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Investigating on possible use of Diyarbakir basalt waste in Stone Mastic Asphalt

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ABSTRACT

Stone Mastic Asphalt (SMA) improved for road construction which has been utilized in Europe and America for 40 years is a rather new process in Turkey. SMA basically consists of 93–94% aggregate and mineral fillers, 6–7% bitumen and additives. Road and construction industry consume stone in large amounts. Stone used are obtained from nearby quarries and carried to the location where they are to be used, destroying the nature and causing large costs. The constantly increasing demand on quarries harms the general structure of the earth thus causing the emergence of large scale environmental problems. The use of basalt waste from stone processing plants as aggregates and mineral filler in SMA might help to meet this increasing demand thus solving environmental problems. In this study, primarily some important material properties of fine and coarse basalt waste, taken from basalt processing plants in Diyarbakir, such as sieve analysis, chemical analysis, specific gravity, water absorption, Los Angeles abrasion loss value, soundness of aggregate by Na_2SO_4, flakiness index and stripping strength were determined. Then by using this waste material, a SMA was designed according to Turkish Highway Technical Specifications. Marshall stability and flow tests have been carried out on designed SMA specimens. Test results indicate that properties of the basalt waste and the SMA produced were within the specified limits and that these waste materials can be used as aggregates and mineral filler in SMA.

1. Introduction

Turkey, like Portugal, Spain, Italy, Greece, Iran and Pakistan, has an important place in natural stone production. The types of natural stone in Turkey number more than 250. Approximately one hundred of these stones are well known and regularly in demand in the international market. Only in natural stone processing plants, approximately 30% come out as dust waste Wastes, either coarse-grained or in dust in 22 natural stone processing plants in Diyarbakir are almost never used. In studies carried out on regional natural stones in the plants reaching the capacity of total 3 million m^2 (for strip of 2 cm thickness), average 33% dust waste is formed on the gang saw line and 35% on S/T cutting line; almost 140,000 tons of dust waste forms in the processing plants in Diyarbakir as to the given rates [1]. Large figures are reached, when in particular the waste amount obtained in the past is added to the wastes obtained in plants established after 2000. Natural stone dust waste can cause environmental problems such as land covering, surface and subterranean water degradation, air pollution and visual pollution if the waste is not used. The wastes generally collect when stone processing is realized in the plants operating in the industrial zone. Those plants form large aggregations in Diyarbakir Deve Gecidi Valley causing pollution; therefore, investigating possibilities of utilizing these wastes in various areas is highly important. Natural stone dust is generally used as raw material or reinforcement material in various areas such as building materials [2], bricks [3,4], ceramics [5], cement additives [6], desulphurization processes [7] and infiltration [8]. In addition, natural stone dust can be used in the production of polymer based composite material [9,10]. Moreover, natural stone and granite waste can be used in the production of clay-based materials [11]. Coarse natural stone wastes have been used as aggregates [12] and as fillers in asphalt cement [13]. Artificial natural stone waste has been used as a fine aggregate in polymer-modified mortar [14]. Waste natural stone dust has also been used in manufacturing mosaics, mortar, tiles, plasters and white cements [15]. It was reported that natural stone sludge could be used to produce clinker [16] and as an additive material in mortar [17]. The other potential use of coarse and dust stone waste is Stone Mastic Asphalt.

In recent years long life superstructure has been improved for road construction both in Europe and in America. In the late sixties, some special additives were prepared by several large asphalt companies and were launched on the market under their own trade names. Later, some standards were established for these additives which were known as 'Splitt Mastic Asphalt' in German and later named "Stone Mastic Asphalt" (SMA) in English. Different performance was observed with asphalt concrete and SMA prototype additives on the highway abrasion layer facing heavy traffic loads. Permanent deformation was observed in high bitumen-rated asphalt concrete, but aging and cracking in low bitumen-rated

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asphalt concrete. However, surveys carried out in the following years proved that SMA additive produced better results than asphalt concrete mixture. Finally, SMA was upgraded to the class of a certified product in 1984 and introduced as standard by the Federal Department of Transportation. SMA, with its 40 year experience up till the present, is being applied in Germany [18]. SMA basically consists of coarse aggregates, fine aggregates, mineral fillers, bitumen and additives (cellulosic fibers, mineral fibers, polymers, and artificial silicate materials). A number of researchers indicate that quarry aggregates produced from waste natural stone during mining could be utilized as construction material in low-traffic asphalt pavement-based courses [15,19–22]. However, the author could not find any study that made use of waste natural stone aggregate in abrasion layer of the highways facing heavy traffic loads as base.

