EFFECT OF FILLER AND BITUMEN EMULSION TYPE ON SET TIME AND CURE TIME OF SLURRY SEAL

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ABSTRACT

This paper presents a laboratory investigation to compare three types of mineral filler on the set time and cure time of slurry seal, based on two types of bitumen emulsion. Testing indicated that using Type V (5) Ordinary Portland Cement (OPC) as the mineral filler in slurry seal shows more reduction in curing time when compared to other fillers. In addition, it was found during the consistency test that the higher the percentage of mineral filler, the greater the resulting percentage of water content in the asphalt. The cone-consistency test showed that increasing the proportion of mineral filler in the slurry seal will lead to an increase in water content.

Keywords: Preventive Maintenance, Bitumen, Slurry Seal, Emulsion

1. INTRODUCTION

Preventive maintenance, such as the use of asphalt surface seals, is the main strategy for cost-effective treatments to an existing roadway system and its appurtenances. This strategy preserves the system, retards future deterioration and maintains or improves the functionality of the system without increasing its structural capacity [1]. Asphalt surface seals are defined as slurry seals, micro surfacing, and chip seals. Various types of asphalt seals are applied to asphalt concrete pavement surfaces to renew skid resistance, fill ruts, retard raveling, restore ride quality, and reduce intrusion of surface water and to improve appearance [2].

Slurry seal mixtures, as described in ASTM D3910 [3], are mixtures of fine aggregates, with or without mineral fillers or mixing water, and uniformly mixed with emulsified bitumen [3]. Slurry seal is generally considered to be the most promising technique for achieving cheaper, faster and improved solutions to various functional failures of deteriorated pavements, such as stripping, raveling, excessive wear and low surface skid resistance [4]. The service life of a slurry seal depends mainly on the selected material, design effectiveness, placement method and prevailing environment and traffic conditions [5].

The objective of this study is to examine the effect of three types of mineral filler and two types of bitumen emulsion on the performance of the slurry seal, and to define an optimum mix ratio.

2. Pavement Preventive Maintenance (PPM) – An Overview

Several highway agencies have successfully employed preventive maintenance strategies for both low and high volume roads. Several treatment types fall within the remit of preventive maintenance, such as [1].

- Crack treatment
- Fog seal
- Chip seal
- Thin hot mix overlays
- Slurry seal and micro surfacing

A PPM program requires a periodic application of the treatment, as shown in Fig. 1 [1].

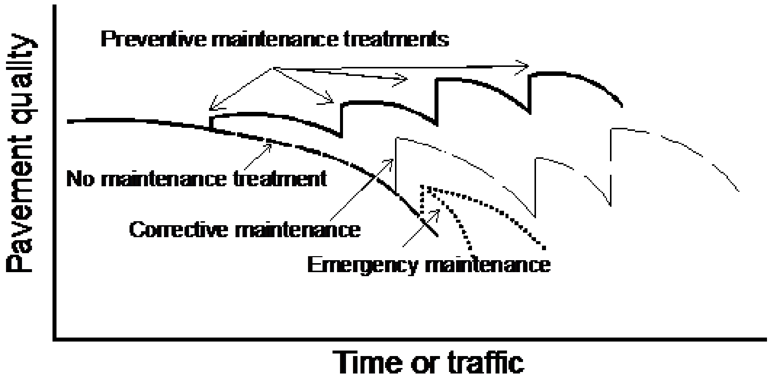

Figure 1 Performance of material treatments applied to pavements with different conditions

During the literature study, it was noted that timing is crucial in preventive maintenance, in that it should be performed before a failure actually occurs. Several distress types contribute to pavement failure, some of which can be corrected with preventive maintenance, and others where the treatment serves as a corrective or emergency measure. Flexible pavements subjected to structural distress, such as fatigue cracking, are not candidates for preventive maintenance. Other causes of distress, such as weathering and raveling, may be entirely corrected with a preventive maintenance treatment [1, 6].

