Natural and Applied Sciences International Journal (NASIJ)
eISSN: 2788-4619 (online)
https://www.ideapublishers.org/index.php/nasij
Vol. 5, No. 1 (January-June), 2024, pp. 44-54
https://doi.org/10.47264/idea.nasij/5.1.4

Research Article

Performance evaluation of marble dust as a filler material in asphalt concrete in Peshawar, Pakistan

Atif Ali[1] | Muhammad Majid Naeem[1] | Fawad Ahmad*[1] | Fazle Subhan[2]

1. Department of Civil Engineering, Iqra National University, Peshawar, Pakistan.
2. School of Economics and Management, Dalian University of Technology, Dalian, China.

* Corresponding Author Email: fawad.cengr@gmail.com

Abstract:

Marble dust generated during cutting, grinding, carving, and polishing is one of the significant sources of marble production. Due to its high production, it can be used as an alternative material and has been used as a filler replacement to retain outstanding usability. This study aims to assess the effectiveness of marble dust as filler in asphalt concrete. A mixed design was developed for asphalt concrete with marble dust. To assess the impact of various percentages of these industrial waste on the qualities of the asphalt filler matrix by contrasting it with the properties of the mix, including stone dust as filler, various tests like Marshall stability and flow, indirect tensile, wheel tracker and Resilience Modulus (MR) were carried out. The comparison results reveal that modified asphalt concrete has 1.63% more stability than normal concrete. Similarly, the indirect tensile test shows 23% more strength, the wheel tracker test shows low rutting depth for modified HMA and a 44% increase in MR. The bitumen extender marble dust infill reduces the ideal binder by 4.05%. As a result, marble dust can be used as a filler in asphalt concrete up to 4.5% with success, creating a stable, economical, and eco-friendly pavement.

Article History

Received:
12-Dec-2023

Revised:
22-Jan-2024

Re-revised:
23-Feb-2024

Accepted:
6-Mar-2024

Published:
27-Mar-2024

Keywords: Marble dust, Marble production, Dust as a filler, Asphalt concrete, Wheel tracker test, Indirect tensile test, Marshall stability and flow, Resilience Modulus (MR).

How to Cite:
Ali, A., Naeem, M. M., Ahmad, F., & Subhan, F. (2024). Performance evaluation of marble dust as a filler material in asphalt concrete in Peshawar, Pakistan. *Natural and Applied Sciences International Journal (NASIJ)*, *5*(1), 44-54. https://doi.org/10.47264/idea.nasij/5.1.4

1. Introduction

Mineral fillers are important for the high performance of pavement structures. The primary source of filler is the stone dust obtained from stone crushing. The lack of stone dust is one of the challenging problems for highway construction. Cutting, grinding, and polishing are three complex operations of making marble. The amount of waste produced via these processes increases as more marble is produced (Careddu & Marras, 2015). Marble slurry is a byproduct of the production of marble blocks. Approximately 20% of the total marble handled is garbage (Rajgor *et al.*, 2013). This marble slurry is spread throughout a large area of surrounding land by the marble-cutting businesses (Celik & Sabah, 2008). This slurry threatens agricultural productivity and public health when it evaporates, causing severe environmental damage (Kumar & Yaashikaa, 2019). The increase in alkalinity decreases the porosity and permeability of the top soil layers, leading to water logging and reducing soil fertility (Greenway *et al.*, 2006). It burdens landfills, pollutes groundwater, and creates drainage concerns (Adeniran & Shakantu, 2022).

The various components that makeup the bitumen undoubtedly contribute to its properties in some way or another. Asphalt is the fractions that give the material its body (Caputo *et al.*, 2020). The resin content of the bitumen improves the material's ductility and adhesiveness. The oils found in bitumen regulate the material's rheology and viscosity. The sulphur, which is present in significant amounts and is primarily found in the high molecular weight fractions, regulates the material's stiffness. The acidity of the bitumen varies according to the presence of a specific oxygen complex (Zhang *et al.*, 2016). Therefore, the ability of the bitumen to adhere to the aggregate particles is determined in part by the acidity of the bitumen (Choudhary *et al.*, 2020).

