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EFFECT OF COAL FLY ASH ON FROST RESISTANCE OF HOT MIX ASPHALT

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Abstract: This paper presents the utilization of coal fly ash in pavement construction that acts as filler replacement which could improve the performance of its properties, particularly improving the foundation of road bases, which would be also considering the seasonal effects such as frost. Frost damage in cold regions is a phenomenon of great practical importance in highway engineering design and construction. One of the objectives of this study is to investigate the effect of coal fly ash (CFA) as a filler replacement on the mechanical properties of bitumen-aggregate mixtures at various percentages 1%, 2%, 3%, 4%, 5% and 6% by weight of aggregate. Freeze and thaw cycle test was conducted to simulate cold region countries condition, and compared with normal condition. Marshall Test was done to evaluate the suitability of coal fly ash as mineral filler for normal and frost conditions. Result obtained from test was compared between control sample and sample with CFA. Marshall Parameters can be improved by adding CFA as filler replacement to the HMA as compared to normal filler, although, results showed that by addition of CFA some specifications of ST RK 1218-2003 «Materials on the basis of organic binders for road and airfield construction. Test Methods» were not met requirements. It was observed that there was a definite increase in Marshall stability and decrease in flow values. Optimum CFA was determined to be in range of 1% to 3% by applying the range method. The mechanical properties, namely modulus of resilient and tensile strength were determined by carrying out modulus test and indirect tensile test respectively. The results revealed that the highest value of modulus of resilient for both conditions when CFA content was 3%. Indirect tensile test conducted for frost condition only and found that the highest value was in range of 2% to 3%.

1.0 Introduction

Nowadays, everyone and everywhere people using the term sustainability. Sustainability can be defined as, “Meeting the needs of the present generation without compromising the ability of future generations to meet their needs” [1]. Therefore, it is common and encouraged practice in highway

engineering to use waste materials. Numerous waste materials result from manufacturing operations, service industries, sewage treatment plants, households and mining.
Asphalt mixtures containing low addition levels of fly ash as a mineral filler exhibit mix design properties that are usually comparable to asphalt mixtures containing natural fillers such as hydrated lime or stone dust. Fly ash can be used as cost-effective mineral filler in hot mix asphalt (HMA) paving applications. In addition, due to the lower specific gravity of fly ash, similar performance is obtained using less material by weight, further reducing the material cost of HMA [2].
The frost action reacts on the highway structure that is a major concern at the locations constructing a highway in cold regions, and frost damage is a phenomenon of great practical importance in highway engineering design and construction [3].

1.1 Problem Statement

Many countries like Kazakhstan facing frost problems during winter. Frost damage is a significant factor in the premature demise of unbound granular pavements in cold regions such as Kazakhstan, USA, Canada, Japan and other European countries.
Traditionally aggregates, sand, bitumen, and Portland cement are used in road construction. The demand of these materials for construction purpose is increased rapidly but naturally material become shortage in nature. Therefore, recycling of waste materials, such as CFA in highway construction should be encouraged.

1.3 Objectives and Scope of the Study

This paper was proposed to investigate the effect of CFA as a filler replacement on the mechanical properties of bitumen-aggregate mixtures at various percentages 1%, 2%, 3%, 4%, 5% and 6% by weight of aggregate. Moreover, to carry out freeze-thaw cycle test in order to achieve desirable frost resistance in laboratory experiments. In addition, to observe the seasonal effects such as frost on road performance. The scope of the study was preparation of AC14 Marshall samples without additive as control samples. The Marshall Test was conducted to determine optimum bitumen content and Marshall Properties. Content of CFA used were 0%, 1%, 2%, 3%, 4%, 5%, and 6% as mineral filler into the mixture. The optimum CFA content was determined using Marshall Method.

2.0 Methodology

The laboratory works can be divided into several stages beginning with the aggregate preparation for conditioned and unconditioned, conducting freeze-thaw test and end up with conducting indirect tensile test. This study used the Marshall method, and the type of mixes that designed was AC 14. Seven mixtures were prepared using different fly ash contents. The laboratory work of modified hot mix asphalt was conducted using procedure of Marshall Method. Marshall Test was conducted on the control sample at normal room temperature. After determining of optimum bitumen content, the sample with CFA as filler was produced and tested. Next stability and flow test, modulus of resilient for both conditions were conducted. For frost condition freeze and thaw cycle test and indirect tensile test as performance test was conducted.

