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Experimental Evaluation of Cement Replacement Fillers on the Performance of Slurry Seal

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Abstract. Reducing the level of roads service is a process that starts from the first day of the operation of road and the slope of deterioration curve of road sustainability becomes faster with the passage of time. After building the road, adopting an economic approach in order to maintain the road is very important. Slurry seal as one type of protective asphalts that works by sealing inactive cracks of the road and increasing skid resistance is the most effective types of restoration with environmentally friendly behaviour. Fillers are responsible for adjusting set time in slurry seal. Cement is the most common filler used in slurry seal. Cements having suitable properties as a filler, has a very energy demanding manufacturing process and a notable amount of energy is used for manufacturing cement in the country annually. On the other hand, manufacturing process and application of cement have increased levels of pollutant gases, followed by significant environmental pollution. So in this study other options as a filler such as hydrated lime, stone powder and the slag from iron melting furnace were compared with two common types of cement (Portland and type-v cement) in the mixtures of slurry seal by wet abrasion and cohesion tests. Results indicated that, in both tests, lime and slag fillers had behaviours close to the cement filler.

1. Introduction

Increasing advances of mixing materials methods, emulsions and equipment, slurry seal was known as one of the most applicable and economical types of protective asphalt. Nowadays, scope of using this type of asphalt has expanded from rural roads to urban roads and airport runways CPM 2015, [1].

Slurry seal is used for rehabilitation of pavements damaged by weather factors. Also, specific type of a slurry seal increases surface friction of road and safety. Additionally, slurry seal reduces the effects of oxidizing or aging. Slurry seal can also create a visible surface and can be used to fill non-structural cracks of road. It should be noted that slurry seal is not suitable for eliminating cracks which arise from the structural problems such as alligator cracks, [2]. Weather conditions of slurry seal at the time of construction should be at last 10° C and also until one day after applying, reducing the temperature to the freezing point of water should not be possible because disposal water from the emulsion is damaging slurry seal, [3]. Type of the used filler should be selected according to the time of preparing the road for users and the needed time from making a mixture until its application. Filler
that creates an early curing can disturb applying process with a consistency decline. So selection of the suitable filler needs a correct engineering judgment of projects and facilities, [2].

2. Research background
Dalirpour and Goli [4] assessed cohesion of a limited sample of slurry seal mixture and concluded that using a slurry seal without adding a filler could increase initial curing time up to five times that is a criterion to open road traffic. It was also observed that the performance of the cement was better than lime. Oikonomou [5] has investigated the effect of different filler types on slurry seal. In this article, he had added 2 percent of different types of filler to slurry seal mixture with type 3 aggregate size and had replaced it with cement because of excessive consumption of energy during the manufacturing of cement. In his researches, he noted that between different types of fillers, results of cement were better than other materials such as ashes, cement and stone soils. Gujar [7] have studied the effect of hydrated lime filler. Their researches were on slurry seal with polymer modified asphalt emulsion (micro surfacing) and they have done consistency, cohesion and wet abrasion tests on made mixtures. The amount of filler in the made samples was 1.5 percent of the gravels dry weight and the results have showed that hydrated lime has a less cohesion time and also performance of the cement is better in the wet abrasion test. In this study, many parameters such as cohesion, abrasion resistance and skid resistance have been investigated.

3. Manufacturing Slurry Seal
Slurry seal is a mixture of aggregates, emulsified asphalt, filler and other additives. Three types of aggregates were used in slurry seal for various applications and it was built and performed by machines in the location project. During time of installation, suitable amounts of aggregates, emulsified asphalt and filler were mixed together in the mixing tank of the machine and simultaneously mixed by spraying water. Prepared slurry seal mixture was carried to the spreader box to be implemented on the road. Each component of the slurry seal is described in the following subsections.

3.1 Aggregates
Aggregates used in this article under the title 6-0 have been taken from the main source in west of Tehran (Garmdareh). Garmdareh is one of the most important sources of aggregates of projects that have been performed in Tehran.

| Test | Test Method AASHTO | Test Method ASTM | Specification | Test result | Conclusion |
|------|--------------------|------------------|---------------|-------------|------------|
| Sand Equivalent Value of Soils and Fine Aggregate | T 176 | D 2419 | 45 Minimum | 51 | OK |
| Soundness of Aggregates by Use of Sodium Sulphate of Magnesium Sulfate | T 104 | C 88 | 15% Maximum | 8% | OK |
| Resistance to Degradation of Small-Size Coarse Aggregate by Abrasion and Impact in the Los Angeles Machine | T 96 | C 131 | 35% Maximum | 30 | OK |

1 This test was necessary for gravels used to build micro surfacing, but this test also was done because of similarity of structural of these two mixtures and quality assessment of gravels health.

2 The abrasion test is run on the parent aggregate.
After taking aggregates, as it is observed in Table 1, their physical and chemical properties were evaluated to check their quality in mixtures of slurry seal. As seen from Table 1, used aggregates had to have physical and chemical necessary specifications. But their gradation should be changed because of the observations from Figure 1.