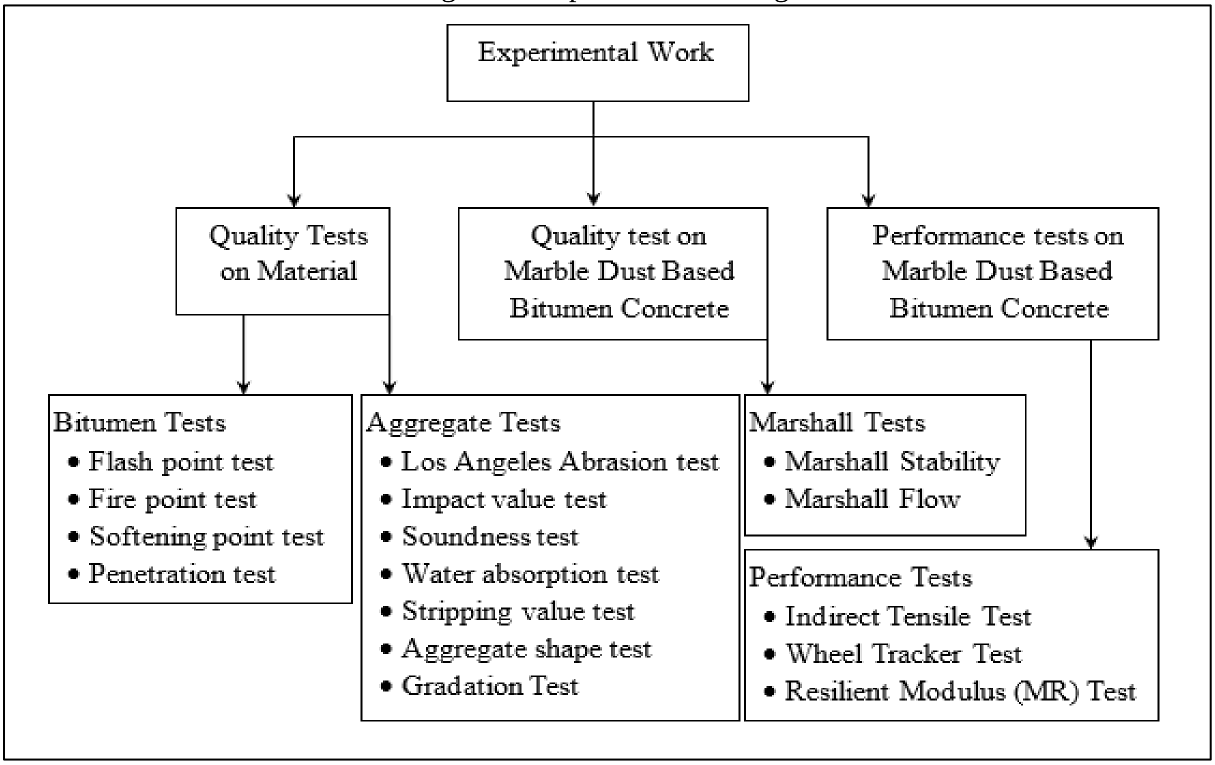
Asphalt is a critical component of construction. Asphalt provides stiffness, bearing capacity, and resistance to repeated axle loads as a building material. Axle load causes either permanent deformation, known as rutting, or fatigue cracking (Joumblat *et al.*, 2023). Pavement construction is typically done in layers, with each layer serving a slightly different purpose. Because they are in direct contact with moving vehicles, the top pavement layers are most stressed (Aliha *et al.*, 2021). Furthermore, because these layers are exposed to the environment, they are more likely to be stressed by temperature changes than by axle loading (Zhu *et al.*, 2021). Bitumen serves as a binder in asphalt concrete, and mineral aggregate serves as a structural framework. Mineral filler, which is divided into fine and coarse aggregate, accounts for nearly 90% of the total volume of asphalt concrete (Hossain, 2022). As a result, the mineral aggregate properties directly impact the hot-mix asphalt. The mineral filler significantly affects the properties of asphalt concrete, particularly how to aggregate the interlocks and the binds. The filler is an active ingredient that alters the properties of the asphalt mastic (Khan *et al.*, 2023).