Maintenance of pavements consists of a set of activities directed toward keeping the structure in a serviceable and functional state. Proper selection of maintenance type and program is crucial to increase the serviceable life of any pavement. Slurry seal and micro surfacing are the most well-known and commonly used maintenance techniques throughout the world. As described, slurry seal is a prolific surface maintenance method because it is cost-effective, extends the life of the pavement, is high-quality and improves the road handling characteristics [7, 8].
In brief, the application of slurry seal is an effective method for serving the following purposes [7].

- To inhibit the flow of moisture into the subgrade through the existing pavement.
- To fill surface voids, cracks and minor depressions in the pavement.

- To retard further oxidation of the existing pavement.
- To provide an anti-skid surface at a moderate cost.
- To achieve the above objectives without causing the problems that arise from build-up at curbs, loose aggregate, asphalt bleeding, and the atmospheric contamination which may accompany conventional chip or sand sealing and hot-mix.

The highway operations research branch of the Strategic Highway Research Program (SHRP), initiated the 'Specific Pavement Study-3' (SPS-3). The SPS-3 experiment was designed to evaluate the effectiveness of different maintenance treatments on asphalt pavements, which included thin asphalt overlays (approximately 3.2cm in thickness), slurry seals, crack seals, and chip seals. The results of the study showed that the probability that a failure would occur was two to four times higher for the sections that were already in poor condition when the treatment was applied, than those sections that were in good prior condition. The median survival times for thin overlays, slurry seals, and crack seals were 7, 5.5, and 5 years, respectively [9].

Another study was performed to investigate the permeability of asphalt concrete. The study indicated that a surface seal can retard oxidative hardening of an underlying asphalt concrete layer by 0 to 2 years, depending on the situation. The research suggested that most of the oxidative aging in the upper stratum of an asphalt concrete pavement occurs during the first four years after construction. After this period, the asphalt aging rate decreases significantly. Therefore, for a surface seal to significantly delay oxidative hardening of the underlying pavement, it must be placed during the first two years of the pavement's life [2].

3. Experimental Study

3.1. Materials

3.1.1 Aggregate

The aggregate used for this study was produced from crushed local limestone. The most important characteristics determined by standard tests are shown in Table 1.

Table 1 Characteristics of Limestone Aggregate

Test	Standard tests	Result
Sand equivalent, %	ASTM D 2419	58
Bulk specific gravity (coarse), gr/cm^3	ASTM C 127	2.59
Bulk specific gravity (fine), gr/cm^3	ASTM C 128	2.32
Water absorption (coarse), %	ASTM C 127	0.67
Water absorption (fine), %	ASTM C 128	2.10
Los Angeles (L. A.) abrasion, %	ASTM C 131	25.28

The gradation curves of used aggregate are within the middle limits of the three types of grading requirements, which are all recommended by the International Slurry Surfacing Association (ISSA) shown in Fig. 2 [10].

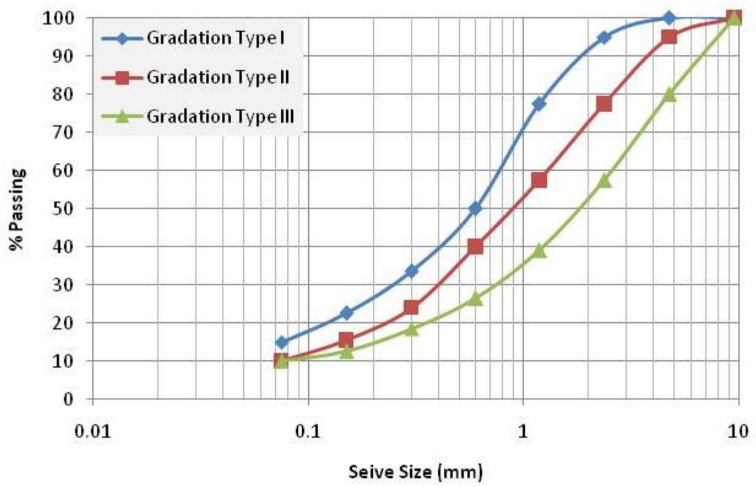

Figure 2 Aggregate gradations for ISSA types

3.1.2 Mineral Fillers

The fillers used in this research were:

- Two types of Ordinary Portland Cement (OPC): Type 1-425 and Type V
- Hydrated Lime

3.1.3 Bitumen Emulsion

Two types of emulsion were used:

- Slow set cationic emulsified bitumen type (CSS-1h)
- Quick set cationic emulsified bitumen type (CQS-1h)

According to ASTM D 2397, the characteristics of these emulsions are shown in Table 2 [11].

