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Characterizing the Aggregate Petrography for Improvement in Asphalt Mix Performance

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ABSTRACT

Pavement failure primarily arises from the inadequate selection of aggregate which is dependent on petrography. Petrographic analysis of the aggregates, commonly performed during the initial phase of quarry exploration, offers valuable insights into the fundamental characteristics on which various others, such as mechanical strength, depend. Previous research efforts in this domain have been limited, with only a few studies attempting to establish a relationship between aggregate minerology and the performance of asphalt mixes. The objective of this study is to evaluate petrographic properties, and to identify the minerals that significantly contribute to rutting resistance and to find out stripping value of different aggregate. For this investigation, three different quarries in Pakistan namely Margalla, Pathargarh, and Sargodha were selected to collect samples of aggregate. Basic testing of all quarries was found out. After that performance tests were conducted on the asphalt mix, specifically the wheel tracker test, in order to ascertain the extent of rutting. The study concludes that aggregate having greater amount of carbonate and less amount of other minerals i.e., feldspar, quartz and hematite offer better resistance to rutting.

KEYWORDS: Rutting, Quartz, Petrography, Aggregate, Carbonate

1 INTRODUCTION

Petrographic analysis is a methodology employed to forecast the performance and behavior of a substance. This particular approach utilizes the study of mineralogy and its constituent components to predict and analyze the behavior of aggregates in various scenarios [1]. Within the realm of geology, specifically petrology, the focus lies in the examination of rocks and the circumstances surrounding their formation [2]. Consequently, stratigraphy is often combined with sedimentary petrology as it delves into the processes involved in the creation of sedimentary rock. Mineral chemistry, crystal structure, and physical properties, including optical properties, are subjects of study in mineral chemistry and mineralized artifacts. The realm of mineralogy-specific research encompasses investigations into the origin and development of minerals, as well as their classification, distribution, and applications [3]. By developing experimental procedures or employing microscopic approaches to evaluate asphalt materials, as described above, the performance of asphalt mixtures can be enhanced [4].

Due to its outstanding performance and affordability, asphalt pavements are frequently employed in modern transportation infrastructure. Over the course of their useful lives, these pavements experience numerous distresses and significant traffic loads. Rutting is a serious problem that shortens the lifespan and degrades the performance of asphalt pavements. Rutting is the term used to describe the persistent deformation or displacement of the pavement surface brought on by continuous wheel loads and resulting in the formation of a small depression or groove. It not only degrades the pleasure of the ride and the safety of other road users, but it also demands expensive, frequent maintenance and repairs [5].

In-service performance and mechanical behavior of aggregates are significantly affected by their mineralogy and degree of alteration. In higher concentrations, certain secondary minerals can cause aggregates to lose their physical and mechanical properties due to their smooth layers, cleavage, or fibrous or platy crystal habits, and as a result they will perform poorly as aggregates [6]. Due to the rise in construction-related failures, it is critical to comprehend that mineralogy can be used to identify issues with building engineering. The most important factors in each application and their classification for diverse technical reasons are the physicomechanical characteristics of rocks used as aggregates.

2 METHODOLOGY

A three-phase study was designed to accomplish the study objectives. In phase one, we selected and collected the sample from three quarries and further we determine the engineering properties of aggregate. In second phase petrographic characteristics of the selected aggregate quarries were found out and stripping test were performed. In phase three, performance tests were performed and compared the results of the selected quarries among each other based on the petrographic characteristics of selected aggregates quarries.

2.1 Testing of Aggregate and Binder

Different physical and mechanical properties of aggregates i.e., specific gravity, flakiness index, elongation index, un-compacted voids, Aggregate Crush Value & impact value, and water absorption were determined using BS and ASTM Standards and basic testing of binder content is also found out as shown in **Table-2 & 3** respectively.

2.2 Petrography

Petrographic examination serves as one technique to forecast the performance and behavior of a material. This approach utilizes the knowledge of mineralogy and its constituent parts to forecast and analyze the behavior of the aggregate in various scenarios. In the domain of geology referred to as petrology, the study focuses on rocks and the circumstances encompassing their formation. In this particular investigation, a petrographic assessment was conducted on aggregates sourced from three distinct quarries: Margalla, Pathargarh and Sargodha. A microscopic examination of thin sections of the samples was carried out, and the mineralogy was determined using the X-Ray Diffraction method.

