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USE OF EAF SLAGS AS ASPHALT AGGREGATE

Ayşe Ece YILDIZÇELIK[1], Samet YILMAZ[1], Aslan ÜNAL[2], Onuralp YÜCEL[1]

[1] Department of Metallurgy and Materials Engineering, Istanbul Technical University,Turkey
[2] COLAKOGLU Metalurji A. S., Turkey, EUROSLAG Representative

yildizcelik@itu.edu.tr, sametylmaz89@gmail.com, aunal@colakoglu.com.tr, yucel@itu.edu.tr

Abstract

As a result of the increase in the production of iron-steel, slags and valorisation of slag have become more important. EAF slags are used as landfilling materials, aggregates in asphalt and concrete as well as fertilisers in agricultural applications. It is shown that the aggregates that are used in highways have similar physical and chemical properties to the iron-steel slags. The purpose of this study is to investigate the use of EAF slags as asphalt aggregates, finding the appropriate rate of slag and limestone mixture and to investigate properties of the asphalt according to these mixtures.

Introduction

Nowadays, steel production increases day by day in all over the world. The amount of world steel production was 1.49 Gt in 2011[1]. Because of steel production, it is estimated that 5 Mt of slag occurs every year in Turkey[2]. Aggregate is the main material used in highway construction. Asphalt, which is used in road, airfields and upper layers of other areas, is prepared by mixing mineral aggregates, bitumen and bituminous binders[3]. Asphalt is composed of three layers: wearing layer, binder layer and bituminous base layer[4]. Physical properties of EAF slag and natural aggregates are very similar.

Experimental Procedure

In this study, the experiments were performed according to ASTM standards and include chemical analyses and physical experiments. EAF slag is also compared with aggregates in terms of mechanical properties.

Chemical analyses

Chemical analyses were performed to determine the chemical composition of EAF slags and the amount of free CaO. The results of the analyses are shown in Table 1.

Table 1: Chemical compositions of EAF slags (%)

Size Distribution	Fe_2O_3	CaO	SiO_2	Al_2O_3	MgO
0-5mm	39.26	25.45	16.82	7.53	5.79
5-9mm	39.95	24.68	17.20	7.57	5.01
9-12mm	38.62	24.75	17.38	7.79	4.84
12-25mm	43.44	23.77	16.23	7.73	4.94

Physical properties

Tests were performed to determine if the properties of EAF slag are suitable to use it as asphalt aggregates. The tests were carried out in three groups: physical testing of EAF slags, design study and wearing surface experiments. EAF slags are compared with natural aggregate in accordance with physical tests. For this purpose, the following tests were performed: sieve analysis, Los Angeles abrasion test, determination of resistance to freezing and thawing, measurement of specific gravity and water absorption test, filler density, flakiness index, peeling strength and methylene blue absorption test.

In the design study, different slag and limestone mixtures were prepared for three different asphalt layers. Percentages of slag in the mixture are: 45 wt% for bituminous base layer, 35 wt% for binder layer and 15 wt% for wearing layer. After adding bitumen to these mixtures, cylindrical specimens called Marshall briquettes were prepared.

Wearing surface experiments consist of water sensitivity test and wheel track test. Water sensitivity of asphalt mixtures test is measuring the resistance of mixtures to damage after they have been in contact with water. This test was performed to wearing and binder layers. Wheel track testing was performed according to TS EN 12697-22 standard. The Hamburg Test Device is measuring the sensitivity to permanent deformation of bituminous mixtures when a force is applied. This test was performed to wearing and binder layers.

Results and Discussion

Results of Los Angeles abrasion test, resistance to freezing and thawing test, specific gravity and water absorption test, filler density, flakiness index and methylene blue absorption test were in accordance with technical specification for highways. The peeling strength of EAF slag was determined 15-20%, but this value is slightly different according to technical specification for highways. The amount of optimum bitumen was calculated for three layers of asphalt and the results are shown in Table 2 according to Marshall Method.

Table 2: Results of Marshall experiment at base layer, binder layer and wearing layer

	Bituminous base layer	Binder Layer	Wearing Layer
Optimum Bitumen, wt%	3.97 ± 0.5	4.37 ± 0.3	4.87 ± 0.3
Practical specific weight, g/cm^3	2.609	2.583	2.469
Stability, kg	1510	1640	1670
Void, vol%	5.20	4.80	4.25
Filled voids with asphalt (bitumen), vol%	60.0	65.0	71.0
V.M.A. (voids between aggregates), vol%	13.70	14.30	14.90
Yield, mm	3.50	3.60	4.20
Max. Theoretical specific gravity (DT)	2.757	2.717	2.609
Rate of Filler/Bitumen	-	1.06	1.16

The wearing surface and the binder layer were tested with Wheel track method. The result of this test was found 5.95% reduction in thickness for the wearing surface layer and 5.50% reduction in thickness for the binder layer.

Test of water sensitivity is applied according to TS EN 12697-12 standard, and results of the test are shown in Table 3. Marshall briquettes were tested by compressive testing machine and some cracks were seen partly. There was no crack at aggregates.

Table 3: Results of water sensitivity experiment for wearing type 1 and binder layer

Definition of specimen and mixture type	Wearing Type 1	Binder Layer
Average density of dry specimen	2.42 g/cm^3	2.59 g/cm^3
Average density of wet specimen	2.41 g/cm^3	2.54 g/cm^3
Average indirect tensile strength of dry specimen (ITS_d)	1060.2 kPa	1012.9 kPa
Average indirect tensile strength of wet specimen (ITS_w)	832.8 kPa	663.6 kPa

Conclusions

Natural aggregates and EAF slag have some similarities in terms of physical features compared to each other. For example: resistance to freezing, resistance to fragmentation (LA) and bulk density have approximately same values with related standards[5]. The peeling strength value of the EAF slag is slightly different according to standard. Additives providing an increase on peeling strength need further investigation. Also, the use of EAF slag within the bottom layer of the asphalt coating is more appropriate and studies are in progress. Natural aggregate resources run out day by day.

Based on this fact, usage of slag on bottom layer of asphalt coating and road structure should be considered.

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