Table 2 Properties of Bitumen Emulsion

Test	Result
Content of the asphalt residue,(%)	62
Water content, (%)	38
Viscosity, Saybolt Furol Viscometer (25$^{\circ c}$), (Sec)	25
Particle charge	positive

3.1.4 Water

Regular potable water was used in this research.

3.2 Mix Design and Test Methods

The mix design was performed according to ASTM D 3910 and ISSA specifications [3, 10]. The proper ratios of mineral filler, water and asphalt emulsion to the dry weight of the aggregate shall be determined during the laboratory sessions. The main objectives are to test the selected materials for quality, to construct a suitable slurry seal mix design and to check the cone-consistency, set time, cure time and the wet-track abrasion loss of the slurry seal [3, 4]. The first step was to carry out premixing of the water, to enhance the surface properties of the aggregate. Subsequently, the optimum proportions of aggregate, asphalt emulsion, mineral filler and water were determined using the cone-consistency test readings. These proportions were designed to give specified consistency to qualify the field workability and flow conditions. Set time and cure time were then determined by analysis of curing specimens [4].

4. Results and Discussion

The results obtained from the use of the various specified fillers in the slurry seal are discussed in relation to the following tests:

4.1. Consistency Test

This test method is used to determine the proper consistency (mix design) for a slurry seal mixture. The consistency test should be performed as a method of determining the optimum mix design in terms of the proper consistency for pavement surface placement. An allowance of 2 to 3 cm is usually considered to be the consistency required for a workable field mix [3].

The results of cone-consistency test water for different types of aggregate gradation and addition of several fillers, with varying percentages of bitumen emulsion content in slurry seal are presented in Table 3.

Table 3 Cone-consistency Results for different Mix Types

Filler type	Gradation type	Emulsion, (%)	Pre mix water, (%)									
			4	5	6	7	8	9	10	11	12	13
OPC (V)	I	16	-	-	-	-	-	13	-	23	-	48
	II	13	-	-	7	-	-	21	-	-	50	-
	III	12	-	18	25	-	-	-	55	-	-	-
OPC (1-425)	I	16	-	-	-	-	-	10	-	25	-	55
	II	13	-	-	-	12	-	22	-	-	50	-

	III	12	11	-	24	-	48	-	-	-	-	-
Hydrated Lime	I	16	-	-	-	-	-	-	15	-	27	41
	II	13	-	-	8	-	-	-	24	35	-	-
	III	12	-	14	-	27	-	-	-	-	56	-
No Filler	I	16	-	-	-	15	-	-	29	34	-	59
	II	13	-	13	-	-	26	-	39	-	-	-
	III	12	17	22	-	-	-	40	-	-	-	-

- No results for this content

Fig. 3 shows the results of the consistency test for types of aggregate gradation with different fillers. By analyzing figure 3, it can be seen that adding mineral fillers to slurry seal will lead to an increase in water content, and subsequently the seal will retain workability.

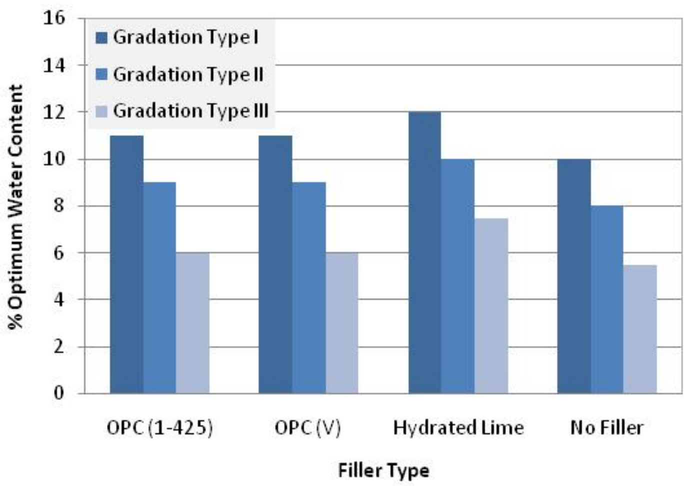

Figure 3 Results of consistency test

4.2. Set Time Test

This test determines the time required for the slurry seal to reach its initial set, with the paper blot method. A properly designed slurry mix should be set at the end of 12 hours [3]. The results in this section have been split into two categories based on two types of bitumen emulsion. These are shown in Figs. 4 and 5.