2.3 Stripping Value Test

The stripping value test is performed to assess the vulnerability of asphalt-aggregate blends to damage caused by moisture, specifically focusing on the potential detachment of the asphalt binder from the aggregate surface. This test is performed according to ASTM D3625. Firstly, prepare the sample of aggregate and binder. Clean the aggregate and make it in oven dry. Then take 5% of bitumen and make a coating of it in a beaker containing aggregate. Then immersed the prepared sample in the boiling water for 60-120 minutes. After that cool the sample to room temperature and visually examine each specimen.

2.4 Performance Test

The combination of compaction and shearing causes the formation of rutting, which leads to depressions along the wheel paths and minor upheavals along the edges of the sidewalk. In order to evaluate the susceptibility of Hot Mix Asphalt (HMA) to deformation under load, the depth of these ruts is measured using the wheel tracking test. This test involves subjecting a loaded wheel to repeated passes at a specified temperature. In this study, Binder of 60/70 penetration grade is used to make asphalt mix.

2.4.1 Gradation of Mix Design

Adopted gradation of aggregate for different areas of Margalla, Pathargarh and Sargodha was measured for NHA-B upper and NHA-B lower having variability in sieve sizes and shown in Table 1.

Table 1 Adopted Gradation of Aggregate

Sieve Size	Margalla	Pathargarh	Sargodha	NHA-B upper	NHA-B Lower
19	100	100	100	100	100
12.5	84	82	85	90	75
9.5	72	65	70	80	60
4.75	46	55	50	60	40
2.36	35	30	34	40	20
1.8	18	19	16	27	12
0.6	13	11	17	19	8
0.3	9	8	10	15	5
0.15	7	6	6	11	4
0.075	4	7	5	8	3

2.4.2 Optimum Binder Content

Samples for Mix Marshal test is being prepared and tested according to specifications using different percentage of bitumen according to hit and trial method and with past experience.

Performed the test according to mix design criteria which may include flow, air voids, voids in mineral aggregate and stability parameters. Identify the bitumen content at which optimum mix properties is achieved. The bitumen content for Margalla, Pathargarh and Sargodha is 4.15,4.2 and 4.30 respectively.

Figure 1 Wheel Tracker Apparatus

3 RESULTS AND DISCUSSION

3.1.1 Engineering Properties of Aggregate & Bitumen

The engineering properties of aggregates and bitumen are shown in Table 2 and all the results are within the range specified in National Highway Authority.

Table 2 Engineering properties of aggregate

Test Title	Margalla	Pathargarh	Sargodha	Specifications Limits with units
Specific Gravity	2.7	2.59	2.68	2.5-3
Flakiness index	6.20	7.40	7.10	10 % max
Elongation index	6.45	7.80	9.00	10% max
Un-compacted voids	48.50	49.50	48.50	45% min
Aggregate Crush Value	22.00	25.00	23.00	40% max
Aggregate Impact Value	24.50	27.40	28.50	40% max
Water Absorption	1.10	1.30	1.25	2% max

Table 3 Engineering Properties of Bitumen

Bitumen Test	Standard	Bitumen	Units	Specification Limits
Penetration at 25°C	ASTM D 5	67	(1/10th mm)	_
Softening Point	ASTM D 36	47	°C	_
Ductility at 25°C	ASTM C 88	100	cm	100 (min)
Flash and Fire point	ASTM C 142	261	°C	232 (min)

3.2 Petrographic Properties

First of all, samples were collected from selected quarries. Then broken the sample into pieces, then crush the sample for making thin sections for analysis. In next step grind and polish one side for analysis. After that place the sample into microscope for examination. Laboratory procedure is shown in fig 2 and results are shown in Table 4

Figure 2 Petrography of aggregate

Table 4 Minerals of different aggregates

Component	Margalla	Pathargarh	Sargodha
Carbonate	95.5	93.0	79.5
Quartz	1.5	3	5.70
Hematite / Limonite	1.0	2.5	1.60
Chert	-	-	-
Magnetite	-	-	6.50
K-Feldspar	-	0.5	4.20
Clay	2.0	1.0	2.5

3.3 Stripping Value Test Results

Stripping test is performed on three different aggregates and results shown that aggregate having more percentages of carbonate shows better resistance to stripping because carbonate aggregate has rough surface and it make better bond with the bitumen. In contrast quartz have polished surface and it does not make better bond with bitumen. Results are shown in fig 3

