Southern Journal of Engineering & Technology – Special Issue, Vol. 01, Issue 01, 2024

Performance Evaluation-WMA with Glass and Plastic as aggregate Replacement

Muhammad Bilal[1], Sheikh Abdul Haseeb Amir[1], Sajjad Ahmad[2], Rahmat Ullah[3]

[1]Fatima Fertilizer Limited Multan; aamir@fatima-group.com,

[2]Department of Civil Engineering, Bahauddin Zakariya University, Multan; sajjadahmad@bzu.edu.pk,

[3]Hokkaido University Japan, rahmatullah289@gmail.com,

Abstract. This paper explores the utilization of waste materials-specifically plastic and glass-in road construction to mitigate environmental impact and enhance sustainability. Highlighting projects from India, Indonesia, and Pakistan, where plastic and glass are replacing traditional aggregates, the study examines their effectiveness in reducing resource consumption and ocean pollution. Additionally, the adoption of Warm Mix Asphalt (WMA) technology is discussed for its environmental benefits, including lower emissions and improved asphalt performance. Performance tests reveal enhanced rut resistance and moisture tolerance in plastic and glass-modified asphalt mixtures compared to Hot Mix Asphalt (HMA). Economic evaluations underscore potential cost savings, supporting the viability of integrating these materials into mainstream road construction practices.

Keywords: Waste Management; Glass and Plastic; Warm Mix Asphalt; Cost Reduction;

Email address: engr.mbilal9@gmail.com,

1. Introduction

Pakistan's construction industry faces challenges due to economic constraints and unstable conditions, leading to suboptimal practices. To address these issues and ensure a cost-effective transportation system, innovative technologies such as Warm Mix Asphalt (WMA) have emerged.

WMA reduces asphalt mixing temperatures by 20-40°C, cutting energy consumption and emissions significantly. High traffic demands and limited funds necessitate the development of economically viable and high-performance asphalt solutions. Despite global advancements in utilization of waste materials like plastic and glass in pavements, Pakistan has yet to adopt these sustainable practices effectively [1-6].

This study explores integrating plastic and glass waste into WMA for asphalt pavements in Pakistan, aiming to enhance performance while reducing environmental impact and costs.

2. Literature Review

Pakistan's economic growth hinges on well-developed transportation networks, primarily focusing on highways and motorways due to inadequate railway infrastructure. Major projects like the China Pakistan Economic Corridor (CPEC) are pivotal in enhancing connectivity and economic progress across the country [7].

Glass, composed mainly of silica, lime, and soda ash, is indispensable in various applications due to its transparency, durability, and thermal resistance. However, its widespread use leads to significant environmental challenges when not recycled properly, as seen in Pakistan and globally [8].

Research has explored using recycled glass in asphalt mixtures to enhance stiffness modulus and fatigue life, emphasizing the importance of proper particle size and bonding agents to optimize performance [10-12]. Plastic's versatility and low cost have made it ubiquitous in consumer goods, but its disposal leads to severe environmental pollution, affecting marine life and terrestrial ecosystems. In Pakistan, unregulated plastic production exacerbates these issues [14-15]. Studies indicate that incorporating recycled plastic in asphalt improves fatigue behavior and mechanical properties while reducing rutting when used in optimal proportions [16-18].

WMA technologies, such as Sasobit additives, lower asphalt mixing temperatures, reducing energy consumption, CO_2 emissions, and improving asphalt workability and longevity compared to traditional Hot Mix Asphalt (HMA) [19-23]. Studies show that optimal Sasobit usage enhances asphalt performance by reducing rutting and improving binder flexibility at lower production temperatures, offering significant environmental and economic benefits [24-25].

3. Research Methodology

Experimental investigation was adopted to evaluate the performance potential of waste modified asphalt concrete, major comparing rutting potential and moisture susceptibility. Rutting is the most common pavement failure and moisture results in lowering the tensile strength of asphalt. Material Characterization: Aggregate tests including Impact Value, Shape Test, Specific Gravity, and Los Angeles Abrasion Test. Bitumen tests such as Penetration Test, Softening Point Test, Ductility Test, Flash Point, and Fire Point Test. Asphalt Mixture Preparation: Marshall Mix Design procedure was used to obtain optimal bitumen content for asphalt concrete as per table 1.

