COMPARATIVE EVALUATION OF REPLACEMENT FOUNDRY SAND WITH MINERAL FINE AGGREGATES ON HMA PROPERTIES

Bekir AKTAŞ, Şevket ASLAN

Department of Civil Engineering, Erciyes University, Kayseri, Turkey

baktas@erciyes.edu.tr

Abstract: In this study the influence of using waste foundry sand (WFS) as replacement for mineral fine aggregates on the Hot Mix Asphalt (HMA) properties is evaluated. An experimental program was conducted on the asphalt concrete samples prepared with 5% replacement of mineral fine aggregates. HMA samples, made of WFS and conventional mineral aggregate, were compared in terms of their Marshall Stability, Flow, Bulk Specific Gravity, Void in Mineral Aggregates and Voids Filled with bitumen in the total mixture properties. The results obtained from the experiments indicate that the replacement of WFS with mineral fine aggregate has a significant potential to use in bituminous hot mixtures.

Keywords: Foundry sand, HMA Properties

Introduction

One of the waste materials having that has a possibility to be used in road construction is waste foundry sand. For metal casting process to make molds and cores, uniform silica sand is used. Usability of foundry sands as an aggregate in road construction field gives the engineers the ability to construct better sustainable structures which is important to reduce their environmental pollution. Recently waste foundry sand has been used as a partial replacement for aggregate in bituminous asphalt mixture. Some states in USA have reported that the use of 8 to 25 % foundry sand is possible HMA to replace conventional aggregate (FHA 2004).

Use of waste foundry sand has a great potential in HMA for positive performance. Especially, the mixture stability, moisture resistance with waste foundry sand can be higher than HMA with conventional sand. In addition, some studies reported that foundry sand added samples demonstrated have increased rutting resistance (Delange et al 2001).

Foundry sands added HMA mixtures have good durability characteristics for weather affect. (Emery 1993). The same equipment and methods are used for foundry sand added HMA production. Regarding to HMA production at the plant, if the foundry sand has less than 5% moisture, it can be dispatch directly into a batch plants pug mill. Likewise, it can also dispatch through a recycled asphalt feed for drum plants where the foundry sand can be further dried, by the already heated conventional aggregates. Generally, foundry sand should be clean of thick coatings of burnt carbon, binders, and mold additives. It can be adhesion problem between the asphalt cement binder and the foundry sand. Clay clumps also can be removed by screening and/or washing. To remove iron and rubbish from the foundry sand, magnets and/or hand separation can be used (D'Allesandro et al 1990). At the drying process the presence of organic binder and bentonite materials can increase the time required. Also, this can increase the load on the hot mix plant dust collection system (Bradshaw et al. 2010).

The aim of this paper is to determine the general mechanistic characteristics of HMA that were made replacement foundry sand with mineral fine aggregates by measuring essential Marshall properties and by performing various laboratory tests. Marshall Stability, Flow, Bulk specific gravity (G_{mb}), Void in Mineral Aggregate (WMA) and Voids Filled with bitumen (VFA) were determined on the Marshall samples made with waste foundry sand and with conventional mineral aggregate added samples.

Materials and Methods

Mineral Aggregates

As a mineral aggregate a type of crushed dolomite was used for the coarse and fine aggregates for the asphalt concrete production. The crushed aggregates were produced in the Kayseri, Turkey. The quarry was made the aggregates in fractions 0/5, 5/9.5, 9.5/12.5 and 12.5/19.5 mm.

Waste Foundry Sand

The grain size of waste foundry sand has very uniform distribution. According to sieve analysis 88% percent of waste foundry sand that used in this study is in between #10 (2 mm) and # 200 (0.075 mm) sieve sizes. 11 percent of foundry sand is smaller than #200 sieve size. Particle shape of the foundry sand is typically sub angular to rounded. Foundry sand consists primarily of silica sand which has more than 80% silicon dioxide, coated with a thin film of burnt carbon and residual binder (Du et al 2002). Figure 1 shows a view of foundry sand used in this study.

Figure 1. A picture of waste foundry sand used in mixtures

Experimental Work

Marshall Test

Foundry sand passing through a #4 sieve were added 5% to mixture instead of mineral aggregates of the same size to evaluate the usability of foundry sand in the binder course of HMA. For each mixture were designed according to Turkish General Directorate of Highways (KTŞ 2016) and the Marshall Mix design (ASTM D 6927) was carried out. Asphalt mixtures with mineral aggregate and foundry sand were prepared with a 3.5, 4.0, 4.5, 5.0, 5.5 and 6.0 percent rate of bitumen content for each dry mixture. Then, the Marshall Stability and flow tests were conducted.