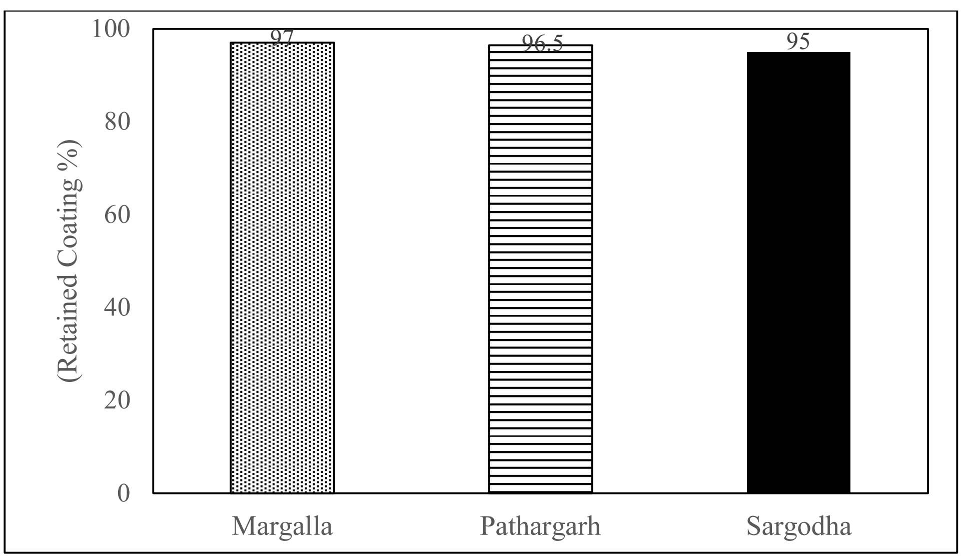

Figure 3 Results of Stripping Value test

3.4 Wheel tracking test

The wheel tracking test is utilized to quantify the extent of grooves formed by multiple passes of a weighted wheel under a specified temperature, in order to evaluate the susceptibility of Hot Mix Asphalt (HMA) to deformation when subjected to a load. The wheel tracker test is conducted on different specimens composed of three distinct aggregates. This examination is carried out at a temperature of 55 degrees Celsius, with a load of 720 Newtons, and with a total of 10,000 passes.