3.0 Data Analysis and Discussion

Data analysis was done according to Marshall Test and all the results were compared to ST RK 1218-2003 specification. After determining optimum bitumen content, CFA was added as mineral filler to the specimen in order to determine the optimum CFA content.
The average effective specific gravity of blended aggregate was 2.564. In order to determine the OBC Marshall Test was conducted. Table 3.1 shows the summary of the test result obtained.

Table 3.1: Summary of the Marshall Test result

Bitumen Content (%)	Density (g/cm3)	Stability (N)	VTM %	VFB %	Flow (mm)	Stiffness (N/mm)
4.0	2.305	16657	4.8	65.7	3.6	4615
4.5	2.320	15500	3.5	74.3	4.6	3399
5.0	2.346	14823	1.7	87.0	6.1	2438
5.5	2.354	13440	0.7	95.5	5.8	2325
6.0	2.352	11713	0.1	99.3	7.7	1520

From the graphs and calculation that has been done, the value of optimum bitumen content was 4.6 %.

The value for density, stability, VFB, VTM, flow and stiffness were determined from the graphs at the optimum bitumen content. Another six samples with 0% of CFA were prepared; three for normal condition and three for frost condition using the optimum bitumen content value for verification purpose to make sure that all Marshall Parameter at optimum bitumen content were same with the result obtained from the graph. The results showed that control samples passed the ST RK 1218-2003 specification.

After optimum bitumen content was obtained, Marshall Test was conducted with mineral filler replacement for both conditions. Table 3.2 and Table 3.3 provided the summary of the test result obtained for various content of CFA added for normal and frost conditions respectively.

Table 3.2: Marshall Test result for various content of CFA for Normal condition

CFA Content (%)	Density (g/cm3)	Stability (N)	VTM %	VFB %	Flow (mm)	Stiffness (N/mm)
1	2.328	16176	3.0	77.6	3.7	4336
2	2.334	14361	2.8	78.8	4.6	3139
3	2.339	16323	2.5	80.0	4.1	3973
4	2.345	15166	2.3	82.0	4.2	3659
5	2.342	14891	2.4	83.3	4.5	3276
6	2.349	13802	2.1	81.4	4.0	3492

Table 3.3: Marshall Test result for various content of CFA for Frost condition

CFA Content (%)	Density (g/cm3)	Stability (N)	VTM %	VFB %	Flow (mm)	Stiffness (N/mm)
1	2.328	22101	3.0	77.6	3.5	6307
2	2.329	18570	3.0	77.6	4.1	4532
3	2.340	18207	2.5	80.0	3.6	5061
4	2.342	16834	2.4	84.7	3.4	4954
5	2.338	15872	2.6	80.0	3.7	4286
6	2.354	17520	1.9	81.4	3.4	5179

Results of samples for various amount of CFA were compared to verification samples for optimum bitumen content without CFA added. In addition, comparison between control sample, CFA added sample for normal and CFA added sample for frost were shown in Appendix A.

The results of modulus of resilient for different percent of CFA content shown in Table 3.4 for normal and frost conditions. Modulus of resilient versus CFA content graph was plotted as shown in Figure 4.1.

Table 3.4: Modulus of Resilient for Normal and Frost Conditions

CFA Content %	0	1	2	3	4	5	6
Resilient of Modulus (MPa) N C	6101	2861	3459	4236	4541	3856	3542
Resilient of Modulus (Mpa) F C	6275	5222	4579	5429	5423	3985	3328

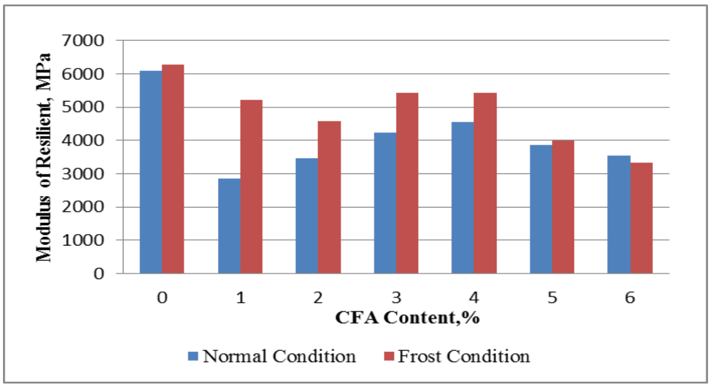

Fig. 4.1: Effect of CFA on Modulus of Resilient

The results of indirect tensile test for different percent of CFA content shown in Table 3.5 for frost condition. Stability versus CFA content graph was plotted as shown in Figure 4.2