![Figure 1](image1.png)

**Figure 1.** Comparison of gradation of present gravels with standard gradation of slurry seal

Considering that in this research gradation 1 was selected as slurry seal aggregates type, so gradation of the mixture was built as observed on Figure 2 due to the range of gradation noted in ISSA standard.

![Figure 2](image2.png)

**Figure 2.** The graph of selected gradation for mixtures with type I

### 3.2 Emulsion bitumen

In this article, asphalt emulsion used for making slurry seal mixtures was type CSS-1h which was cationic emulsified bitumen. Percentage of bitumen residue was selected to be 15% based on gradation of aggregates that is in accordance with the range listed in the ASTM D3910 standard. The basic bitumen used for making emulsions was also penetration grade 60/70 produced by J Oil Company in Yazd city.

### 3.3 Water

Water was used to improve workability of mixture in implementation and production. As pollution of the water can cause an unpredictable breaking of the emulsion, using the water must be careful.
Consistency of the product should be set and then it was moved 2 to 3 cm on the test plate. More movement of product makes it difficult to reach a suitable thickness and maintain slurry-seal on the surface of the road and less movement than the mentioned amount causes difficulty in implementation. In Table 2, emulsion dilution percentage by water can be seen that is obtained using consistency tests in the laboratory:

Table 2. Percentage of water added to the mixture for obtaining a suitable consistency Aggregate Type I with 15% bitumen

| Emulsion dilution percentage | Mixture movement | Result |
|-----------------------------|-----------------|--------|
| 70                          | 3.5             | Wrong  |
| 50                          | 2.4             | OK     |
| 30                          | 1.1             | Wrong  |

3.4 Filler
Filler as an additive in slurry mixture is responsible for setting curing time. In this article, effects and behaviours of different types of fillers in slurry seal mixture are investigated. Fillers used in this article are cement, cement type 5, hydrated lime, ash slag and stone powder. Used slag ash was produced by Isfahan Steel Factory. Used cements were selected from Borujerd Cement Factory.

4. Tests
4.1 Cohesion test
Cohesion test was performed to determine the curing speed and consistency of the mixture, as well as to calculate the needed time that should be prevented from passing traffic. These tests were performed at 20, 30, 60, 90, 150, 210, and 270 minutes after making the mixture. The results of different fillers examined in the cohesion test at various times can be observed in Figure 3:

Fillers after construction cause a very fast increase of cohesion during first fifty minutes as seen from Figure 3. After that, the slope of the curves is decreasing. It means that the effect of different fillers in strength gaining is reduced.

![Figure 3. Effect of different fillers on the adhesion test results](image-url)
As can be seen from Figure 3, after long time resultant cohesions will desire a certain value irrespective of the type of filler. Stone powder and cement increase the cohesion of mixture with less and more gradient than other types of filler, respectively. Hydrated lime at the beginning of construction of cement increases the cohesion with a gradient similar to cement but after a short time loses its capability for increasing the cohesion. Ash slag increases the adhesion with a slow gradient at first, but after a short time increases its cohesion speed and, its diagram will be placed very close to Portland cement shortly after making.

4.2 Wet Abrasion test

In this test, samples with different fillers were first made in the mould of the device and then the samples were dried and weighed. Afterwards, they were placed in water bath for 1 h and were subsequently eroded for 5 minutes. After abrasion, the samples were dried and weighed. Weight loss during the abrasion should be a digit less than 807 g/m² after converting abrasion surface to square meters. Figure 4 shows the results of this test on samples with different fillers.

As seen from Figure 4, a change in the type of filler can change the aggregate loss rate in the wet abrasion test. In this test as well as the cohesion test, stone powder has a weaker effect compared to the other types of filler. Poor result of stone powder is because of the consistency of the mixture is obtained later by using the stone powder and creates less cohesion with aggregates. Cement types 2 and 5 are the best fillers in terms of aggregates storage. Slag ash in tests provided better results than lime and stone powder and its behaviour is very close to the cement.

5. Conclusions

Following conclusions can be drawn based on the experimental results:

1. Cement leads to the rapid curing of slurry seal product in the cohesion test and prepares the road for traffic faster than products made from other types of filler.
2. The curing time for stone powder is long compared to the other types of fillers.
3. The lime causes a fast increase in the curing of mixture at first, but its strength is reduced with time and the slope of curing is slowly increased. Slag ash slowly increases the curing of mixture at first and its strength is increased with time.
4. All made mixtures have the abrasion figure less than 807 grams per square meter that means the feasibility of making the slurry seal is possible with materials in the country.
5. Among the different types of fillers, abrasion rate of mixtures made by cement was less than that made with other types of fillers.
6. Addition of 50% water for gradation type I results in a proper consistency for performing slurry seal.
7. Both cohesion and wet track test results show that hydrated lime and fly ash can be replaced with cement because their results are similar.

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