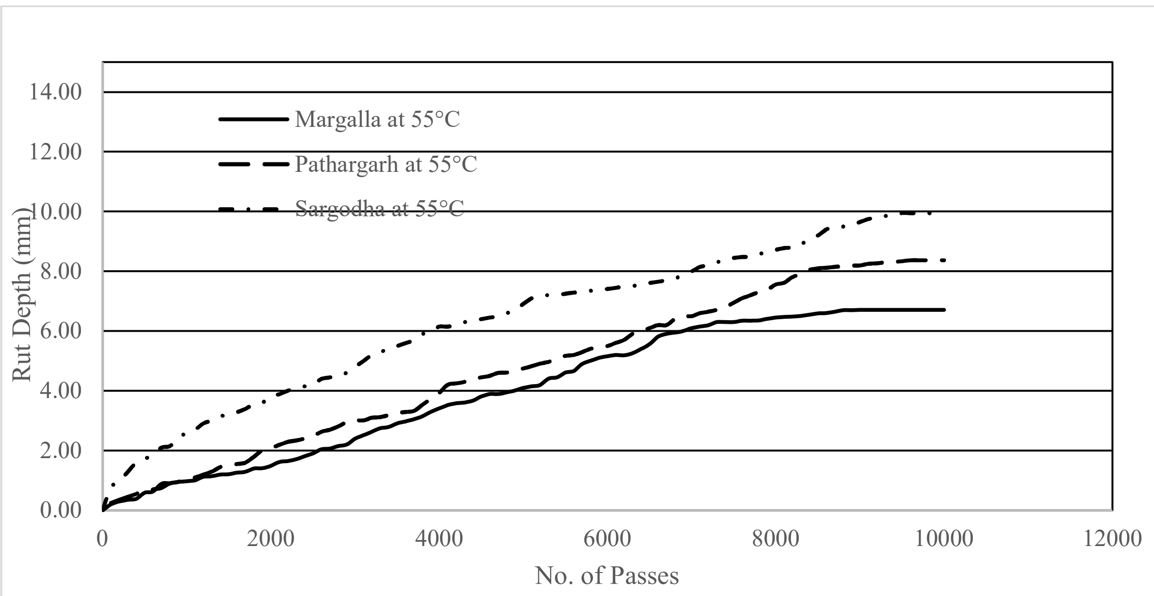

Figure 4 Rutting Graph of aggregate

In Figure 4, the measurements of rut depth were taken at a testing temperature of 55°C for three different areas: Margalla, Pathargarh and Sargodha. It was observed that the rutting depth varied among these three regions. Specifically, Sargodha exhibited the highest rutting depth, measuring 9.95 mm. On the other hand, Margalla showcased the lowest rutting depth, i.e., 6.71 mm. Pathargarh, meanwhile, showed a rutting depth of 8.37 mm. Importantly, all three mixtures, namely Margalla, Pathargarh and Sargodha demonstrated rutting values that fell within the prescribed criterion of 12 mm at a temperature of 55°C.

4 CONCLUSION

In this study engineering properties of aggregate and bitumen were in specified limits. The petrographic properties shows that Margalla has highest mineral content of carbonate i.e., 95.5 percent while Sargodha has higher content of Magnetite, K-feldspar and Quartz as compared to Margalla and Pathargarh. From the study it is concluded that the aggregate having higher quantity of carbonate and less quantity of quartz and K-feldspar has greater resistance to rutting because carbonate aggregate makes stronger bond with bitumen because of its surface texture. Inversely, quartz have polished surface and it makes weak bond with bitumen and chemical degradation of feldspar causes micro-cracks and rapid disintegration. Also stripping test shows that Margalla aggregate has better adhesion with bitumen and more retained percentage of coating because of carbonate content while Sargodha contains more quartz content so it is more exposed to stripping as compared to Margalla.

REFERENCE

1. Antolik A, Dąbrowski M, Jóźwiak-Niedźwiedzka D. Petrographic Evaluation of Aggregate from Igneous Rocks: Alkali–Silica Reaction Potential. Minerals. 2023; 13(8):1004. https://doi.org/10.3390/min13081004
2. El-Desoky H, Abd El-Hafez N, Khalil A, Arafat A, Hasan MG, Youssef T. The Geology, Petrography, and Geochemistry of Egyptian Dokhan Volcanics: A Potential Source for Construction Aggregate. Minerals. 2023; 13(5):635. https://doi.org/10.3390/min1305063
3. Marques de Sá, Carlos Dinges and Martins, Bruno Luiz Leite and Conceição, Herbet, Petrography and Mineral Chemistry of Fe-Ti Mineralization from the Canindé Gabroic Complex and Associated Rocks, Canindé Domain, Sergipano Orogenic System, Brazil. http://dx.doi.org/10.2139/ssrn.4341667
4. Sara Anastasio et.al. (2016) Relevant Petrological Properties and their Repercussions on the Final use of Aggregates. Energy Procedia Vol.97, 546 – 553
5. Sabahat Hussan,, Imran Hafeez, Naveed Ahmad, et al. (2020) Modelling asphalt pavement analyzer rut depth using different statistical techniques, Road Materials and Pavement Design.
6. Telloli C, Aprile A, Marrocchino E. Petrographic and Physical-Mechanical Investigation of Natural Aggregates for Concrete Mixtures. Materials. 2021 14(19):5763. https://doi.org/10.3390/ma14195763
7. Sabahat Hussan, Mumtaz Ahmed Kamal, Imran Hafeez, Danish Farooq, Naveed Ahmad & Shahab Khanzada (2017): Statistical evaluation of factors affecting the laboratory rutting susceptibility of asphalt mixtures, International Journal of Pavement Engineering, DOI: 10.1080/10298436.2017.1299527
8. Mohsen, Aboutalebi, Esfahani., Mohebali, Kalani. (2020). Petrographic analysis method for evaluation and achieving durable hot mix asphalt. Construction and Building Materials, 234:117408-. doi: 10.1016/J.CONBUILDMAT.2019.117408
9. Ding, Xunhao, Tao Ma, and Wang Gao. "Morphological characterization and mechanical analysis for coarse aggregate skeleton of asphalt mixture based on discrete-element modeling." Construction and Building Materials 154 (2017): 1048-1061.
10. White, Thomas D., John Ernest Haddock, and Erza Rismantojo. Aggregate tests for hot-mix asphalt mixtures used in pavements. Vol. 557. Transportation Research Board, 2006.
11. Sara Anastasio et.al. (2016) Relevant Petrological Properties and their Repercussions on the Final use of Aggregates. Energy Procedia Vol.97, 546 – 553