LABORATORY INVESTIGATION OF SKID RESISTANCE FOR STEEL SLAG UTILIZATION AS CHIP SEAL

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Abstract

Slag as waste material of steel-making process has similar characteristics with aggregate that has been widely used in pavement construction. The use of slag as chip seal aggregate to provide skid resistance needs to be analyzed. In this laboratory study, the chip seal samples are made using steel slag and natural aggregate. The bonding materials used are asphalt and epoxy resin. Skid resistance tests for all chip seal samples and also hot rolled sheet pavement without chip seal application are performed using the Portable British Pendulum Tester. The results show the variations of chip seal aggregate weight are inconsistent. The natural aggregate used as chip seal material could produce high skid resistance value of 10.3% higher than that using steel slag. Also the skid resistance of chip seal with the ALD 3 mm are not significantly different with that of ALD 6 mm. Similar results occur on the skid resistance of chip seals using epoxy resin and asphalt.

Keywords: steel slag, waste material, chip seal, the Portable British Pendulum Tester, skid resistance.

Abstrak

Terak sebagai bahan limbah proses pembuatan baja yang memiliki karakteristik yang sama sebagai agregat yang banyak digunakan dalam konstruksi perkerasan. Penggunaan terak sebagai agregat *chip seal* yang memberikan kekesatan perlu dianalisis. Di penelitian laboratorium ini, sampel *chip seal* dibuat dengan memanfaatkan terak baja dan agregat alam. Material pengikat yang digunakan adalah aspal dan resin epoksi. Pengujian kekesatan dilakukan terhadap sampel *chip seal* segel dan perkerasan Hot Rolled Sheet tanpa aplikasi *chip seal* dengan menggunakan alat Portable British Pendulum. Hasil uji laboratorium ini menunjukkan bahwa variasi berat agregat *chip seal* tidak konsisten. Pemanfaatan agregat alam sebagai bahan *chip seal* dapat menghasilkan nilai kekesatan 10,3% lebih tinggi daripada yang menggunakan terak baja. Kekesatan *chip seal* yang menggunakan ALD 3 mm tidak berbeda nyata dengan kekesatan *chip seal* yang menggunakan ALD 6 mm. Hasil yang serupa terjadi pada kekesatan *chip seal* yang menggunakan bahan pengikat resin epoksi dan aspal.

Kata-kata kunci: terak baja, bahan limbah, *chip seal*, Portable British Pendulum Tester, kekesatan.

INTRODUCTION

Skid resistance is resistance measurement of the vehicle sliding or skidding on the pavement surface. It is recognized as an important factor to provide a fair contribution for road surfacing since the road surface should facilitate the friction between vehicle wheels and pavement surface. The most important thing in providing skid resistance is the pavement surface texture and its ability to resist traffic polishing effect. The aggregate polishing is the reduction in microtexture resulting in the smoothing and rounding of exposed aggregates. This process is caused by particle wear on a microscopic scale. It is a common fact that the lower the skid resistance, the higher the possibility of traffic accident to occur, especially in the rainy condition and in the initial rain showers that reduces the skid resistance.

Skid resistance of pavements is the friction force developed at the tire-pavement contact area. In other words, skid resistance is the force that resists sliding on pavement surfaces. This force is an essential component of traffic safety because it provides the grip that a tire needs to maintain vehicle control and to stop in emergency situations. Skid resistance is crucial to prevent excessive skidding and to reduce the stopping distance.

Many methods, which have been applied in many countries, such as America, Australia, Canada, Japan, and United Kingdom, can be used to increase the skid resistance. One of those methods is applying chip seal on the pavement surface. Chip seal is a form of seal coating with an exception that a thin layer of coarse aggregate is spread onto a previously sprayed application of a binder (Lavin, 2003).

In chip seal method, the coarse aggregate is commonly applied. However, waste materials can be used to replace aggregates as chip seal materials, and this method has gained popularity recently. Not only does this method reduce the amount of waste materials that should have been disposed but also it provides construction materials with less costly than materials. Also, the use of waste materials can actually provide value to what was once a costly disposal problem (Wilburn and Goonan, 1998).

Steel slag, as waste material of steel production, has been used widely in road construction because it has high density and hardness similar to those of coarse aggregates. For this reason, steel slag was used in this study as chip seal material. The objectives of this study are as follows:

1. to study skid resistance of chip seals using steel slag and using natural aggregate;
2. to investigate skid resistance of chip seals with different sizes of aggregates;
3. to study skid resistance of chip seal using asphalt binder and epoxy resin; and
4. to compare the skid resistance of pavement surfaces with and without chip seal.