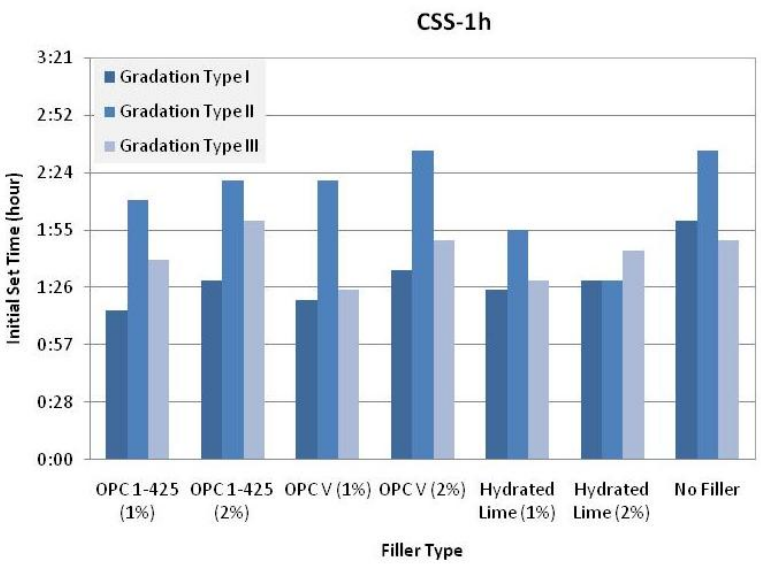

Figure 4 Results of set time test with CSS-1h emulsion

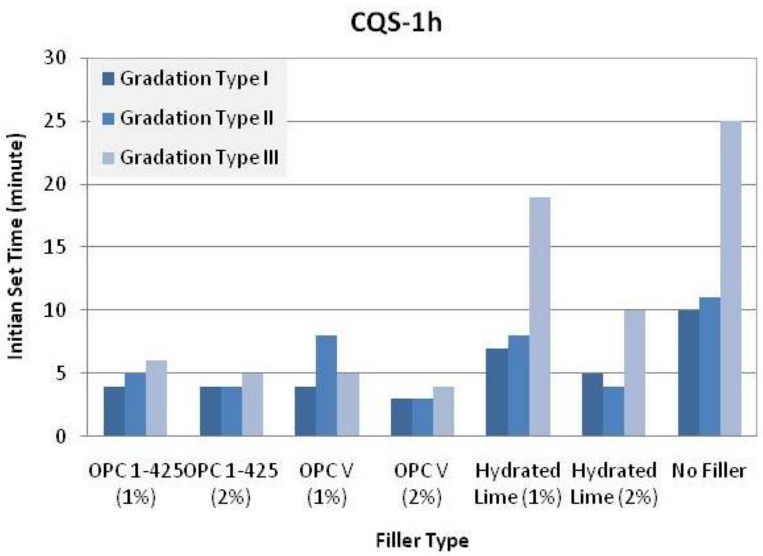

Figure 5 Results of set time test with CQS-1h emulsion

From the figures above, one can see that adding OPC (whether type 1-425 or type V) as filler in slurry seal in most cases has a significant effect on decreasing the set time. Unless for gradation type II, it is observed that adding 1% OPC (type 1-425 or type V) lead to minimum decrease in set time with the mix incorporating the CSS-1h emulsion, Also adding 2% OPC shows minimum result in set time when using the CQS-1h emulsion.

4.3. Cure Time Test

This test is used to determine the initial cohesion of the slurry seal mat, and its resistance to traffic. A properly designed slurry seal mix should be completely cured 24 hours after placement. A cohesion testing device (torque measurement system of the slurry seal) is used to measure cure time, as shown in Figure 6. The time required to reach a constant maximum torque, or the time for the rubber foot to ride freely on the slurry seal sample without any aggregate particles being dislodged, is recorded as the cure time [3].