As highway construction requires a significant investment. Lowering this investment is one of the agency's major objectives. Marble dust has properties similar to stone dust (Pateriya *et al.*, 2022) thus, it can be hypothesised that, the use of marble dust as a filler in asphalt concrete can produce similar or better results. Since marble dust is a kind of solid waste, utilising this waste material in asphalt concrete will lower the issue of environmental pollution (Victory, 2022). To achieve the objective, different percentages of marble dust were be replaced with stone dust to achieve the desired results.

2. Experimental work

Local marble industries provided the marble waste dust on Warsak Road in Peshawar. Various lab tests were performed to determine the quality and characterisation of both bitumen and aggregate in accordance with predetermined standards. Furthermore, marble dust-based concrete was subjected to three different performance tests. The experimental procedure is explained in Figure 1.

Figure 1: Experimental testing



3. Research methodology

The main components of asphalt concrete are as follows:

- Coarse aggregates: These aggregates have good interlocking properties as well as high compressive and shear strengths. The material was retained by the 4.75mm AASHTO No. 4 sieve. (Refer to Margalla)
- Fine aggregates: Provide stiffness to the binder and fill voids in the coarse aggregate. AASHTO No. 4 sieving of the material (4.75mm). (Refer to Margalla)
- Filler: By filling the crevices between the fine aggregate, filler adds stiffness and permeability. The material has been sieved using AASHTO No. 200. Marble dust (obtained from the Mohmand Agency).
- Binder: Fills voids and uses adhesive forces to hold the aggregate together. This uses grade 60/70 bitumen (from Attock Oil Refinery).
- Test protocol for aggregate: Protocol for aggregate testing to withstand the effects of traffic, the aggregate used must be strong, hard, tough, and lasting, as well as the necessary ideal shape. In order to achieve this, the following aggregate quality checks were carried out:

4. Results and discussion

The results of the material quality tests are shown in Tables-1 and 2, along with their relevant standards and limits.

Table-1: Quality testing on bitumen

S No.	Description of quality test	ASTM code followed	Results	ASTM specification limits
1.	Flash point	ASTM D92	221ºC	> 200ºC
2.	Fire point	ASTM D92	299ºC	> 220ºC
3.	Softening point	ASTM D36	51ºC	44-55ºC
4.	Penetration test	ASTM D5	66 mm	60-70 mm

Table-2: Quality testing on aggregates

S No.	Description of quality test	ASTM Codes followed	Results	ASTM specification limits
1	Los Angeles Abrasion test	ASTM C131	23.7 %	Max. = 40 %
2	Impact value test	ASTM D5874-16	9.30 %	< 10% = very strong
3	Soundness test	ASTM 88	2.38 %	Max. = 12 %
4	Water absorption test	ASTM C127	1.4 %	< 3 %
5	Stripping value test	AASHTO T 182-84	97.4 %	Min. 95 %
6	Shape test	ASTM D 4791	9.22 %	< 15 %

The results of the Marshall stability and Marshall flow of bituminous material are shown in Figures 2 and 3.