Asphalt mixes with waste foundry sand are designed using standard HMA design method. In this study 50/70 penetration grade asphalt were used with dolomite and foundry sand aggregates for the fabrication of asphalt concrete specimens. The asphalt cement binder was provided from TUPRAS Company in Turkey. The physical properties of the bitumen were determined and controlled according to ASTM standards. Asphalt cement that is used in this research has a penetration grade of 55 (0.1 mm at 25 °C, 100 g & 5 s) and 1.025 g/cm^3 specific gravity. The aggregate gradation for two mixtures was selected in accordance with the guidelines specified by the Turkish General Directorate of Highways, as can be observed from Fig. 2. The total weight of aggregate for the standard Marshall specimens was prepared at 1150 g. and 75 blows were applied on each side to compact the specimens.

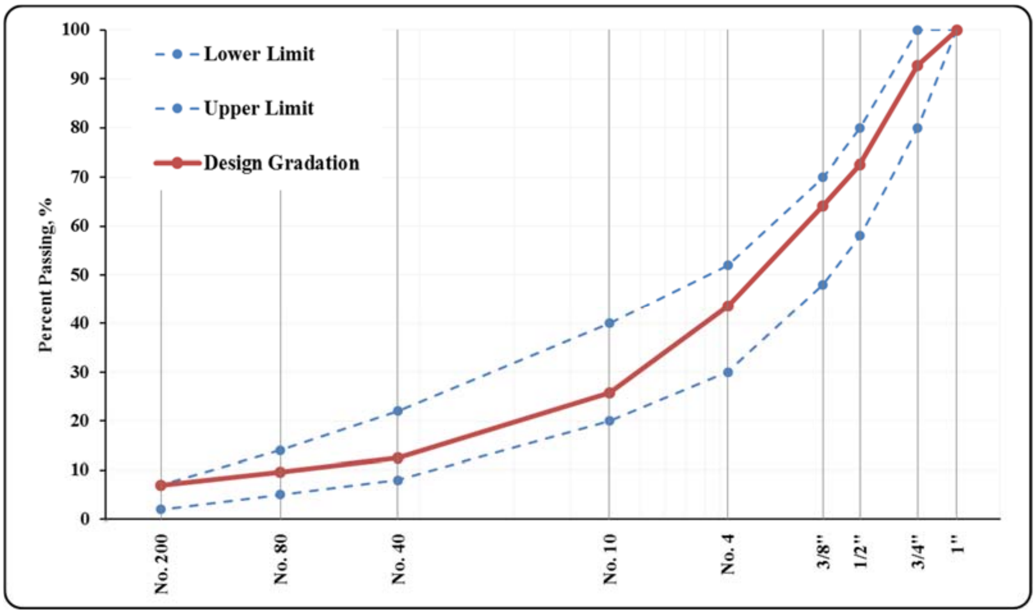

Figure 2. The aggregate gradation for the mixtures

Results

Marshall samples were compacted and tested by employing the asphalt cement content corresponding to maximum stability, maximum Gmb, median of designed limits of percentage air voids in the total mix and median of designed limits of percentage voids filled with bitumen in the total mix. In order to determine the optimum bitumen content for the mix design, the bitumen content corresponding to median of designed limits of percentage air voids is taken.

Fig. 3 shows the Marshall Stability and flow results of HMA made with foundry sand added and mineral aggregates. Structural strength of the compacted HMA determined by Marshall stability. Aggregate properties and gradations affect this strength in the first order with binder. When Fig. 3 is observed, it can be clearly seen that the asphalt concrete stability with foundry sand is higher than the samples which were produced with mineral aggregates at the optimum binder content. Also, the Marshall Stability values of each asphalt concrete sample passed the 750 kgf that is the minimum limit for Turkey roads. The flow value of asphalt concrete is important due the fact that it reflects the plasticity properties and asphalt mixtures flexibility under traffic loads. The Marshall samples corresponding to the deformation of the load are broken; this represents a measure of the flow and flow with the value of the internal friction. Flow has a linear inverse trend relationship with internal friction (Brawn E.R. et al. 2009). Fig 3. Shows the relationship between flow and bitumen content for all mixtures. The results showed that the specimen flow results of the foundry sand added samples are lower than the control samples. Asphalt concrete samples containing waste foundry sand yielded better stability and flow resistance performances.

