Investigating the Effect of Limestone Powder as Mineral Fillers in Asphalt Mixtures

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1. INTRODUCTION

Mineral filler is a small proportion of the total aggregate content, but due to its high asphalt affinity, it may change the behavior of the HMA (Hot Mixture Asphalt) during the design life or deteriorate rapidly. To fix this moisture-damaged asphalt, some researchers have turned to develop anti-stripping additives, where limestone is a common among them [1)].

Afghanistan does not have sufficient technical expertise to use existing limestone for road paving. Yet pavements are made with stone dust fillers as a result of the wide production and long-term technical expertise. The goal of this study was to investigate the performance of limestone powder as a mineral filler in asphalt concrete and compare the results with the use of conventional stone dust as a mineral filler consider the loading condition in Afghanistan. Aggregates and filler were utilized from the available aggregates and filler in Japan. Research data would be modified to show the various types of asphalt mixtures.

2. METHOD AND MATERIAL

Marshall mix design method was used to produce different aggregate sizes in mixtures using limestone and stone dust as mineral fillers of the mixtures. Specimens were prepared as per ASTM D-3515[2)] standard obtaining the OAC (Optimum Asphalt Content). Then the stability and wheel tracking test of each mixture was analyzed.

The elemental composition of each mineral filler was determined by X-ray fluorescence spectrometry EDX-720 (Shimadzu) and the minerals fillers have extremely different elemental structures, with the limestone having 98% Calcium and the stone dust filler having more Silicon, Aluminum and Ferrous. Aggregates and stone dust were extracted from different quarries and limestone was produced in Japan. The basic gravities, proportions of grains < 75µm, and compositions of each mineral filler is described in Table 1 and 2. Penetration grade (60/80) bitumen has been utilized for creating each mix design of asphalt mixtures.

Table.1 Properties of Mineral Fillers

	Limestone	Stone Dust
Specific Gravity	2.71	2.63
Passing of 75 µm Sieve	81.6%	61.4%

Table.2 Components of Mineral Fillers

Elements	Limestone	Stone Dust
Si	1.55%	64.05%
Al		18.98%
Fe		7.01%
K	0.52%	4.33%
Ca	97.81%	4.18%
Ti		0.91%
S		0.20%
Mn		0.16%
Zr		0.069%
Sr	0.071%	0.03%

3. MARSHALL STABILITY TEST

Mix designs of ASTM D-3515 standard namely (D2, D3, D4 and D5) having nominal maximum aggregate size (NMAS) of 37.5mm, 25mm, 19mm and 12.5mm, respectively, have been used for investigation of the performance of two different filler materials.

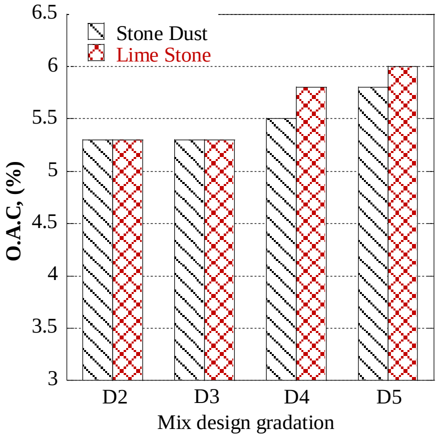

Fig. 1. OAC of each mix design

Fig.1 represents the OAC of mixtures where D2 and D3 has 5.3% bitumen for both fillers, however D4 and D5 has higher OAC, for the mixtures having limestone fillers. As per surface area of aggregates, finer aggregates have high tendency to absorb higher bitumen content which results in smaller air voids content Fig.2. Mixtures with limestone fillers exhibit lower air void content than stone dust fillers. Low air void in mixtures causing increased fatigue distress whereas increased air void content can increase the moisture damage of the mixtures.

4. WHEEEL TRACKING TEST

In Wheel Tracking Test, for each mixture, on a specimen of 30cm by 30cm, a 686±10N load was applied at a constant speed of 42 pass per minute at a regulated air temperature of 60°C. The permanent deformation of the surface was reported in measured time intervals. Considering the NMAS of aggregates, specimen thickness for D2, and D3 is 10cm, while D4, and D5 is 5cm. To examine the effects of specimen thickness, a 10cm D4 specimen was prepared. In every aspect of the test, specimens containing stone dust as mineral filler has represented superior performance against mixtures with limestone.

