Laboratory Evaluation On Waste Slag Produced Zinc Industry As Mineral Filler In Stone Mastic Asphalt

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ABSTRACT

To provide sustainable development, environmental and economic issues have encouraged to researchers to investigate reuse of the waste materials in some fields. Road construction is an important sector owing to need more materials and to evaluate recycling waste materials in comparison with other fields of civil engineering. The purpose of this study is to investigate usability of waste slag produced zinc industry as mineral filler in Stone Mastic Asphalt (SMA). Waste slags were added to mixture as a mineral filler replacement with conventional aggregate to produce SMA specimens. The same gradations of mixtures were produced using normal crushed aggregate as control samples. The Marshall mix design system was used for sample preparation in accordance with Turkish specifications. The SMA specimens, made of waste slags and conventional asphalt concrete, were evaluated through their fundamental engineering properties such as Marshall stability, flow tests and resistance to moisture-induced damage tests. The results indicate that the application of waste slag as mineral aggregate improves the Marshall stability and flow performance but it influences the performance of moisture-induced damage negatively.

Keywords: Aggregate, Asphalt, Reclaimed asphalt pavement (RAP) Recycling, Stone Mastic Asphalt, Waste

1. INTRODUCTION

Environmental conservation and preservation are becoming more important in recent years because of the increase in the waste materials and population. Researchers are paying more attention to figuring out the negative environmental effects of these waste materials. To prevent these materials from harming the nature, many authorities are enforcing the reuse of materials in a way that is more economical and sustainable. [1].

There are many materials such as glass, aluminum, paper etc. being recycled in the industry for many purposes. In addition to these materials, there are a bunch of easy-to-recycle materials in the construction sector. Some of these materials are concrete, asphalt, roofing shingle, PVC etc. Similarly, the usability of the hazardous materials have been being studied for many years. [2].

In Civil Engineering, industrial wastes are considered remarkable materials for a considerable period of time. Moreover, Highway Engineering is the major area among the construction sectors where waste materials are used. [3,4,5]. Waste materials have been being used in HMA and SMA by the researchers for many years. Wu et al. [6] explored, in stone mastic asphalt (SMA) samples, the feasibility of utilizing steel slag as aggregates. Authors using steel slag found that volume properties of SMA mixtures with steel slag are in the upper and lower limit of the special specification. They also revealed that when compared with basalt, the resistance to low temperature cracking of SMA mixture and high temperature property were developed by replacing steel slag with aggregates. Lin et al [7] studied the analysis of test roads constructed using conventional asphalt concrete and test roads constructed using basic oxygen furnace slag. A bunch of laboratory experiments were made by the authors such as the Marshall test and measurements of the indirect tensile strength and resilient modulus. The performance of basic oxygen slag and conventional aggregates showed minor differences. Sengoz and Topal [8] made a laboratory evaluation on using of waste roofing shingles as % 1, % 2, % 3, % 4 and % 5 ratios in HMA. Authors stated that the mixtures with waste roofing shingles have better stability and rutting performance when comparing to that with conventional samples.

The main purpose of this study was to determine the effects of zinc slag as a mineral filler on the engineering properties of SMA. Resistance to moisture-induced damage test, Marshall stability and flow experiments were conducted on the Marshall samples made with conventional mineral filler and zinc slag and the results received form the laboratory experiments were evaluated.

2. MATERIAL AND METHOD

2.1 Aggregate

In the experimental studies three different aggregate gradations were used: 5-13 mm and 0-5 mm and mineral filler. The aggregates were supplied by a basalt quarry in Kayseri, Turkey. After determining physical properties of these materials, mix gradation was prepared in accordance with TCK stone mastic course specification [9]. Physical properties of these materials, mix gradation and specification limits are seen in Table 1, and Figure 1 respectively.