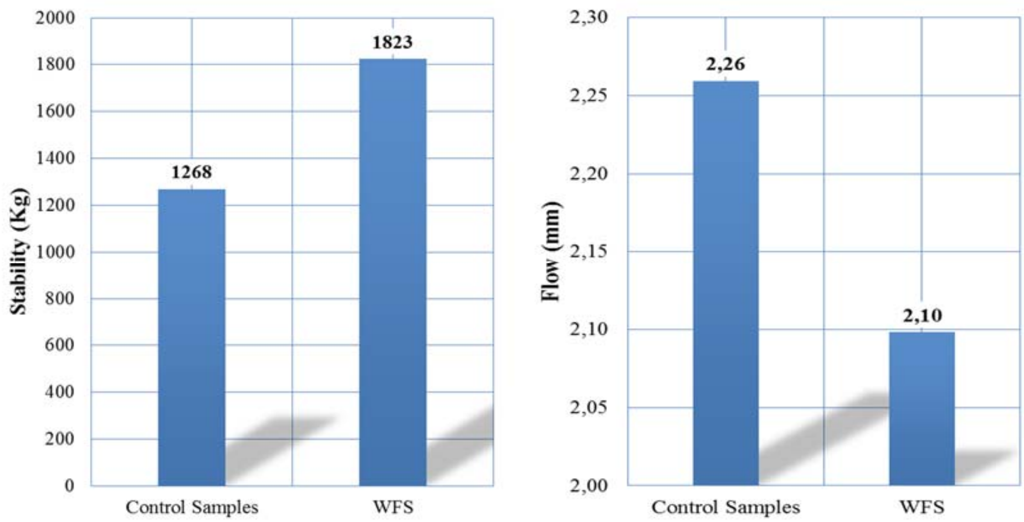

Figure 3. Marshall stability and flow values of asphalt samples at optimum binder content

Figure 4 shows the results of the optimum bitumen content, Gmb, VFA, and VMA of the specimens with foundry sand used and control mixtures. According to these results, it can be seen that the optimum bitumen content of WFS added samples is lower than the control samples. Also, bulk specific gravity increased with the WFS adding to mixture. Regarding to Vf and WMA, it also can be seen that they are slightly decreased with WFS added samples.

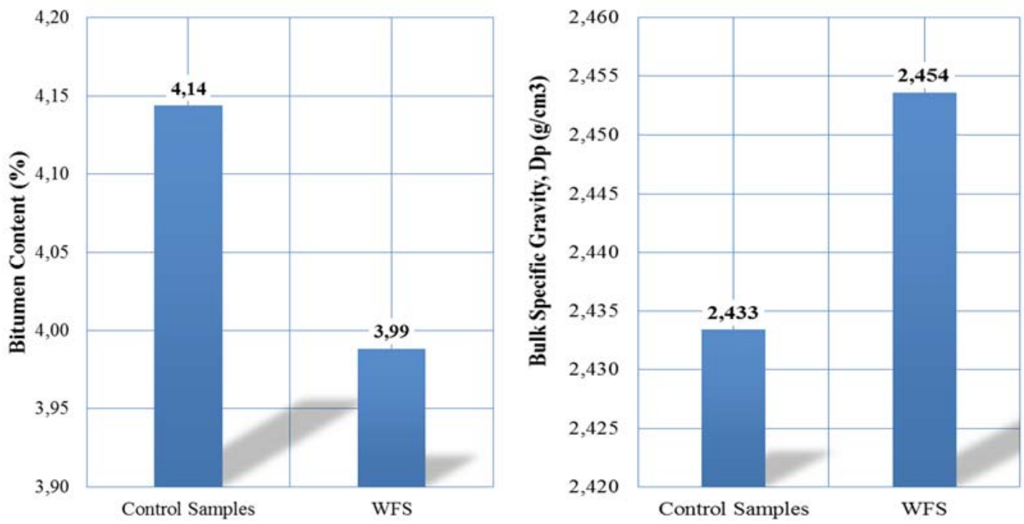

Figure 4a. Bitumen Content and Gmb results of the samples.

