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# Using Marble Wastes as Fıne Aggregate in Hot Mix Asphalt Production

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**Abstract- Waste disposal problem leads to negative effects on environment, health and economy. Recent years, recycling and reusing of waste materials in various sectors have been implemented to solve this problem. This experimental study was conducted to demonstrate the possibility of using marble wastes as a substitute rather than natural aggregates in hot mix asphalt (HMA) production. The marble wastes were crushed and ground to obtain fine aggregates. Based on experimental evidences, it can be stated that the use of recycled marble aggregate (RMA) instead of virgin aggregate (VA) as a fine aggregate is promising in many applications where cost and environmental aspects are primarily considered.**

***Keywords- F*ine aggregate, recycled marble aggregate, hot mix asphalt**

## I. Introduction

Concerns in recent decades about achieving sustainable growth has resulted in attempts to recycle or reuse a large portion of construction waste materials [1]. The construction and maintenance of roads consume large amounts of quarried aggregates [2]. The use of recycled aggregates would reduce both demand of extractions and landfill pressures, leading to a more sustainable road construction.

Different waste materials was used as aggregate in HMA by many researchers. HMA made with recycled concrete aggregate coated with bitumen emulsion exhibited mechanical properties similar to those obtained for conventional mixtures [3]. HMA materials designed with coarse recycled aggregate met the Marshall parameters for low volume roads and present a good resistance to permanent deformation [4].

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However, HMA materials designed with coarse recycled aggregate presented poor stripping behaviour which has a negative effect on the durability of the mixtures.

At optimum asphalt content, the mixtures containing up to 15% municipal solid waste satisfied all criteria for the use as bituminous surface or base course [5]. In addition, the mixtures satisfied the moisture susceptibility and raveling potential test limits. Boiler slag from thermal power plants can be used as a substitute for the fine aggregate fraction in hot bituminous mixes since its properties comply with the official requirements forthis type of material [6].The slag mix had a better resistance to water though it had a slight increase in permanent deformations.

Turkey, due to its location in the Alpine-Himalayan belt, has numerous marble deposits [7]. More than 250 marble types with different colors and patterns are being produced from these deposits. USA, Belgium, France, Spain, Sweden, Italy, Egypt, Portugal, Braziland Greece are among the countries with considerable marblereserves [8]. Seven million tons of marble are produced in Turkey annually. One of the major waste generating industries is the construction and marble production industry [9]. Nearly 70% of this precious mineral resource gets wasted in the mining, processing and polishing procedures. Asphalt mixtures containing marble waste can be useddirectly in the mix without any process [10]. Since the asphaltmixtures containing the marble waste have slightly higher plastic deformations, it is recommended to the asphalt mixturescontaining marble waste for low volume roads such assecondary roads and local roads.Investigations on the effect of marble as a filler, fine and coarse aggregate on hot mix asphalt concrete are still not sufficient in the literature. Large amount of waste has a detrimental effect on the environment, live health and budget. Experimental study have been made in order to evaluate the influence of marble waste as fine aggregate in HMA.

## II. Materials and methods

### *A. Aggregate and bitumen*

The bitumen with a 50/70 penetration grade was obtained from Aliağa/İzmir Oil Terminal of the Turkish Petroleum Rafinery Corporation. The bitumen 50/70 penetration grade used in this study is commonly used by the Turkish Highway Authority in Mediterranean Region in Turkey. Aggregates were obtained from Pamukalan, Antalya, Turkey. Aggregates commonly divided into two groups in asphalt studies such as coarse and fine limestone aggregates. Two kind of aggregates were used; limestone and recycled marble aggregates. Coarse aggregates were remained the same for all mixtures. Only fine aggregates were replaced. RMA aggregates were obtained from sieving test of the aggregate from No. 4 sieve. The different asphalt concrete (AC) mixtures prepared were coded as follows:

C: Control mixture with 100% limestone aggregate
C1:Mixture with 50 % limestone fine aggregate + 50 % RMA
C2: Mixture with 100% RMA

### B. *Experimental Design*

The plan of this study is outlined below:

1. Determination of physical and mechanical properties of aggregates and bitumen . This section includes sieve analysis, determination of specific gravitiy of coarse, fine and filler aggregates, determination of los angeles abrasion value of aggregates, aggregate freezing and thawing test, aggregate flakiness index test, bitumen penetration, softening point, flash point, specific gravity tests and performance tests of bitumen after RTFOT test.
2. Determination of mechanical properties and optimum bitumen content of mixtures based on Marshall test. In this study, series of tests specimens were prepared with a range of different bitumen contents were prepared for the determine optimum bitumen content for C, C1, C2.