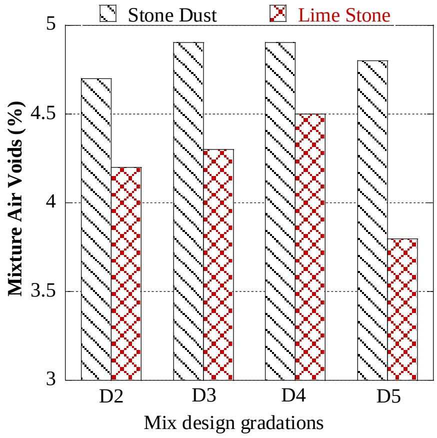

Fig. 2. Air void of each mix design

DS (Dynamic Stability) values (pass/mm deformation) of each mixture regardless of NMAS and specimen thickness, mixtures containing stone dust filler showed higher DS values compare to limestone. However, the tendency of DS values of mixtures decreased as the NMAS is increased Fig. 3. In Fig. 4 the maximum deformation of mixtures, containing the stone dust fillers have minimized deformation compare to limestone fillers after 60 minutes of dynamic loading.

It was found that Silica based fillers could withstand rutting and require less compaction energy during the construction process [3].

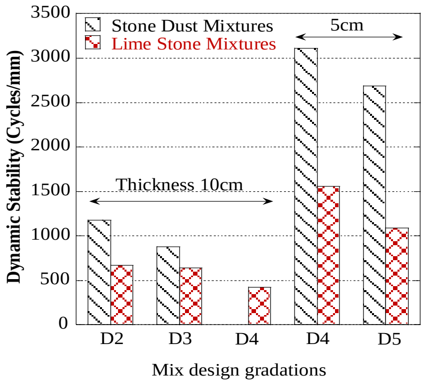

Fig. 3. Dynamic Stability Mixtures

5. DISCUSSIONS

Marshall stability tests showed, limestone filled specimens had lower air voids, relative to stone dust filled specimens, which resulted in higher stability values. As a consequence of surface area of the mineral fillers that greatly affect OAC, in return it may significantly change the rheological properties of asphalt mixtures. The test result of the wheel-tracking test indicates that stone dust specimens is performing slightly better and it is more resistant to permanent deformation from dynamic loading compare to limestone mineral fillers. Overall, all specimens with stone dust as a filler showed improved performance. By EDX analysis it was found that these two mineral fillers have entirely different chemical elements. Further studies are required to see how each filler interacts with the chemical substance of the bitumen.

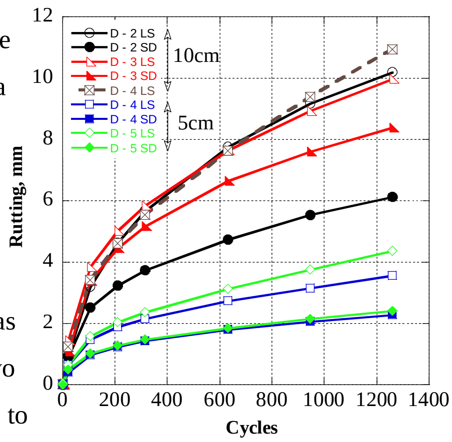

Fig. 4. Max. Deformation of Mixtures

In conclusion, the stone dust filler outperformed the limestone filler under laboratory environment and loading conditions while the better performance of the limestone filler is proven globally but, in this research, it decreased the performance of the asphalt mixtures under laboratory loading conditions. Therefore, focus should be put on the additional needs to compare both minerals fillers in terms of moisture damage and fatigue damage to preserve the very optimum performance of the asphalt pavement during its design life in comparison here maintenance's efforts will be reduced.

REFERENCES

1) Evaluating the Impact of Lime on Pavement Performance, National Lime Association, Final Report, June 9, 2010,
2) “Specification for Hot-Mixed, Hot-Laid Bituminous Paving Mixtures, ASTM”
3) Yohannes Gebremeskel Kiflat; The Effect of Filler Type and Shape on HMA Energy Dissipation Performance, Master thesis dissertation. Royal Institute of Technology (KTH), 2013