Table 1: The Physical Properties of Aggregates

Experiment	Course Aggregate	Fine Aggregate	Filler	Specification
Bulk Specific Gravity, gr/cm^3	2,820	2,690		TS EN 1097-6
Apparent Specific Gravity, gr/cm^3	2,915	2,825	2,750	
Absorption, %	1,16	1,79		
Mix Effective Specific Gravity, gr/cm^3			2,823	
Na_2SO_4 Sulfate Soundness Test, %			0,02	ASTM C - 88
Los Angeles Abrasion Test, %			22,3	AASHTO T - 96
Flakiness Index, %			8,4	BS 812
Stripping Test, %			75 - 85	TCK-KTŞ Part 403 Appendix A

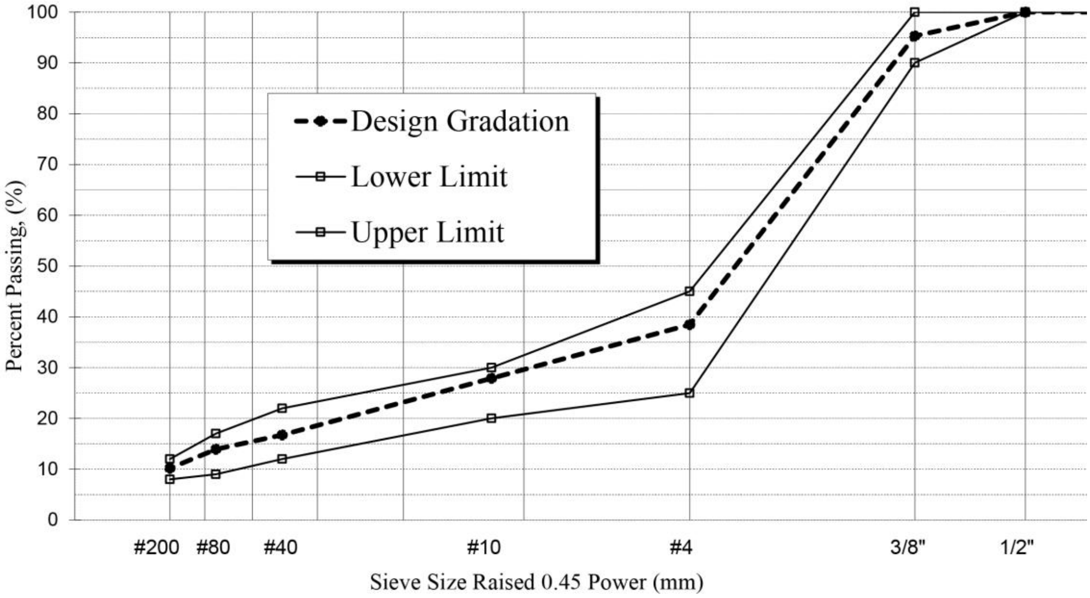

Figure 1: Mix Gradation and Specification Limits for SMA

2.2 Bitumen

Bitumen in 50/70 penetration grade supplied from Tupras Kirikkale Refinery was used in preparing Marshall samples. Properties of bitumen are presented in Table 2.

Table 2. The Physical Properties of B 50/70 Bitumen

Property	Value	Standard
Bitumen Specific Gravity, gr/cm^3	1,027	TS 1087
Bitumen Penetration, dmm	57	TS EN 1426

2.3 Zinc Slag

Zinc slag was taken from ÇİNKOM company located in Kayseri, Turkey. The original gradation of the zinc slag generally ranging from 0-5 mm. Only the filler part of the zinc slag was used after sieve analysis. Chemical compositions of zinc slag mostly consist of CaO, SiO_2, Al_2O_3, Fe and other elements. The reason of why zinc slag is used in this study is that due to the increase of the zinc slag production of the company, the stock area shown in figure 2 is expanding. This is why necessary steps must be taken immediately to prevent the slag from harming the nature. Moreover, because of the effects of the wind, rain and snow, the slag is being moved from its stock area and joining the private residential area.