A flowchart summarizing the experimental study was given in Fig. 1in this study, three samples were prepared for each of mixtures. Totaly, 54 (6x3x3) were prepared.Automatic Marshall Compactor was used for preparing each samples. All of these samples were tested with Marshall Stability Machine for determining the percent of optimum bitumen. The test was repeated for the samples of each bitumen content. Optimum bitumen contents for each mixture were determined from the graphs which are obtained from Marshall tests. Conclusions were presented based on the Marshall test results.

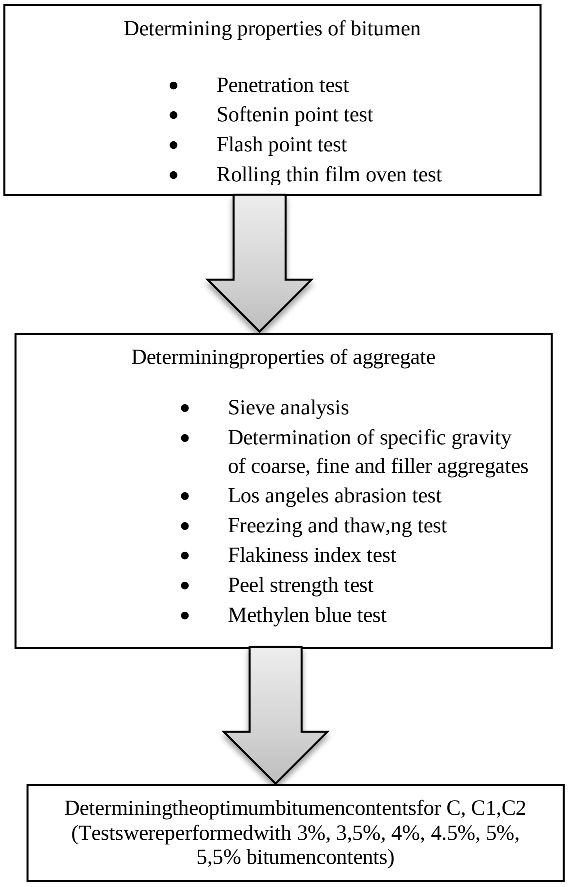


Figure 1. Flowchart of the study

## III. TEST RESULTS

### A. *Bitumen Tests*

Conventional bitumen tests were performed at the begining of the study. According to results obtained from tests, bitumen was evaulated whether it is appropriate for this study or not. Table 1 gives a summary of the results of tests performed on the bitumen. This table shows us, the bitumen is provides specificition limits for study.

TABLE 1. PROPERTIES OF THE BITUMEN USED IN THE STUDY

| **Source** | Aliağa / Turkey | | |
|---|---|---|---|
| **Penetration** | 50/70 | | |
| **Test** | Specification | Results | Specification limits |
| **Penetration (25 $^0$C; 0.1 mm)** | TS EN 1426 ASTM D5 | 66 | 50-70 |
| **Softening Point ($^0$C )** | TS EN 1427 ASTM D36 | 50 | 46-54 |
| **Flash Point ($^0$C )** | TS EN ISO 2592 ASTM D92 | 307 | 230 (min) |
| **Specific gravity** | TS EN 15326+A1 ASTM D70 | 1.031 | 1.0-1.1 |
| **Rolling Thin Film Oven Test (RTFOT); (163 $^0$C; 85 min.)** | TS EN 12607-1 ASTM D 2872 | | |
| **Change of** | | 0.34 | 1.0 (max) |

| | | | |
|---|---|---|---|
| **mass(%)** | | | |
| **Change of softening point($^0$C)** | TS EN 1427<br>ASTM D36 | 7 | 8.0 (max) |
| **Retained penetration** | TS EN 1426<br>ASTM D5 | 56 | 50 (min) |

## *B. Aggregate tests*

In this study, aggregate grading curves for all mixtures were obtained from Turkish Highway Construction Specificions 2006 [11]. Table 1 shows the binder and wearing course layer gradiation limits for aggregates .