This study is commenced with preparing the materials and equipment that support the laboratory works. The work includes the tests for material characteristics and the preparation of supporting devices. Then, samples made of hot rolled sheet mixture are prepared a mold with a dimension of 25cm x 10cm x 5cm.

The skid resistance of all samples is measured using the Portable British Pendulum Tester (BPT). For each sample, the skid resistance is tested five times (the five tested points are shown in Figure 1). If the skid resistance values obtained are greater than 3 units or more, then the tests have to be repeated until the measurement gives three successive constant readings.

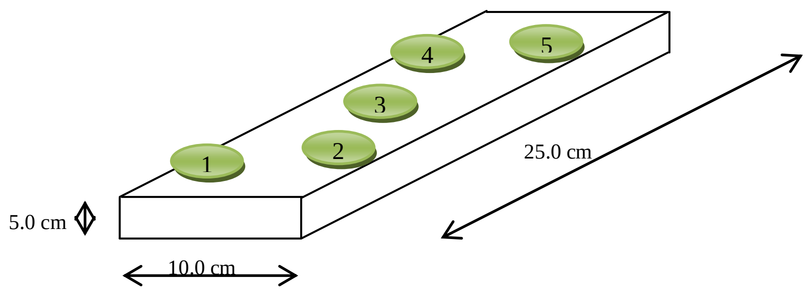

Figure 1 The Skid Resistance tested points

MATERIAL CHARACTERISTICS

Hot rolled sheet wearing course (HRS-WC) investigated in this study consists of coarse aggregate, fine aggregate, filler, and asphalt cement penetration 60 grade. The aggregate data, including physical characteristics and gradation, asphalt data, and the optimum asphalt content of the mixtures are taken from previous studies (Candra, 2009).

Chip seal aggregates spread onto pavement surface are natural aggregates and steel slag. Natural aggregate used as chip seal is taken from Desa Clereng, Kulon Progo, Yogyakarta. From the laboratory test, it is found that the natural aggregate has bulk specific gravity 2.55.

Slag used in this study is waste material of steel production from PT. Krakatau Steel, Cilegon, Banten. From laboratory test, it is known that the slag has specific gravity higher than that of the natural aggregate, i.e. 3.45.

This study investigates the single-size chip seal method with the aggregate size is uniform. The aggregates with the size of 9.5 mm or 10 mm and 6 mm are used as aggregate spreading.

The Average Least Dimension (ALD) for aggregate spreading is referred to Whiteoak (1990). The ALDs for the aggregate size 9.5 mm and 6 mm are 6 mm and 3 mm, respectively.

The loose unit weight is needed to calculate the voids in the aggregate in loose conditions and can be used to calculate the air voids expected between the chips after initial rolling takes place. It is affected by the gradation, shape and specific gravity of the aggregate. The loose unit weight of natural aggregate and steel slag in this study are 1.368 gr/cm^3 and steel slag is 1.715 gr/cm^3, respectively.

The wastage factor (E) is to account for whip-off and handling. A reasonable value for this factor is 5 % for low volume and residential type traffic roads and 10 % for higher speed roadways. In this laboratory study, the wastage factor is assumed to be 0 %.

The aggregate spread rate is used to determine the amount of aggregate needed to create an even, single coat of chips on the pavement surface. The amount of 2 different types of chip seal aggregate and sizes is shown in Table 1.

Table 1 Aggregate Spread Rate

Aggregate spread rate	Natural aggregate (kg)		Steel slag (kg)	
	ALD: 6 mm	ALD: 3 mm	ALD: 6 mm	ALD: 3mm
Per m^2	8.208	4.104	10.29	5.145
Per 0.025 m^2	0.205	0.103	0.257	0.129

The aggregate spread is considered as 100 % of the weight of chip seal aggregate. Two other variations of aggregate spread rate using 90 % and 75 % of chip seal aggregate weight are made to evaluate if they make significant difference of skid resistance values.

The two types of binder used in this study are asphalt and epoxy resin. The void in the loose aggregate is determined using the following equation:

$$V = 1 - \frac{W}{1000G} \quad (5)$$

with: W is the loose unit weight (kg/m3),
G is bulk specific gravity of the aggregate.
For natural aggregate, V is 0.46 and for steel slag, V is 0.50.

The pavement adjustment factor (PS) is -0.05. It is also assumed that the pavement has a new surface layer and the residue asphalt content (R) is 65 % or 0.65. The asphalt spread rate is shown as in Table 2.