Table 1. Samples for Optimal Bitumen Content Table

Plastic (%)	Glass (%)	Bitumen	No. Of Samples
0	0	3	3
		3.5	3
		4	3
		4.5	3
		5	3
0.5	2	3	3
		3.5	3
		4	3
		4.5	3
		5	3
1	4	3	3
		3.5	3
		4	3
		4.5	3
		5	3

Table 2. Samples prepared for rutting potential evaluation and moisture susceptibility test

Sr. no	Plastic (%)	Glass (%)	Sasobit (%)	Indirect Tensile Strength		Hamburg Wheel Tracker
				Conditioned	Unconditioned	
1	0	0	0	3	3	3
			3	3	3	3
2	0.5	4	0	3	3	3
			3	3	3	3
3	1	4	0	3	3	3
			3	3	3	3

The samples were prepared as per NHA specs for heavy traffic with 75 blows on each side of the sample. Then the samples were tested for flow and stability, to determine OBC at 4% air voids as per table 1.3. After finding OBC for each mix ratio as per table 1. The samples were prepared for wheel tracking test and indirect tensile strength test.

Table 3. for OBC at 0% Plastic and Glass

Asphalt Content (%)	AIR VOIDS	Flow(mm)	Stability (KN)	VMA%	VFA%	Gmb	Gmm
3	8.04243295	3.07	8.13	15.90731	49.44189	2.245361	2.441736
3.5	5.775168961	3.18	8.69	15.35567	62.39065	2.271801	2.411042
4	4.167451102	3.27	9.47	16.10482	74.12295	2.246653	2.344353
4.5	2.387423437	3.46	10.3	15.65866	84.75334	2.324588	2.381443
5	1.979030479	3.55	8.8	14.15122	86.01513	2.340508	2.387763

4. Results and Discussions

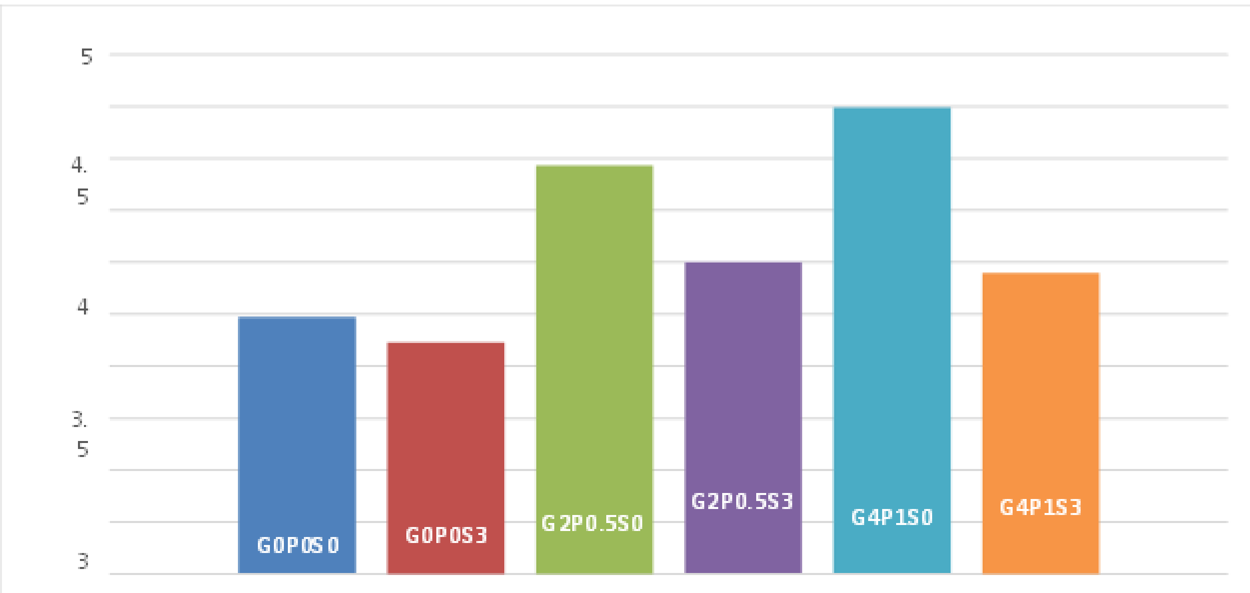
The rutting potential of asphalt pavement and moisture susceptibility was evaluated at various percentages of glass and plastic.

4.1. Results

The results were analyzed and compared with controlled samples to identify deviations.

Hamburg Wheel Tracker test: The wheel tracking (rutting) test was conducted to evaluate the resistance of the asphalt specimens against deformation under dry conditions. A total of 18 samples were tested, including control samples and samples with various percentages of glass and plastic as aggregate replacements. Each sample underwent 10,000 passes under controlled conditions at 25°C, with a failure criterion set at a rut depth increase exceeding 12mm (Graph 1 & Table 4).

Moisture Damage (ITS Test): After completing the mix design, moisture susceptibility tests were performed on the asphalt concrete samples according to ASTM D 6931-07. Samples were conditioned using ALDOT 361 procedures, with a total of 36 samples prepared at 4% air voids for testing moisture susceptibility (Table 5).