Figure 2: Marshall stability test of conventional and modified asphalt

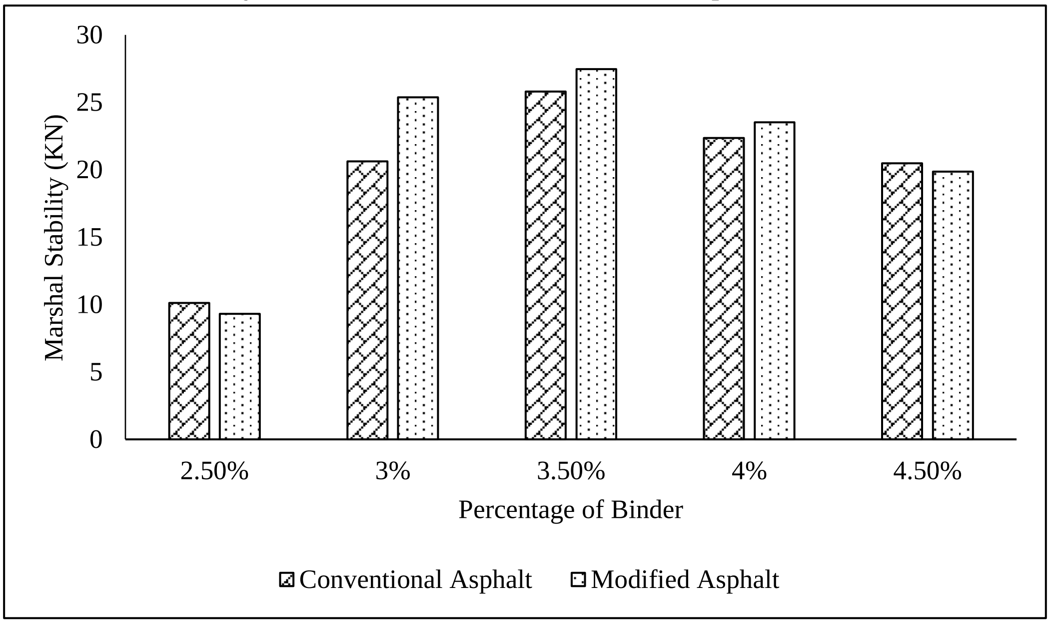
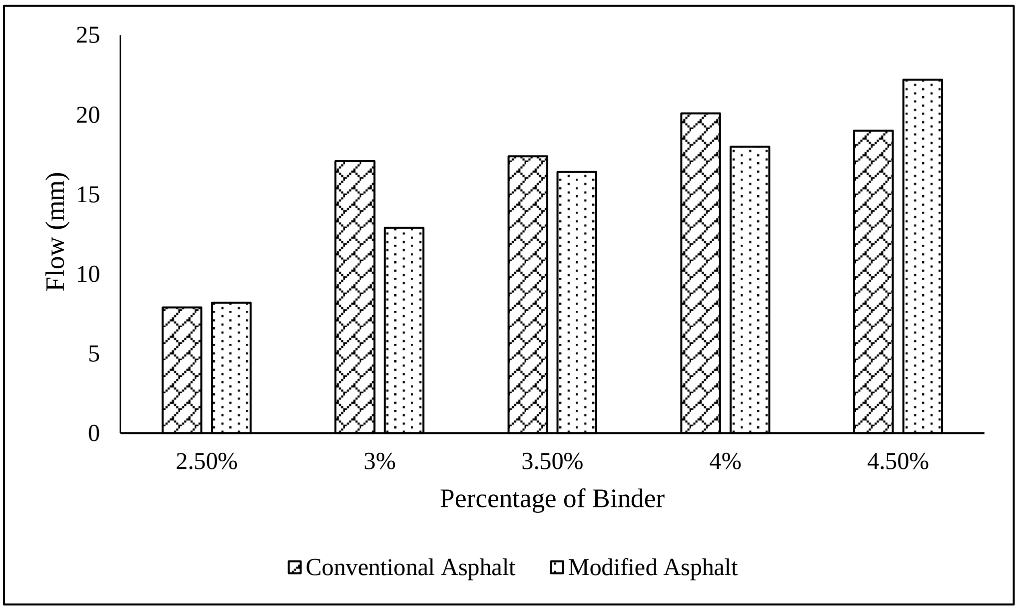


