Properties of plastic modified asphalt concrete
In the comparison of the tensile strength of the mixture type PP has the greatest tensile strength than the other types of plastic mixture with a large tensile strength of 5983.738 Kpa. In the Mixed Type PET has the highest strain with 0.0107 inversely proportional to the voltage which is relatively smaller than the other types of mixture. From the graph the comparison of PP modulus of elasticity has the greatest modulus of elasticity because it has the largest voltage and a smaller strain which is 5983.7376. On general, the type of PP mixture has the highest tensile strength due to the nature of PP plastic which changes shape to become soft when the heat conditions make the aggregate attachment become more and make the test object denser when after compacting and causes tensile strength to be greater.

3.2. Unconfined Compressive Strength

The UCS test was carried out to determine the vertical compressive strength of a deep pavement supporting the weight. For comparison of the UCS values for each mixture will be presented in Table 3 and illustrated in Figure 2.

Table 3. The UCS comparison for three types of Asphalt concrete

| Type of Mixture | LDPE  | PET  | PP    |
|----------------|-------|------|-------|
| UCS (KPa)      | 2372.24| 3350.26| 11840.37 |

Figure 2. The UCS comparison for three types of asphalt concrete.

The results in the graph show that the type of mixture using PP has the highest vertical compressive strength compared to other types of mixtures with a result of 11840.37. With these results PP is superior in vertical compressive strength rather than LDPE and PET mixture types. The type of PP mixture has the highest compressive strength due to the nature of PP plastic that changes shape to become soft during hot conditions and in conditions it will be composted to make the PP type mixture becomes more dense with less air space, after compacting.

3.3. Cantabrian Test

Cantabile testing is carried out to determine wear or weight loss on specimens expressed in grains. Comparisons of 4 types of mixtures will be presented in Table 4 and Figure 3.

Table 4. The Cantabro Loss comparison for three types of asphalt concrete

| Type of mixture | LDPE | PET | PP |
|----------------|------|-----|----|
| Cantabro Loss (%) | 4.89 | 1.60 | 1.33 |
Figure 3. The Cantabro Loss comparison for three types of asphalt concrete

It can be seen in the graph that LDPE has a high level of weight loss and vice versa the loss of assets of mixed PET and PP specimens has a loss of 1.6% and 1.3%. From the graph PP has a better weight loss rate than other types of mixtures. With more plastic content in PET and PP, the aggregate attachment has more value and causes the cantabro loss value to be smaller, and the nature of PP itself which is easier to soft can better cover and embed the aggregates.

3.4. Permeability
Permeability testing is carried out to determine the ability of water to pass through the pavement in this case in the form of a test object, a comparison of the results of 4 types of mixtures will be presented in Table 5 and Figure 4.

Table 5. The coefficient permeability for three types of asphalt concrete

| Type of mixture | LDPE    | PET     | PP       |
|-----------------|---------|---------|----------|
| Coefficient     | 1.7E-04 | 1.4E-04 | 2.9E-05  |
| Permeability    |         |         |          |

Seen on the PET graph has higher permeability results and is easier to pass through with the results of the permeability coefficient of 0.000141 with the classification of poor drainage. PET has high permeability results because heated PET plastic will tend to be like fibers that make pavement or in this case the test specimen has more cracks to pass through and vice versa PP has properties when heated it will easily soften making when compacting aggregates mixed and attached and make the test object have fewer slit paths.

Figure 4. The coefficient permeability for three types of asphalt concretes

4. Conclusion
In the UCS test the PP Mixed Type has the power to withstand a vertical compressive load of 11,840.37 KPa, PET 3,350.26 KPa and LDPE 2,372.24. In the ITS test, the PP Mixed Type has a tensile strength of 5,983.74 KPa, with PET 3,828.70 KPa, with LDPE 1,204.21 KPa. In the Cantabro
test the mixture type PP has lost weight 1.33%, PET 1.60% and for LDPE 4.88%. In the Permeability test PP has 0.000029 for PET 0.000141 and for LDPE 0.000167.

In the UCS Type PP Mixed test has the highest compressive strength with a strength ratio of 253.42% stronger than PET and 399.12% stronger than the LDPE Mixed Type. In the ITS test the Mixed Type has the strongest tensile strength with a strength ratio of 56.27% stronger than the PET Mixed Type and with a strength ratio of 396.90% stronger than the LDPE Mixed Type. In the Cantabro Loss Test Type of PP Mix have the least weight loss with a PET ratio which has a Cantabro Loss value of 1.60% and LDPE with a Cantabro Loss value of 4.88%. And in Permeability Test PP has a smaller Permeability result than the mixture type LDPE and PET with the classification Practically Impervious. 386.72% smaller than PET and 475.63% smaller from LDPE.

5. References
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