The purpose of this study was to investigate the possibility of using coarse and dust waste basalts to produce SMA and determine its properties. Utility of waste basalts as aggregates and filler materials in SMA will reduce unit cost of road construction as well as contributing to environmental protection.

2. Experiment

Experimental studies were basically undertaken in two stages. In the first stage an asphalt design gradation was prepared according to SMA specifications regarding previous experiences and some material specifications of aggregate and mineral filler material was identified. Samples prepared according to the Marshal experiment method were used in hot asphalt applications as proposed in the design and tested in the second stage.

Table 1
Gradation of mixture and limit values.

Sieve (mm)	Gradation of mixture% passing	Limit values [23]% passing
16.0	100	100
12.7	91.2	85–100
9.5	64.3	50–75
4.75	31.9	25–40
2.00	25.4	20–30
0.425	15.2	12–22
0.180	12.1	9–17
0.075	10.1	8–14

Table 2
Some important properties of aggregates and limit values.

Properties	Coarse aggregate	Fine aggregate	Mix	Coarse aggregate limit values [23]	Standard
Specific gravity	2.835	2.820	2.837		ASTM C-127
Los Angeles abrasion loss value (%)	13.2			⩽25	ASTM C-131
Soundness of aggregate by Na_2SO_4	2.11			⩽8	ASTM C-88
Flaxiness index%	22.8			⩽25	BS-812
Water absorption%	1.6	1.8		⩽2.0	ASTM C-127
Stripping strength (%)	85–90			⩾60	Turkish Highway Technical Specification 2006, Part 403 add-A

Table 3
Chemical composition of basalt used as aggregate and mineral filler.

Component	%
SiO_2	46.25–45.90
TiO_2	3.01–2.59
Al_2O_3	13.92–13.65
Fe_2O_3	4.51–4.32
FeO	8.39–8.33
MnO	0.16–0.15
MgO	9.01–8.55
CaO	8.71–8.65
Na_2O	3.30–3.16
K_2O	1.22–1.02
P_2O_5	0.51–0.42
LIO(CO_2)	0.71–1.03

Table 4
Properties of bitumen and modified bitumen.

Properties	Bitumen	Modified bitumen	Standard
Source	Kirikkale/ Turkey	Kirikkale/Turkey	
Penetration grade	50/70		
Penetration at 25 °C	63	42	ASTM D 5
Specific gravity	1.030	1.028	ASTM D 70
Softening point °C	52	71	ASTM D 36
Ductility (5 cm/min)	>100 cm	>100 cm	ASTM D 113
Viscosity at 135 °C	0.411 Pa s	0.392 Pa s	ASTM D 4402
Viscosity at 165 °C	0.121 Pa s	0.102 Pa s	ASTM D 4402

2.1. Aggregate and mineral fillers

Basalt dust waste in the rate of 10.1% of total mixture was used as mineral filler in the experimental study. These wastes were obtained from the natural stone plant belonging to ART Mining Company located on the Diyarbakir–Sanliurfa Highway and from Dibaz Natural Stone Plant waste area in the Industrial Zone. As coarse and fine aggregates are obtained through crushing in the crushing plant, 10 tons of basalt stones taken from waste basalt areas belonged to ART and Dibaz Natural Stone Plant. The aggregate proposed to be used was prepared as Type 1 in accordance with Turkish Highway Specifications [23]. Sieve analysis carried out according to ASTM C136-06 [24] as basis to the design, mixture gradation and specification limits are shown in Table 1. The aggregate used are mainly classified in three different grain sizes such as coarse aggregate (+4.75–16.0 mm), fine aggregate (+0.075–4.75 mm) and mineral filler (−0.075 mm). As seen in Table 1, this mixture consists of 68.1% coarse aggregate, 21.8% fine aggregate and 10.1% mineral filler in weight.

Specific gravity of materials in the mixture, water absorption of coarse and fine aggregate, apparent gravity [25], Los Angeles abrasion loss value of coarse aggregate [26], soundness of aggregate by Na_2SO_4 [27], flakiness index [28], and stripping strength [23] were all determined and indicated in Table 2.

Aggregate used in SMA is required to be of high quality. The aggregate quality, however, is measured with parameters such as: Los Angeles Abrasion loss value (%), soundness of aggregate by $N_{a2}SO_4$ (%), water absorption (%) and flakiness index (%). It is seen in Table 2 that the properties of basalt aggregate mentioned above are within the specified limits.

There are major oxides, such as Si, Fe, Mg, Al, Ca, Na, K and Ti in the composition of the basalts. In order to determine the percentage of these elements, chemical experiments were conducted on 10 specimens. As a result of these experiments, determined chemical composition of the aggregates and mineral filler are shown in Table 3.