Figure 3: Marshall flow test of conventional and modified asphalt

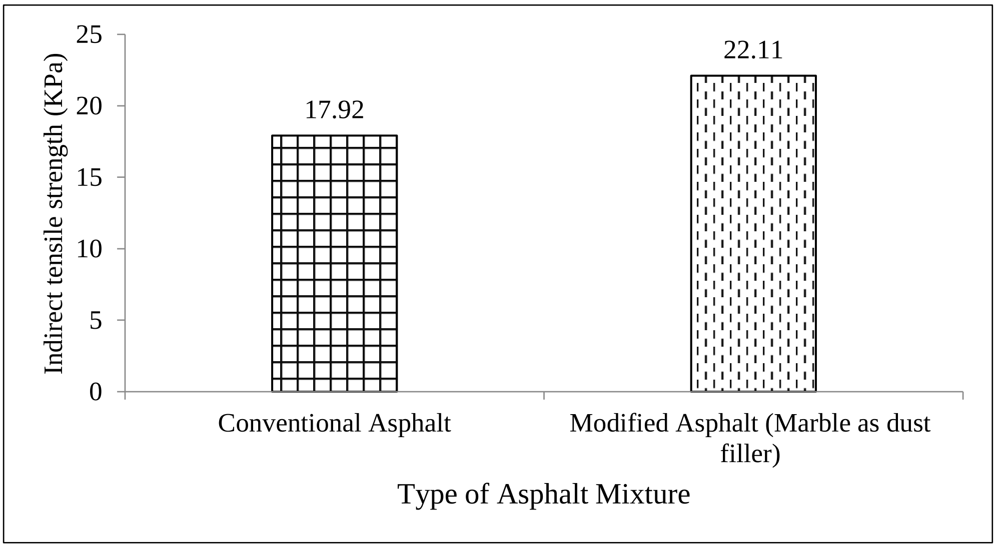


This study has investigated the effects of using marble dust as filler on the properties of bituminous concrete mixes. Marshall Stability and flow were used to determine the optimal bitumen content OBC of each mix at bitumen contents of 2.5%, 3%, 3.5%, 4%, and 4.5% of conventional asphalt and modified asphalt containing marble dust as filler. When compared to traditional bituminous concrete mixes, the former demonstrated greater stability. For conventional and modified asphalt (marble as dust filler), 3.5% Optimum Binder Content was chosen due to higher Marshall Stability with significant Marshall Flow for further performance testing.

4.1. Indirect Tensile Strength (ITS)

The results of the ITS of both conventional and modified bituminous material are shown in the Figure 4.

Figure 4: ITS of conventional and modified asphalt



The ITS of Modified asphalt (Marble dust as filler) was compared with conventional asphalt. Figure 4 shows a 23% increase in indirect tensile strength of Modified asphalt (Marble dust as filler) compared with conventional asphalt. Therefore, adding marble dust as filler in asphalt pavement improves performance.