Figure 6 Photograph of cohesion test device

The results of this test are shown in Figures 7 and 8. It can be observed that for the mix with 2% OPC type V as filler, the lowest cure time is achieved.

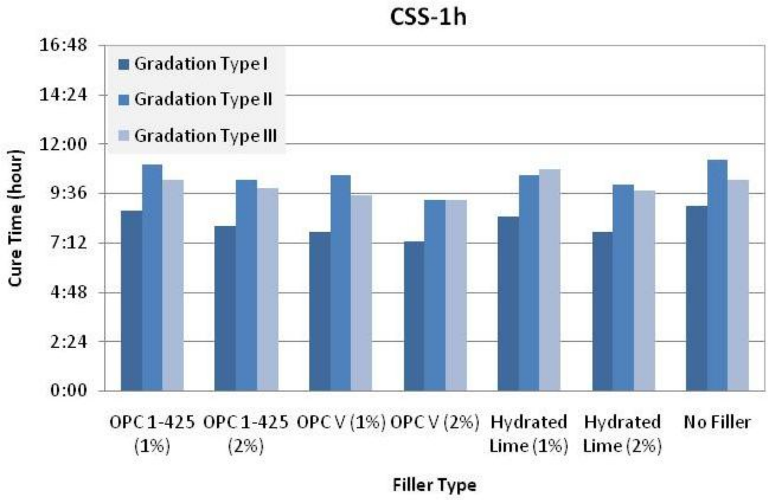

Figure 7 Results of cure time test with CSS-1h emulsion

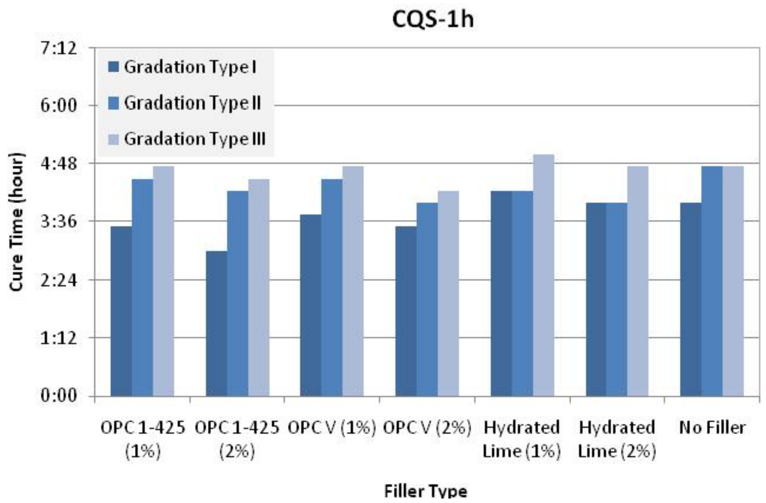

Figure 8 Results of cure time test with CQS-1h emulsion

5. Conclusion

This study was carried out to investigate the effect of the filler type on the performance of slurry seal, and also examines the results with regard to two types of emulsion. The laboratory tests as determined in ASTM and ISSA standards were performed on the slurry seal specimens. On the basis of the findings of these experiments, the following conclusions can be drawn:

- The cone-consistency test showed that increasing the proportion of mineral filler in the slurry seal will lead to an increase in water content, which in turn leads to improved mix workability retention.
- The initial set time for the slurry seal mixture decreases as the mineral fillers are added. The mixture made with quick set emulsion (CQS-1h) and OPC filler showed the lowest initial set time under 10 minutes which in most cases around 5 minutes.
- Unless for gradation type I adding 2% of OPC type V results in the minimum cure time.
- The required time to maximize the cohesion of slurry seal mixture with slow set emulsion in the sample type I is approximately 7 hours and 15 minutes, and in the sample types 2 and 3 is 9 hours and 15 minutes.
- The required time to maximize the cohesion of slurry seal mixture with quick set emulsion in the sample type I is approximately 3 hours, and in the sample types 2 and 3 is between 4 and 4 hours and 15 minutes respectively.

6. Acknowledgment

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