TABLE 2. GRADIATION LIMITS OF AGGREGATES

| Sieve diameter (mm) | Binder layer limit values passing(%) | Wearing layer limit values passing (%) | |
|---|---|---|---|
| | | *TYPE 1* | *TYPE 2* |
| 25 ( 1’’) | 100 | - | - |
| 19.0 (3/4’’) | 80-100 | 100 | - |
| 12.5 (1/2’’) | 58-80 | 83-100 | 100 |
| 9.5 (3/8’’) | 48-70 | 70-90 | 80-100 |
| 4.75 (No.4) | 30-52 | 40-55 | 55-72 |
| 2.00 (No. 10) | 20-40 | 25-38 | 36-53 |
| 0.42 (No. 40) | 8-22 | 10-20 | 16-28 |
| 0.18 (No. 80) | 5-14 | 6-15 | 8-16 |
| 0.075 (No. 200) | 2-7 | 4-10 | 4-10 |

Sieve analysis were carried out and appropriate intervals belongs to grading curve for the aggregate used in the study was determined closed the binder layer. Fig. 1 shows the gradiation graph of C, C1, C2 and specification limits curves. The major properties of aggregates are presented Table3.

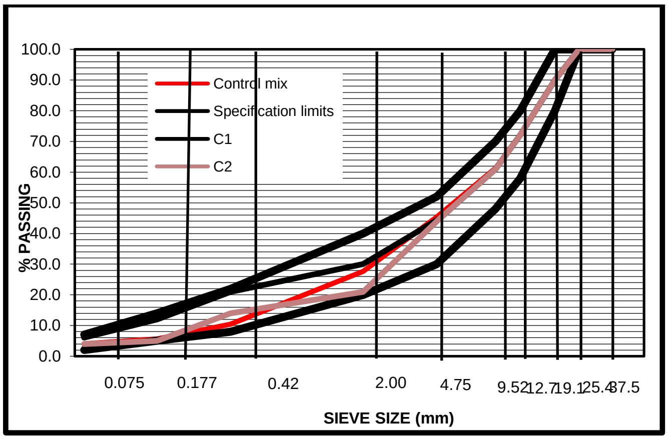


Figure 2.Gradiation graph of mixtures

TABLE 3. BASIC PROPERTIES OF AGGREGATES

| **Test** | **Test result** | **Specification** |
|---|---|---|
| Soundess of aggregates by use of Magnesium Sulfate% | 11,5 | TS EN 1367-2 |
| Los Angeles abrasion,% | 22,5 | TS EN 1097-2<br>ASTM C-131 |
| Flakeness index,% | 18,5 | BS 812 |
| Peel strength % | 65-70 | HTS Part 403 |
| Methylene blue % | 0,75 | TS EN 933-10 |

## *C. Marshall mix design*

54 samples were totally prepared according to Turkish Highway Construction Specificions 2006, tested marshall stability test machine and marshall stability, marshall flow, bulk specific gravity, void volume, void filled with asphalt and void between mineral aggregates valueswere calculated. Following curves were plotted using these values.

1. Bulk specific gravity ($D_p$) versus bitumen content
2. Marshall stability versus bitumen content
3. Marshall flow versus bitumen contents
4. Percentage of air void ($V_h$)versus bitumen content
5. Percentage of void filled with asphalt (V.F.A.) versus bitumen content
6. Percentage of void in mineral aggregates versus bitumen content

Marshall stability values depending on bitumen content were given as graphic in Fig. 3. As can be seen from the figure, maximum Marshall stability value was found for C1 mixture. After this value, it was seen the decrease for other samples. According to Turkish Highway Construction Specificions 2006, the marshall stability value must be minimum 750 kg. for binder layer. All marshal stability values were found less than 750 kg.