Hamburg Test Results Graph 1.1

Table 4. Test Results for Hamburg Wheel Tracker Test

Sr. no.	Plastic (%)	Glass (%)	Sasobit (%)	AVG. Rutting Depth (mm)	Remarks
1	0	0	0	2.44	Ok
			3	2.23	Ok
2	0.5	2	0	3.93	Ok
			3	3.04	Ok
3	1	4	0	4.46	Ok
			3	2.90	Ok

Table 5. for ITS Test Results

Specification	Codes	Unconditioned Strength, S1 (kN)	Conditioned Strength, S2 (kN)	TSR=S2/S1 (%)
0% Glass, 0% Plastic,0% SASOBIT	G0P0S0	3.731	3.448	92.709
0% Glass, 0% Plastic,3% SASOBIT	G0P0S3	3.881	3.684	93.335
2% Glass, 0.5% Plastic,0% SASOBIT	G2P0.5S0	2.637	2.238	85.139
2% Glass, 0.5% Plastic,3% SASOBIT	G2P0.5S3	2.917	2.352	89.12
4% Glass, 1% Plastic,0% SASOBIT	G4P1S0	1.885	1.694	90.15
4% Glass, 1% Plastic,3% SASOBIT	G4P1S3	2.077	1.901	91.81

4.2. Discussion of Results

From the results, it can be observed that the addition of sasobit for WMA significantly improves rut resistance, and moisture susceptibility compared to the control samples. This indicates that the WMA (Warm Mix Asphalt) samples generally exhibited good resistance against rutting, possibly due to the improved properties of WMA. Currently, plastic roads are being constructed in Pakistan for locations i.e., F-9 Park which are not under heavy loadings as the performance potential is not comparable to virgin asphalt concrete. However, the use of WMA technology considerably improves the properties which can be used for construction of major traffic streets.

Previously the researches were conducted with HMA and waste glass or plastic. However, the study explains incorporation of WMA technologies to improve performance of waste modified asphalt concrete.WMA is a new technology and therefore several aspects are yet to be analyzed. The study can be conducted with higher percentages of glass and plastic or increase the percentage of Sasobit.

5. Conclusions

In conclusion, WMA technology combined with glass and plastic additives shows promise for sustainable asphalt solutions in Pakistan's transportation sector. It not only meets performance and volumetric criteria but also contributes to resource conservation and environmental stewardship. Continued research and implementation of WMA are essential steps toward achieving sustainable infrastructure goals.

References

[1] Abendeh, Raed. (2017). Effect of Waste Glass on Properties of Asphalt Concrete Mixtures. Jordan Journal of Civil Engineering.

[2] Hurley, G. C., & Prowell, B. D. (2005). Evaluation of Sasobit for use in warm mix asphalt. NCAT report, 5(06).

[3] Tutu, K. and Tuffour, Y. (2016) Warm-Mix Asphalt and Pavement Sustainability: A Review. Open Journal of Civil Engineering.

[4] Jahanzaib Khalil, Muhammad, Muhammad Aslam, and Sajjad Ahmad. 2021. "Utilization of Sugarcane

Bagasse Ash as Cement Replacement for the Production of Sustainable Concrete – A Review." Construction and Building Materials 270: 121371. https://doi.org/10.1016/j.conbuildmat.2020.121371.

[5] Hurley, Graham & Prowell, Brian. (2005). Evaluation of Sasobit® for use in warm-mix asphalt. National Center for Asphalt Technology (NCAT), Auburn, NCAT Report.

[6] https://www.weforum.org/agenda/2021/11/4-ways-pakistan-is-tackling-plastic-waste-and- pollution/

[7] https://tradingeconomics.com/pakistan/road-density-km-of-road-per-sq-km-of-land-area-wb-data.html#:~:text=Road%20density%20(km%20of%20road%20per%20100%20sq.,compiled%20from%20officially%20recognized%20sources.

[8] https://www.britannica.com/technology/soda-lime-glass.

[9] Salamatpoor, S., Salamatpoor, S. Evaluation of adding crushed glass to different combinations of cement-stabilized sand. Geo-Engineering 8, 8 (2017).

[10] Nan Su J.S Chen "Engineering properties of asphalt concrete made with recycled glass" (2001). Arabani, Mahyar. (2011). Effect of glass cullet on the improvement of the dynamic behavior of asphalt concrete. Construction and Building Materials - CONSTR BUILD MATER. 25. 1181- 1185. 10.1016/j.conbuildmat.2010.09.043.

[11] Moreno-Navarro, Fernando & Pérez-Martínez, Miguel & Marin, Jesus & Sol-Sánchez, M. & Gámez, Ma. (2015). Mechanical Performance of Asphalt Mixes Incorporating Waste Glass. The Baltic Journal of Road and Bridge Engineering. 10. 8. 10.3846/bjrbe.2015.32.