Table 3.5: Indirect Tensile Test

CFA Content (%)	0	1	2	3	4	5	6
Stability (N)	12096	13008	15519	15519	12547	13234	11409

Figure 4.2 shows stability versus CFA content (%) graph. Indirect tensile test was conducted only for frost condition and compared to the control sample. The graph in Figure 4.2 shows that, stability for control sample is 12096N, which is lower than sample having CFA content from 1% to 5 %. Optimum CFA was found to be in range of 1% to 3 % as achieved in Marshall Test analysis. The most important finding to appear from the data is that by adding CFA the stability increasing, therefore if the optimum CFA content is used HMA with good stability can be produced.

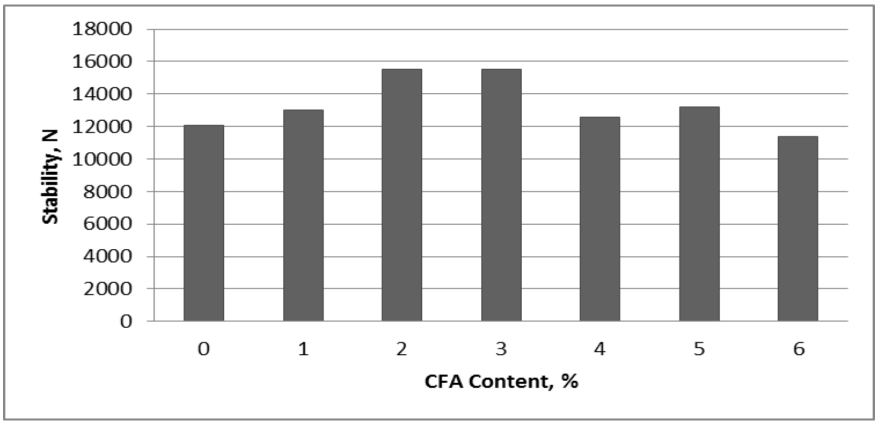

Fig. 4.2: Effect of CFA on Indirect Tensile Test

4.0 Conclusion

From the comparison shown in Table 4.1 and Table 4.2 for normal and frost conditions respectively in Appendix A, there are some parameters of the sample with CFA added that meet the ST RK 1218-2003 specification, which are stability and stiffness for both conditions. Even though, voids filled with bitumen, flow and voids in total mix were not fulfilling the specification in general, but some percentage of CFA content fulfilled. Therefore, by applying the range method optimum CFA was determined to be in range of 1% to 3%.

Modulus of resilient revealed that the highest value for normal and frost conditions when CFA content was 3%. Indirect tensile test conducted for frost condition found that the highest value was when CFA content in range of 2% to 3%.

5.0 Reference

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Appendix A

Table 4.1: Comparison of Marshall Parameter between control sample and CFA sample and ST RK 1218-2003 for Normal Condition

Marshall Properties	**ST RK 1218-2003**	**Coal Fly Ash Content**						
		Control Sample 0%	**1%**	**2%**	**3%**	**4%**	**5%**	**6%**
Stability	> 8000N	20336	16176	14361	16323	15166	14891	13802
Flow	> 2.0-4.0 mm	3.4	3.7	4.6	4.1	4.2	4.5	4.0
Stiffness	> 2000N/mm	6033	4336	3139	3973	3659	3276	3492
VTM	3% - 5%	3.0	3.0	2.8	2.5	2.3	2.4	2.1
VFB	70% - 80%	78.0	77.6	78.8	80.0	82.0	83.3	81.4
Density	-	2.329	2.328	2.334	2.339	2.345	2.342	2.349

Table 4.2: Comparison of Marshall Parameter between control sample and CFA sample and ST RK 1218-2003 for Frost Condition

Marshall Properties	**ST RK 1218-2003**	**Coal Fly Ash Content**						
		Control Sample 0%	**1%**	**2%**	**3%**	**4%**	**5%**	**6%**
Stability	> 8000N	22759	22101	18570	18207	16834	15872	17520
Flow	> 2.0-4.0 mm	3.7	3.5	4.1	3.6	3.4	3.7	3.4
Stiffness	> 2000N/mm	6072	6307	4532	5061	4954	4286	5179
VTM	3% - 5%	3.0	3.0	3.0	2.5	1.9	2.6	2.4
VFB	70% - 80%	78.0	77.6	77.6	80.0	84.7	80.0	81.4
Density	-	2.329	2.328	2.329	2.340	2.342	2.338	2.354