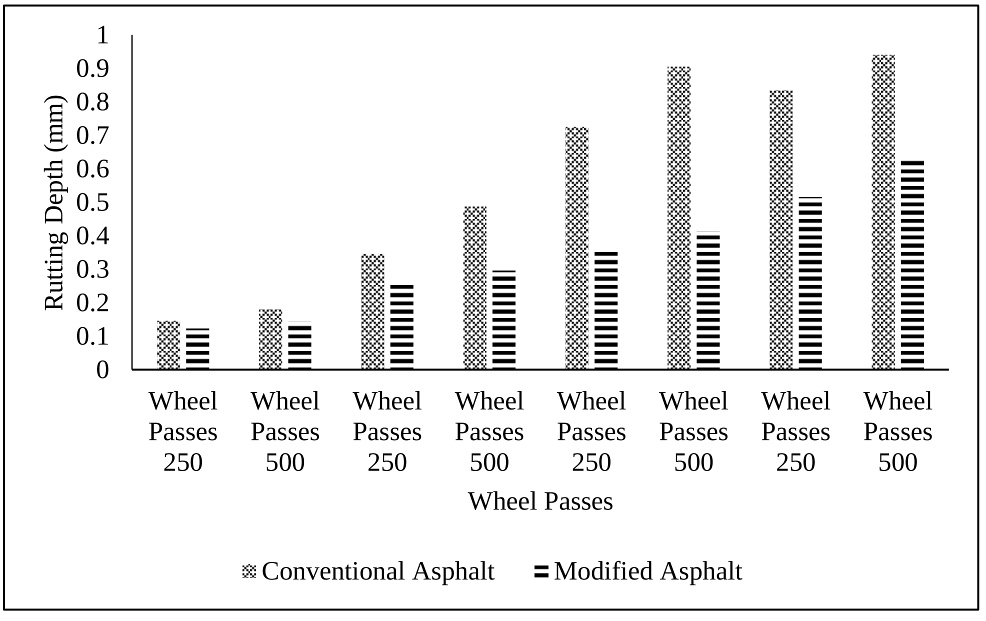
4.2. Wheel tracker test

The Table-3 shows the effects of conventional and modified asphalt on the rut depth of samples under various stresses i.e., 100 and 200 kPa at 40 °C and 50 °C for 250 and 500 wheel passes. Because rutting occurs primarily at high temperatures, using marble dust in asphalt reduces the amount of permanent deformation in asphalt mixtures. This is the result of bitumen that has been modified with marble dust as filler performing better than conventional asphalt. When marble dust is used as filler, it increases the stiffness and viscosity of the bitumen. By improving these two aspects of bitumen, the stiffness of asphalt mixtures can be increased, and the rate of rut depth can be significantly reduced. Marble dust significantly reduces the rut depth of asphalt mixtures at various temperatures and stresses. Marble dust is filler that helps asphalt mixtures perform better at higher temperatures.

Table-3: Rutting depth in mm of conventional and modified asphalt

Type	Pressure 100 kPa		Pressure 200 kPa		Pressure 100 kPa		Pressure 200 kPa	
	Temperature 40°C		Temperature 40°C		Temperature 50°C		Temperature 50°C	
	Wheel Passes 250	Wheel Passes 500	Wheel Passes 250	Wheel Passes 500	Wheel Passes 250	Wheel Passes 500	Wheel Passes 250	Wheel Passes 500
Conventional asphalt	0.146	0.180	0.346	0.487	0.725	0.905	0.834	0.940
Modified asphalt	0.123	0.143	0.263	0.296	0.357	0.414	0.516	0.631

Figure 5: Wheel tracker test



4.3. Resilient Modulus (MR) test

The MR test was conducted in accordance with the ASTM D4123 standard protocol. Construction of a compacted cylindrical asphalt concrete specimen that will be subjected to repetitive diametrical loading is required. The test method suggests measuring the machine's MR by adding load. The load pulse was applied vertically through a curved loading strip in the vertical diameter of a cylindrical specimen. It was possible to see the horizontal deformation brought on by the attachment of two Linear Variable Differential Transformers (LVDT) at either end of the horizontal diameter's middle thickness. Tests were conducted on samples of regular and modified asphalt at 25°C.

MR is the resilient modulus (MPa), F is the maximum applied load (N), is the horizontal deformation (mm), t is the sample thickness (mm) and v is the Poisson's ratio (the value of 0.35-0.40 is assumed for the HMA mixes for all the test temperatures)

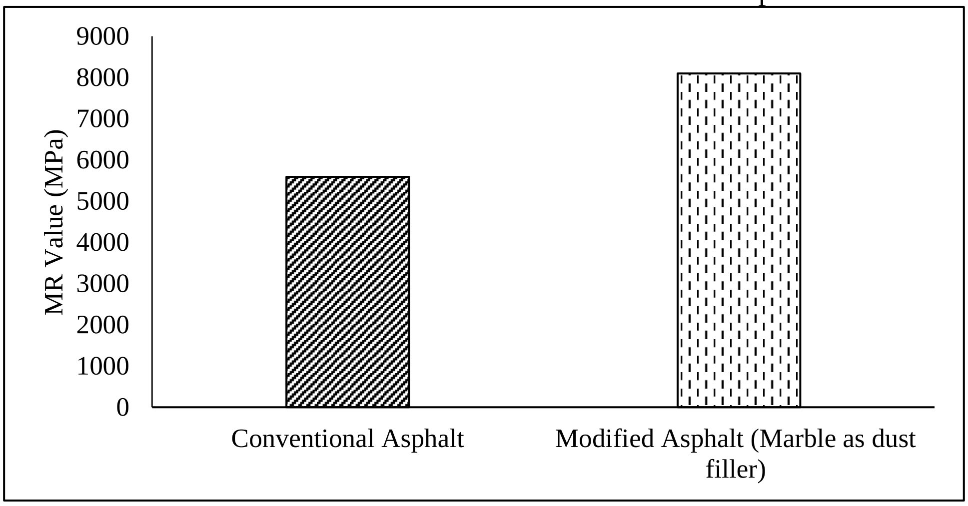
Table-4: MR of conventional and modified asphalt