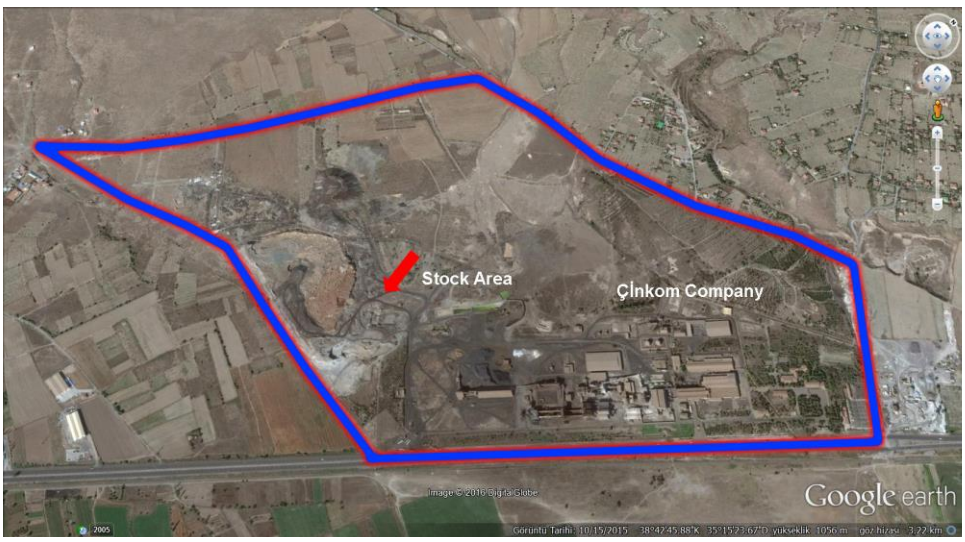

Figure 2: Çinkom Company and Stock Area

3. RESULTS AND DISCUSSIONS

3.1 Marshall Mix Design

In order to determine optimum Bitumen Content (AC), Marshall stability and flow tests were conducted on the samples compacted at various bitumen based on ASTM D 1559. AC was determined using with value of 3% air voids in the total asphalt. Asphalt specimens were prepared on the basis of 0,5% increment of bitumen content. The specimens were heated up to the temperature of 60 ºC. The samples also put in the particular test equipment and the load having a constant stain was applied to the Marshall samples. (2 in/min). During the load application, the dial gauge was used to measure the vertical displacement of the samples; the displacement read at the maximum load capacity is expressed in units of 0,01 mm and is called the Marshall Flow value of the sample. Figure 3 shows the Marshall sample fabrication and stability test process. The tests were repeated for the each bitumen content and optimum AC value was determined. After that, maximum bulk specific gravity, corrected Marshall Stability, Marshall flow, air voids in the total mix and VMA curves versus AC were plotted.

Figure 3: Marshall sample fabrication process

In order to determine optimum bitumen content, created charts of the Marshall design are shown in Figure 4. According to these results, optimum bitumen content was found as 8,34% considering the air void percentage is 3,0%.

The stability value and flow value at the optimum bitumen were determined from the data and it was revealed that all of the values mentioned are in between the upper and lower limits of specification.