Table 2 The Asphalt Spread Application

Asphalt spread rate	Natural aggregate (liter)		Steel slag (liter)	
	ALD: 6 mm	ALD: 3 mm	ALD: 6 mm	ALD: 3mm
Per m^2	1.367	0.645	1.492	0.708
Per 0.025 m^2	0.034	0.016	0.037	0.018

Epoxy resin is also used as another binder to bond chip seal aggregate and pavement. The references for calculating epoxy resin spreading have not been available yet. For this reason, the amount of epoxy resin is assumed to be the amount that bond 2/3 of the ALD of chip seal aggregate with pavement. The amounts of epoxy resin spreading for the ALD 3 mm and 6 mm are 55 gram and 110 gram, respectively.

RESULT AND DISCUSSION

The skid resistance is evaluated for twenty-four different samples of natural aggregate and steel slag as chip seal that are bonded with asphalt and epoxy resin. The skid resistance value from laboratory test has to be corrected for the effect of temperature. Since the tests have been conducted in the laboratory with the temperature of 25 ^{o}C, thus the correction made from temperature 25 ^{o}C to 20 ^{o}C.

All skid resistance test results from all laboratory samples and also from existing surface pavement after correction to temperature of 20 ^{o}C can be summarized in one chart that is shown in Figure 2.

Figure 2 shows that the skid resistance value of three variations (100 %, 90 %, and 75 % of chip seal weight) of each chip seal aggregate show inconsistency. The highest skid resistance value of natural aggregate ALD 3 mm is occurred in the utilization of 100 % chip seal aggregate spreading weight and in the utilization of 90 % chip seal aggregate spreading weight for steel slag ALD 3 mm, and there is no difference whether they are bonded with asphalt or epoxy resin.

Inconsistency is found in the skid resistance value of the chip seal aggregate with the ALD size 6 mm. The highest and the lowest numbers of skid resistance occur randomly among the three variations of chip seal aggregate weight.

Figure 3 shows that generally the skid resistance value of natural aggregate is higher than that of steel slag. A comparison analysis is performed for samples of natural aggregate and steel slag that have similarity of the ALD size and bonding material. Since the skid resistance of some samples indicates inconsistency, then the comparison is performed for 100% chip seal weight only.