Type	F Applied load (N)	Δ horizontal deformation (mm)	t Sample thickness (mm)	v Poisson ratio	MR (MPa)
Conventional asphalt	6985	0.0125	100	0.35	5588.50
Modified asphalt (Marble as dust filler)	9635	0.0119	100	0.35	8097.16

Table-5: MR of conventional and modified asphalt

Type	MR (MPa)	Percent Increase
Conventional asphalt	5588.5	0.0
Modified asphalt (Marble as dust filler)	8097.2	44.9

Figure 6: MR is the resilient modulus of conventional and modified asphalt



In the Table-5, the stiffness of conventional and modified (marble dust as filler) asphalt in the form of MR is shown for each sample under temperatures of 25°C. The MR of modified asphalt (Marble dust as filler) was compared with conventional asphalt. The Table shows a 44%

increase in the resilience modulus of modified asphalt (Marble dust as filler) when compared with conventional asphalt. Therefore, adding marble dust as filler in the bitumen increases resilience modulus. An increase in the MR value leads to an increase in stiffness. Asphalt mixtures containing marble dust as filler have better performance.

5. Conclusions and recommendations

5.1. Conclusions

The following conclusions can be drawn from the conducted study:

- Modified bituminous concrete having marble dust as filler with 3.5% optimum binder content showed higher stability with considerable flow as compared to conventional asphalt.
- The addition of marble dust as filler in asphalt pavement improves the quality.
- Indirect Tensile Strength (ITS) concluded that modified asphalt (Marble dust as filler) shows a 23% increase in indirect tensile strength of Modified asphalt (Marble dust as filler) when compared with conventional asphalt.
- Wheel tracker test concluded that marble dust has a high impact on reducing the rut depth of asphalt mixtures at different temperatures and stresses.
- Resilience Modulus (MR) concluded that modified asphalt (Marble dust as filler) shows a 44% increase in the resilience modulus of Modified asphalt (Marble dust as filler) compared to conventional asphalt.
- The addition of marble dust as filler in asphalt pavement improves the performance.

5.2. Recommendations

It is recommended that marble dust be used in asphalt concrete as filler with an optimum binder content of 3.5% to improve the quality and performance. Moreover, marble dust shall be evaluated for different environmental conditions to gain more insight into its properties in asphalt concrete. Microscopic analysis may also be done through scanning microscopy.

Declaration of conflict of interest

The author(s) declared no potential conflicts of interest(s) with respect to the research, authorship, and/or publication of this article.

Funding

The author(s) received no financial support for the research, authorship and/or publication of this article.

ORCID iD

Atif Ali https://orcid.org/0000-0001-9346-0046

Muhammad Majid Naeem https://orcid.org/0009-0007-8177-994X

Fawad Ahmad https://orcid.org/0009-0000-5977-990X

Fazle Subhan https://orcid.org/0000-0002-8293-2324

Publisher's Note

IDEA PUBLISHERS (IDEA Publishers Group) stands neutral with regard to jurisdictional claims in the published maps and institutional affiliations.

References

Adeniran, A. A., & Shakantu, W. (2022). The health and environmental impact of plastic waste disposal in South African townships: a review. *International Journal of Environmental Research and Public Health*, *19*(2), 779. https://doi.org/10.3390/ijerph19020779

Aliha, M. R. M., Ziari, H., Sobhani Fard, E., & Jebalbarezi Sarbijan, M. (2021). Heterogeneity effect on fracture parameters of a multilayer asphalt pavement structure containing a top-down crack and subjected to moving traffic loading. *Fatigue and Fracture of Engineering Materials & Structures*, *44*(5), 1349–1371. https://doi.org/10.1111/ffe.13434