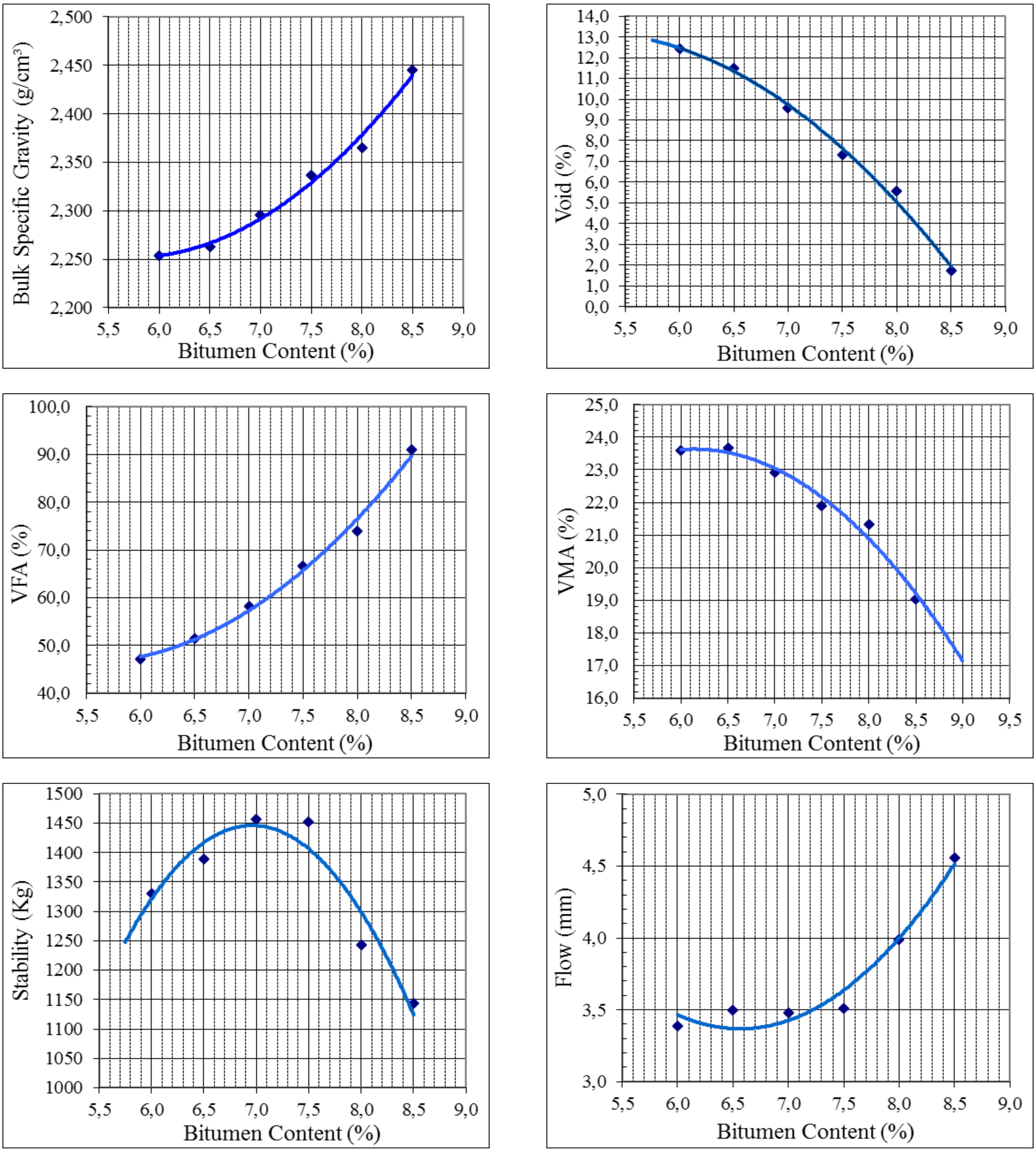

Figure 4: Marshall Test Results to Determine Optimum Bitumen Content

3.2 Marshall Stability and Flow Results of Limestone and Zinc Slag

After determining the optimum bitumen content with limestone, zinc slag was totally replaced with limestone as a filler (No:200 passing) material. In Figure 4, the stability values of limestone and zinc slag are demonstrated. By the replacement, it is understood that zinc slag, with optimum bitumen content, increases the stability of the mixtures comparing to limestone.

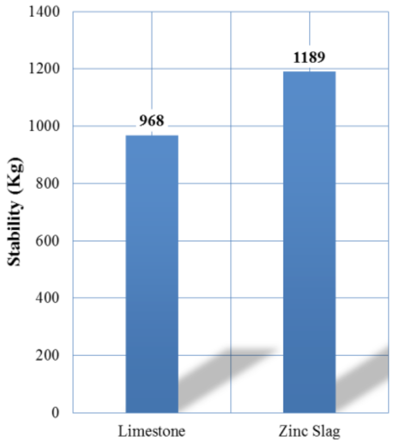

Figure 5: Marshall stability test results

As it is seen in Figure 5, the flow value of zinc slag mixture is less than the mixture prepared with limestone. From the flow diagram, it is found that the mixtures with zinc slag are getting less brittle.

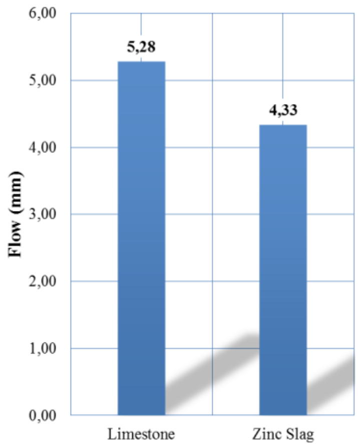

Figure 6: Marshall flow values of the samples

3.3 Tensile Strength Ratio (TSR) Results

In order to figure out the resistancy to moisture-induced damage, 6 mixtures have been prepared and cured in the oven (24 hours at 60 °C) before compaction. 6 marshall samples having the air voids in between 6,5% and 7,5% have been produced. 3 samples have been selected for the indirect-tensile strength test in dry condition. After vacuum saturation and a freeze cycle (16 hours at -18 °C), followed by a warm-water soaking cycle (24 hours at 60 °C), indirect tensile strength test have been conducted for the other subset of 3 marshall samples. Figure 6 shows the results of tensile strength ratios. It is revealed from the figure that when limestone is replaced with zinc slag, the tensile strength ratio decreases from 83,1% to 80,3%, satisfying the minimum limit of 80,0%.