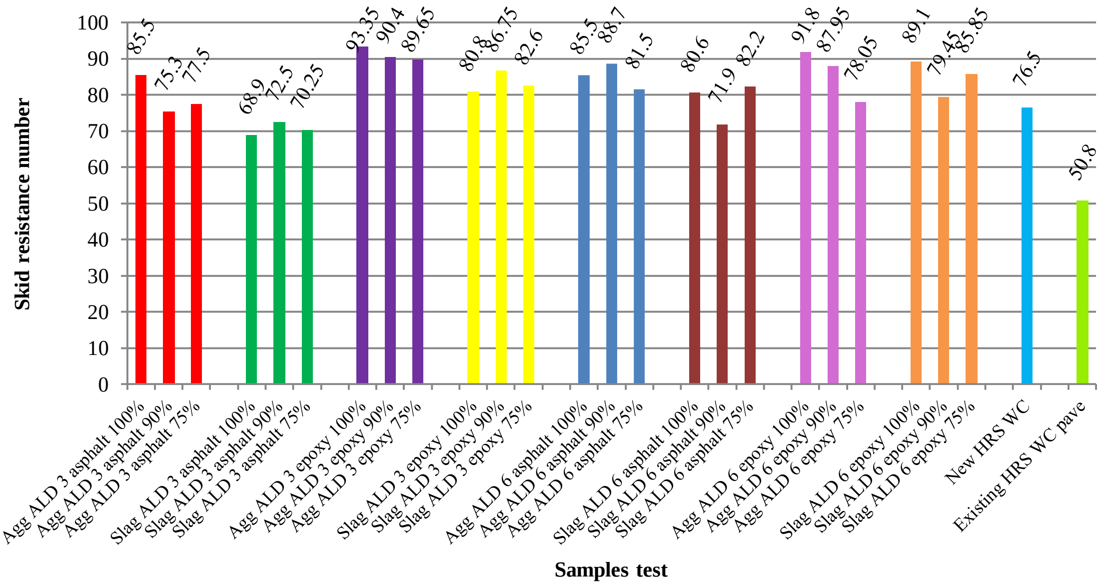

Figure 2 Skid Resistance Number of Samples and Existing Surface Pavement

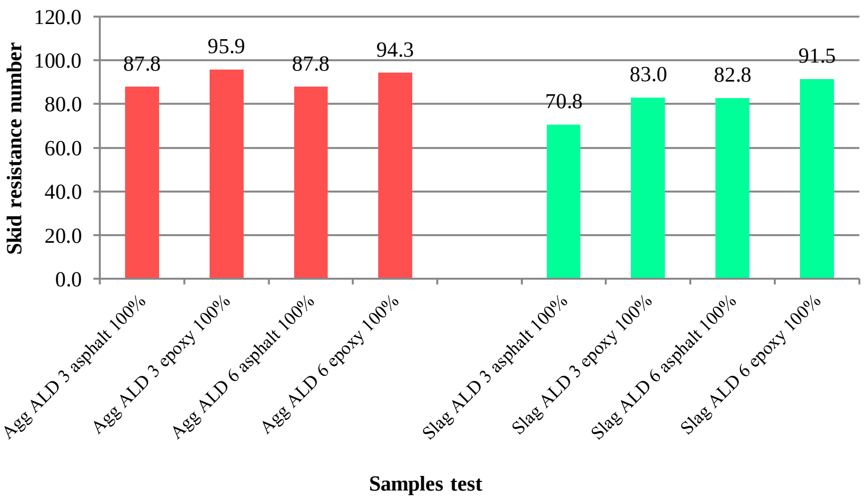

Figure 3 The Skid Resistance Value Of The Difference Chip Seal Aggregate

Figure 4 shows that the natural aggregates tend to have higher skid resistance value than steel slag. The skid resistance mean value of natural aggregate has 10.3 % higher than that of steel slag. Statistical analysis is also conducted the result concludes that the skid resistance value of chip seal using natural aggregate is significantly higher than that of using steel slag. The possible explanation for this is that the natural aggregate has more irregular micro-texture than the steel slag. The mean of skid resistance of chip seal using the ALD 6 mm is 5.27 % higher than that of using the ALD 3 mm. Statistical analysis performed also support this findings.

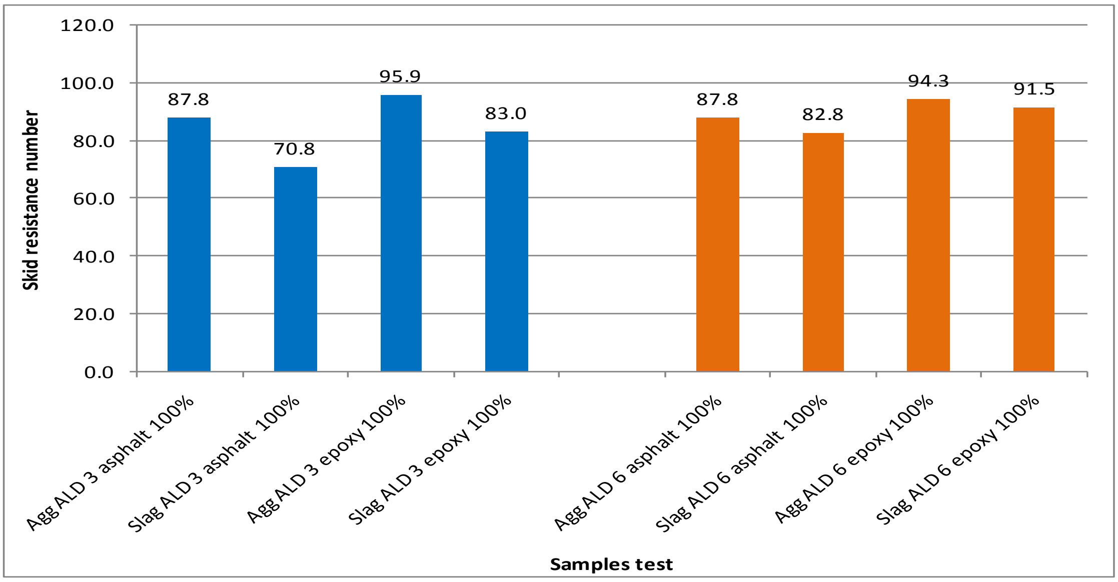

Figure 4 The Skid Resistance Value with Different ALD

Figure 5 shows that skid resistance value of chip seal bonding with epoxy resin tends to have higher value than that of with asphalt. Chip seal bonding with epoxy resin has the skid resistance value 9.76% higher than that with asphalt. However, statistical analysis fails to confirm this result, meaning that the skid resistance value of chip seal aggregate bonding with epoxy resin are not significantly different than that bonding with asphalt.

Figure 6 shows that the skid resistance value after calibration for HRS-WC sample made in the laboratory is 78.6. All skid resistance number of chip seal samples are above 78.6 except for chip seal sample using steel slag ALD 3 mm bonding with asphalt, which has skid resistance value of 70.8. It is 9.9 % lower than skid resistance of HRS-WC laboratory sample. The statistical analysis is conducted to test the hypothesis meanwhile the skid resistance of natural aggregate and/or steel slag has produced higher value than has the skid resistance of HRS-WC sample without chip seal application in laboratory.