[12] Nur Mustakiza Zakaria "The Use of Mixed Waste Recycled Plastic and Glass as an Aggregate Replacement in Asphalt Mixtures" ResearchGate (January 2018).

[13] https://theconversation.com/eight-million-tonnes-of-plastic-are-going-into-the-ocean-each-year-37521#:~:text=You%20might%20have%20heard%20the,of%20coastline%20(excluding%20Anta rctica).

[14] https://theconversation.com/eight-million-tonnes-of-plastic-are-going-into-the-ocean-each-year37521#:~:text=You%20might%20have%20heard%20the,of%20coastline%20(excluding%20Anta rctica).

[15] Modarres, Amir & Hamedi, Hamidreza. (2014). Effect of waste plastic bottles on the stiffness and fatigue properties of modified asphalt mixes. Materials & Design. 61. 8–15. 10.1016/j.matdes.2014.04.046.

[16] Meftah, Mohamed & Mohd Jakarni, Fauzan & Muniandy, Ratnasamy & Salihudin, Hassim. (2021). A Brief Review: Application of Recycled Polyethylene Terephthalate in Asphalt Pavement Reinforcement. Sustainability. 13. 1303.

[17] Moghaddam, T. B., & Baaj, H. (2016). The use of rejuvenating agents in production of recycled hot mix asphalt: A systematic review. Construction and Building Materials, 114, 805- 816.

[18] Almeida-Costa, A., & Benta, A. (2016). Economic and environmental impact study of warm mix asphalt compared to hot mix asphalt. Journal of Cleaner Production, 112, 2308-2317.

[19] McCormack, S. M., Sturgill, R. E., Howell, B., Van Dyke, C. W., & Kreis, D. (2014). Green Infrastructure.

[20] Bražiūnas, J., Sivilevičius, H., & Virbickas, R. (2013). Dependences of SMA mixture and its bituminous binder properties on bitumen batching system, mixing time and temperature on asphalt mixing plant. Journal of Civil Engineering and Management, 19(6), 862-872.

[21] Rossi, D., Filippi, S., Merusi, F., Giuliani, F., & Polacco, G. (2013). Internal structure of bitumen/polymer/wax ternary mixtures for warm mix asphalts. Journal of Applied Polymer Science, 129(6), 3341-3354.

[22] Jamshidi, A., Hamzah, M. O., & You, Z. (2013). Performance of warm mix asphalt containing Sasobit®: State-of-the-art. Construction and Building Materials, 38, 530-553.

[23] Sengoz, Burak & Topal, Ali & Oner, Julide & Yilmaz, Mehmet & Dokandari, Peyman & Kök, Baha. (2016). Performance Evaluation of Warm Mix Asphalt Mixtures with Recycled Asphalt Pavement. Periodica Polytechnica Civil Engineering. 61.

[24] Raveesh J (2018) Experimental Study of WMA by Using Sasobit Additive.

[25] ASTM D4791-19. Standard Test Method for Flat Particles, Elongated Particles, or Flat and Elongated Particles in Coarse Aggregate. ASTM International, West Conshohocken, PA.

[26] ASTM C127. (2007). Standard Test Method for Density, Relative Density (Specific Gravity), and Absorption of Coarse Aggregate. ASTM International, West Conshohocken, PA.

[27] Determination of aggregate impact value (AIV) BS 812-112.

[28] ASTM C535. (2007). Standard Test Method for Resistance to Degradation of Large-size Coarse Aggregate by Abrasion and Impact in Los Angeles Machine. ASTM International, West Conshohocken, PA.

[29] AASHTO T 49, 2007 Edition, 2007 - Standard Method of Test for Penetration of Bituminous Materials.

[30] AASHTO T 53, 2009 Edition, 2009 - Standard Method of Test for Softening Point of Bitumen (Ring-and-Ball Apparatus).

[31] AASHTO T 51, 2009 Edition, 2009 - Standard Method of Test for Ductility of Asphalt Materials 33-ASTM D3143/D3143M-13 Standard Test Method for Flash Point of Cutback Asphalt with Tag Open-Cup Apparatus.

[32] ASTM D2726. (2008). Standard Test Method for Bulk Specific Gravity and density of Non-Absorptive Compacted Bituminous Mixtures. ASTM International, West Conshohocken, PA.

[33] ASTM D2041. (2000). Standard Test Method for Theoretical Maximum Specific Gravity and Density of Bituminous Paving Mixtures. ASTM International, West Conshohocken, PA.

[34] AASHTO T 324, 2019 Edition, 2019 - Standard Method of Test for Hamburg Wheel-Track Testing of Compacted Asphalt Mixtures.

[35] ASTM D6931-07 Standard Test Method for Indirect Tensile (IDT) Strength of Bituminous Mixtures.