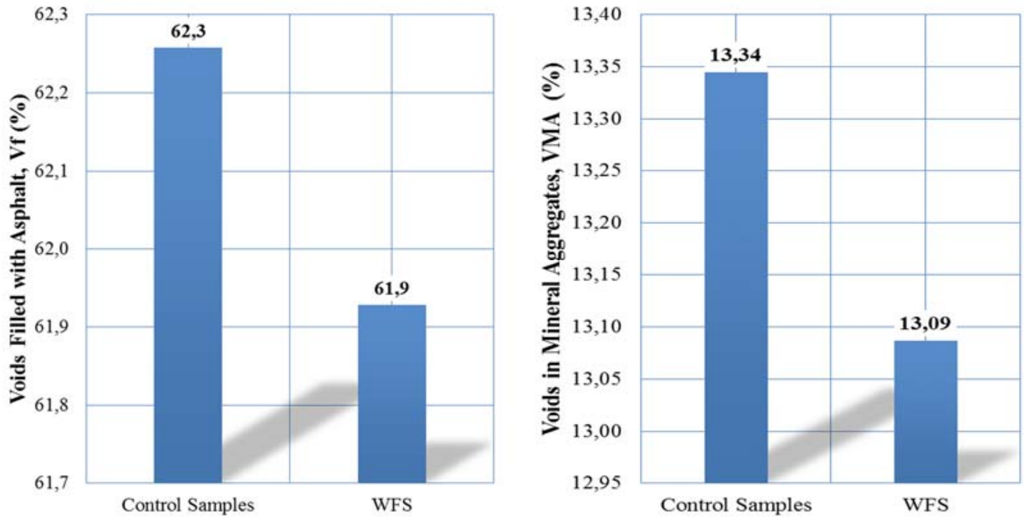

Figure 4b. Vf and VMA results of the samples.

Conclusions

This study aims to compare and evaluate the influence of using waste foundry sand as a replacement of mineral aggregate in HMA. At the laboratory Marshall tests performed to determine the characteristics of HMA with various bituminous rate. According to the results derived from the laboratory test data, these conclusions can be report: Marshall Stability values significantly increase with WFS addition in the mixture replace of mineral aggregate for optimum bitumen content. Both mixtures pass the Turkish Highway standard criterion (750 kgf) for binder course. Regarding to flow resistance of the samples, asphalt concrete samples containing WFS demonstrated better flow resistance than the control samples. Another important result of this study is optimum binder content decreased with the WFS adding. This study shows that there is high possibility to use waste foundry sand in HMA binder course. Performance tests such as rutting, creep test, dynamic modulus tests etc. would be very beneficial to understand successfully influence of this material in the mixture.

Acknowledgement

This study was supported by the Scientific Research Projects Coordination Department of Erciyes University (Project Number: FBA-2015-5890). Authors of this study express their gratitude to ERÜ/BAP for sponsoring the project.

References

Federal Highway Administration (2004). Foundry sand facts for civil engineers. Federal Highway Administration (FHWA); Report no FHWA-IF-04-004.

Delange K, Braham A, Bahia H, Widjaja M, Romero P, Harman T. (2001). Performance testing of hot mix asphalt produced with recycled foundry sand. In: Annual Meeting of the Transportation Research Board

Emery J. (1993). Canadian Foundry Association. Spent foundry sand - alternative uses study. Queen's Printer for Ontario: Ontario Ministry of the Environment and Energy (MOEE)

D'Allesandro L, Haas R, Cockfield RW. (1990). Feasibility study on the environmental and economical beneficial use of waste foundry sand in the paving industry. University of Waterloo; Report for MRCO and the Canadian Foundry Group.

Bradshaw S. L. et al. (2010). Using Foundry Sand in Green Infrastructure Construction. Green Streets and Highways.

Du L, Folliard K, Trejo D. (2002). Effects of constituent materials and quantities on water demand and compressive strength of controlled low-strength material. J. Mat in Civil Eng. (6):485-95.

KTŞ (2013). Ministry of Transport. General directory of highways Turkish State Highway Specifications. Ankara, Turkey

ASTM D 6927 (2006). Standard test method for Marshall Stability and flow of bituminous mixtures., West Conshohocken, PA

Brawn, E.R. et al. (2009). Hot Mix Asphalt Materials, Mixture Design and Construction. Lanham Maryland : Third Edition. NAPA Research and Education Foundation.