Statistical analysis shows that chip seal with the utilization of natural aggregate has produced higher skid resistance value than the sample of hot rolled sheet pavement without chip seal application. The mean value of skid resistance chip seal using natural aggregate is 14.1 % higher than that of the new sample of HRS pavement.

The utilization of steel slag as chip seal aggregate indicates that the skid resistance of pavement with chip seal using steel slag and that without chip seal application shows that they are not significantly different, although the skid resistance of existing pavement is the lowest, i.e. 52.2. This is possible because the existing road has been in service for many years, causing the pavement surface has small skid resistance value.

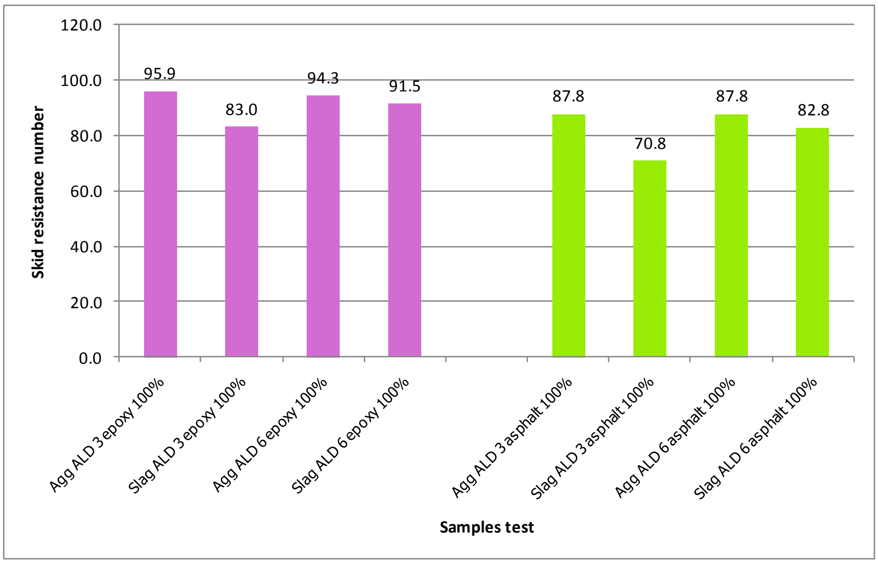

Figure 5 The Skid Resistance Value with Different Bonding Materials

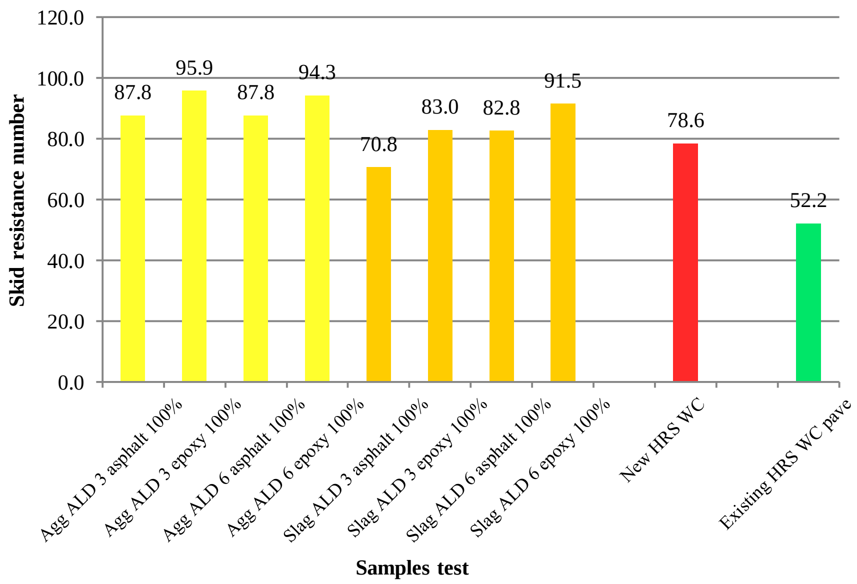

Figure 6 The Skid Resistance Value of Laboratory Samples and Existing Road Pavement

CONCLUSIONS

The conclusions from this sudy can be summarized as follows:

1. Chip seal using natural aggregate produces skid resistance value of 10.3% higher than that using steel slag.
2. The skid resistance of chip seal with the ALD 3 mm are not significantly different with that with the ALD 6 mm. This result is similar with the chip seals using epoxy resin and asphalt.
3. The application of chip seal using natural aggregate produces higher skid resistance value than those of new samples of HRS pavement and existing pavement.

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