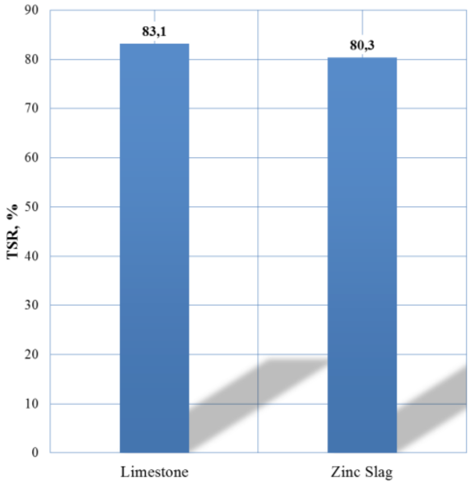

Figure 7: TSR results

3.4 Scanning Electron Microscope (SEM) Views

It is seen that the surface area of limestone shown in Figure 8 is lower comparing to the surface area of zinc slag shown in Figure 9. Since the surface area of zinc slag is higher, the optimum bitumen content of the zinc slag mixtures is higher. This is because the bitumen in the mixtures prepared with zinc slag needs to cover more areas.

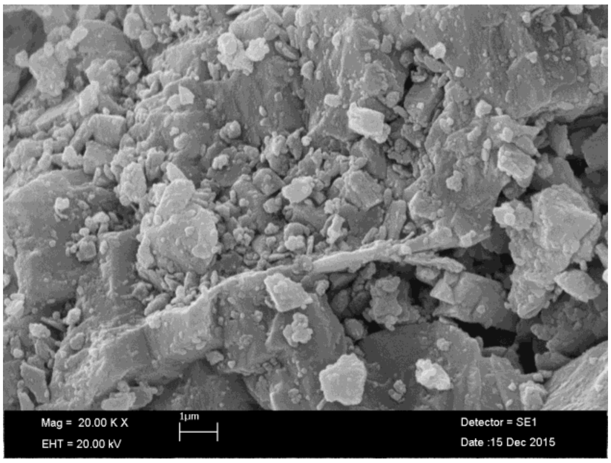

Figure 8: SEM View of Limestone

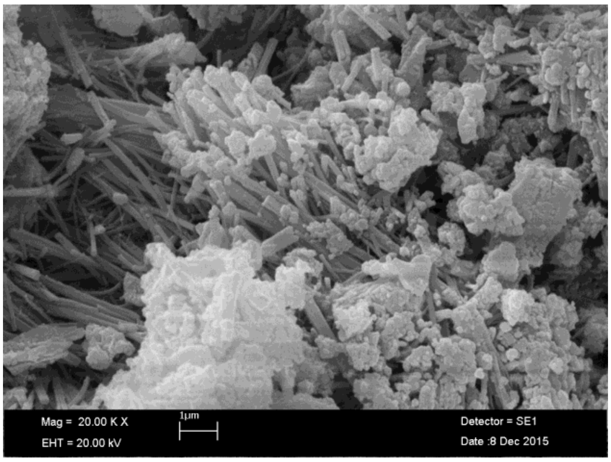

Figure 9: SEM View of Zinc Slag

4. CONCLUSIONS AND RECOMMENDATIONS

The objectives of this study were to evaluate the use of zinc slag in stone mastic asphalt (SMA) concrete as mineral filler. Marshall stability, flow tests and resistance to moisture-induced damage were carried out to evaluate the characteristics of SMA by replacing the conventional mineral filler, which is limestone, with zinc slag. From the results derived from tests showed that Marshall stability values of the mixtures containing zinc slag and limestone are higher than the minimum specification limit. Moreover, marshall stability values are increasing slightly by adding zinc slag. Also, the flow value of zinc slag is less than that of limestone mixtures, which can be regarded as another advantage of the replacement. Moreover, the mixtures prepared with zinc slag have lower resistance to moisture comparing to the mixtures with limestone.

The study of evaluation zinc slag in SMA has been continued comprehensively by the authors of this paper. The first results gained through this study can contribute to the encouragement of zinc slag re-use in SMA asphalt pavement. To determine the exact amount of bitumen for this waste material, different mix design should be prepared with various mineral aggregates. In addition, the zinc slag is required to be tested for the environmental impact.

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