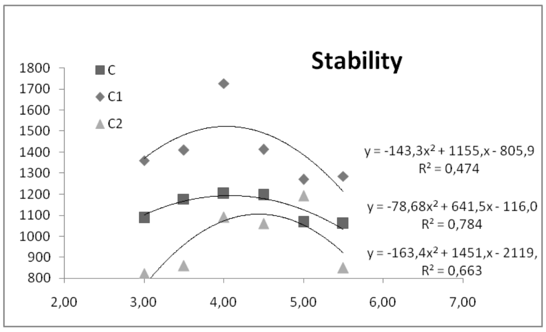


Figure 3. .Marshall stability test results

Fig. 4 shows the flow values for all samples. Turkish Highway Construction Specificions states that, flow values must be ranged between 2 mm. and 4 mm. Flow values of the samples were found to be within specified limits.

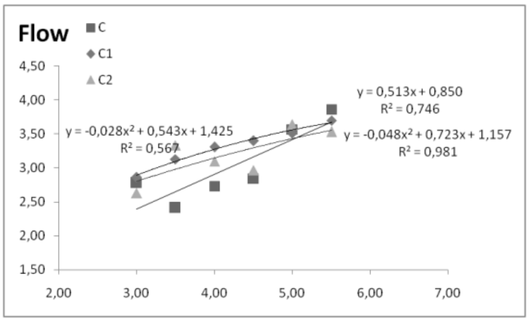


Figure 4. .Marshall flow test results

Fig. 5 shows the Voids in mineral aggregates (VMA) values. According to Turkish Highway Construction Specificions 2006, the VMA values must be minimum 13 % for binder layer. As can be seen from the figure, all VMA values of C and C1 mixtures were found greater than 13 % , but most of VMA values of C2 were found less than 13%.

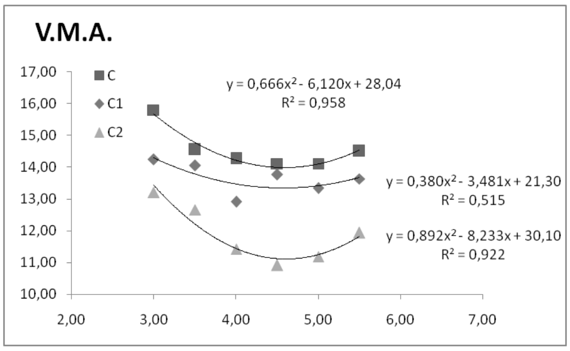


Figure 4. .Relationship of VMA and bitumen content

When considering marshal stability graph, the lowest marshall stability value was obtained at the C2 mixtures. Flow value shows the flexibity properties of hot mixtures. When comparing mixtures according to flow values, C1 mixtures were showed maximum performance. Optimum bitumen content of C, C1 and C2 were determined from the Marshall diagrams respectively as 4,37 %., 4,18% and 4,79%. According these results, it can be said that, C1 is the lowest cost mixtures.

# IV. CONCLUSIONS

In this study, use of RMA in the hot mix asphalt concretes was investigated. The samples containing either RMA fine aggregates or limestone fine aggregates were prepared according to Turkish Highway Construction Specificions 2006. Marshall stability tests were performed for each prepared samples and optimum bitumen content for three mixtures (C, C1, C2) were determined. The following conclusions can be drawn based on the results obtained from in the study:

From the results of hot mix test described above, it has showed that used 100% RMA as a fine aggregate have had the best marshall stability performance when evaluated in terms of marshall stability. This mixture requires minimum bitumen ratio (4,18 %) as well. In addition all of this, it has showed that 100 % RMA mixtures have had the best flexibility performance according to marshall flow values. From the results all of values described above, we can infer that %100 RMA can be used as fine aggregates in hot asphalt mixitures as binder layer.

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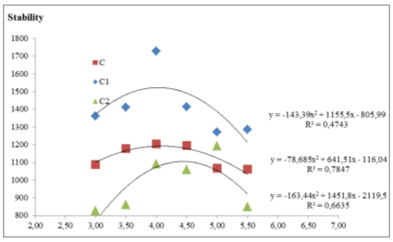


In thisstudy, the usability of marble wastes as fine aggregate in hot mix asphal tproduction was invertigated. Best Marshall Stability value was obtained from %100 recycled marble of fine agregate rate mixtures