Caputo, P., Porto, M., Angelico, R., Loise, V., Calandra, P., & Rossi, C. O. (2020). Bitumen and asphalt concrete modified by nanometer-sized particles: Basic concepts, the state of the art and future perspectives of the nanoscale approach. *Advances in Colloid and Interface Science*, *285*, 102283. https://doi.org/10.1016/j.cis.2020.102283

Careddu, N., & Marras, G. (2015). Marble processing for future uses of CaCO3-microfine dust: a study on wearing out of tools and consumable materials in stoneworking factories. *Mineral Processing and Extractive Metallurgy Review*, *36*(3), 183–191. https://doi.org/10.1080/08827508.2014.900616

Celik, M. Y., & Sabah, E. (2008). Geological and technical characterisation of Iscehisar (Afyon-Turkey) marble deposits and the impact of marble waste on environmental pollution. *Journal of Environmental Management*, *87*(1), 106–116. https://doi.org/10.1016/j.jenvman.2007.01.004

Choudhary, J., Kumar, B., & Gupta, A. (2020). Effect of filler on the bitumen-aggregate adhesion in asphalt mix. *International Journal of Pavement Engineering*, *21*(12), 1482–1490. https://doi.org/10.1080/10298436.2018.1549325

Greenway, H., Armstrong, W., & Colmer, T. D. (2006). Conditions leading to high CO2 (> 5 kPa) in waterlogged–flooded soils and possible effects on root growth and metabolism. *Annals of Botany*, *98*(1), 9–32. https://doi.org/10.1093/aob/mcl076

Hossain, M. S., Nur, B. A., Rahman, M. M. (2022). Improvement of bituminous concrete using cement as Filler material. *6th International Conference on Advances in Civil Engineering (ICACE-2022), CUET, Chattogram, Bangladesh.* https://www.cuet.ac.bd/icace/

Joumblat, R., Al Basiouni Al Masri, Z., Al Khateeb, G., Elkordi, A., El Tallis, A. R., & Absi, J. (2023). State-of-the-art review on permanent deformation characterization of asphalt concrete pavements. *Sustainability*, *15*(2), 1166. https://doi.org/10.3390/su15021166

Khan, N., Karim, F., Latif Qureshi, Q. B. A. I., Mufti, S. A., Rabbani, M. B. A., Khan, M. S., & Khan, D. (2023). Effect of fine aggregates and mineral fillers on the permanent deformation of hot mix asphalt. *Sustainability*, *15*(13), 10646. https://doi.org/10.3390/su151310646

Kumar, P. S., & Yaashikaa, P. (2019). Agriculture pollution. In *Advanced treatment techniques for industrial wastewater* (pp. 134–154). IGI Global. https://doi.org/10.4018/978-1-5225-5754-8.ch009

Pateriya, A. S., Robert, D. J., Dharavath, K., & Soni, S. K. (2022). Stabilization of marble wastes using cement and nano materials for subgrade applications. *Construction and Building Materials*, *326*, 126865. https://doi.org/10.1016/j.conbuildmat.2022.126865

Rajgor, M. B., Patel, N. C., & Pitroda, J. (2013). A study on marble waste management: opportunities and challenges in current age for making value added bricks. In *Proceedings of National Conference CRDCE13* (pp. 20–21).

Victory, W. (2022). A review on the utilization of waste material in asphalt pavements. *Environmental Science and Pollution Research*, *29*(18), 27279–27282. https://link.springer.com/article/10.1007/s11356-021-18245-0

Zhang, J., Airey, G. D., & Grenfell, J. R. (2016). Experimental evaluation of cohesive and adhesive bond strength and fracture energy of bitumen-aggregate systems. *Materials and Structures*, *49*, 2653-2667. https://link.springer.com/article/10.1617/s11527-015-0674-7

Zhu, X., Zhang, Q., Chen, L., & Du, Z. (2021). Mechanical response of hydronic asphalt pavement under temperature–vehicle coupled load: A finite element simulation and accelerated pavement testing study. *Construction and Building Materials*, *272*, 121884. https://doi.org/10.1016/j.conbuildmat.2020.121884