Experimental Investigation on the Use of Dimensioned Stone Waste as a Strengthening Agent in Bituminous Road Construction

Manish Verma[1], Vivek Kumar[2]

[1]Manish Verma, Research Scholar, Department of Civil Engineering, Mewar University, Chittorgarh, Rajasthan
[2]SAssistant Professor, Department of Civil Engineering, Mewar University, Chittorgarh, Rajasthan

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Abstract - *The development of road infrastructure is widely recognized as a key indicator of a nation's socio-economic progress. In developing countries, road networks play a vital role in supporting economic activities and facilitating overall development. However, the construction of flexible pavements conventionally relies on natural resources such as aggregates, soil materials, and bituminous binders, leading to the continuous depletion of these finite resources. This growing concern has created the need to identify sustainable and alternative materials for pavement construction. In this context, the present study investigates the potential use of dimension stone waste, specifically Kota stone and marble waste, in different layers of flexible pavement. Kota stone, abundantly available in the Kota region, and marble, extensively produced in the Kishangarh area, generate significant quantities of waste during mining and processing operations such as cutting, sawing, and polishing. The waste generated from these processes is non-biodegradable and poses serious environmental disposal challenges. The experimental program primarily focused on the utilization of these waste materials in Granular Sub-Base (GSB Grade I and Grade II), Wet Mix Macadam (WMM), and Bituminous Macadam (BM) layers of asphalt pavements. Marble and Kota stone wastes were used as partial to full replacements for conventional fine and coarse aggregates, while marble quarry dust was used as filler material. The replacement levels were varied from 20% to 100% at intervals of 20% in order to evaluate their suitability in pavement applications. The engineering performance of the substituted materials was assessed through a series of standard laboratory tests conducted in accordance with relevant Indian Standards and the specifications recommended by the Ministry of Road Transport and Highways (MoRTH). The study aims to evaluate the feasibility of incorporating dimension stone waste in pavement layers as a sustainable alternative to conventional construction materials. The findings are expected to contribute toward conservation of natural resources, effective utilization of industrial waste, and the promotion of environmentally sustainable road construction practices.*

Key Words: **Dimension stone waste; Kota stone; marble waste; marble dust; granular sub-base; wet mix macadam; bituminous macadam; Marshall stability; California bearing ratio.**

1. INTRODUCTION

Road construction increasingly faces the dual challenge of sustaining material demand and reducing the environmental burden associated with mining and industrial waste disposal. Dimension stone industries in Rajasthan generate large quantities of Kota stone waste, marble stone waste, and marble dust, much of which is non-biodegradable and commonly dumped near production areas. The source thesis investigated whether these materials can function as technically acceptable substitutes for conventional pavement aggregates and filler in flexible pavements.

The study focused on three pavement layers: granular sub-base (GSB Grade I and Grade II), wet mix macadam (WMM), and bituminous macadam (BM). Replacement levels ranged from 20% to 100% in 20% increments. The work is relevant because it links waste reuse with conservation of natural aggregates, reduced dumping pressure, and potentially lower material costs in road construction.

2. Literature Survey

S. No.	Author(s)	Year	Material Used	Layer/Application	Key Findings	Citation
1	Ubani et al.	2025	Quarry dust with cement-stabilized tropical clay	Pavement sub-base / base / unpaved roads	The study reported that quarry dust improved compaction characteristics, strength, and durability. Properly proportioned mixes were found suitable for pavement foundation applications.	[1]

S. No.	Author(s)	Year	Material Used	Layer/Application	Key Findings	Citation
2	Bardini et al.	2025	Waste foundry sand with sandy soil and hydrated lime	Pavement base and sub-base	The addition of waste foundry sand produced good to excellent performance in terms of compaction, CBR, compressive strength, and resilient modulus.	[2]
3	Ohm, Lee, and Le	2025	Crushed recycled marble stone powder with recycled tire rubber	SBS-modified asphalt mixtures	Marble stone powder performed effectively as a filler, and replacement up to 75% improved stability, dynamic modulus, and rutting resistance.	[3]
4	de Medeiros et al.	2024	Marble and granite industry waste	Hot asphalt mixtures (filler replacement)	Partial and full replacement of conventional filler was found technically feasible, with performance comparable to the control mix and little change in production cost.	[4]
5	Ali et al.	2024	Marble dust	Asphalt concrete (filler)	Marble dust improved Marshall stability, indirect tensile strength, rutting resistance, and resilient modulus. Around 4.5% filler content was found suitable.	[5]
6	Benjeddou et al.	2022	Crushed marble waste	Road construction aggregate	The physical, chemical, and mechanical properties of crushed marble waste indicated that it could be used as an alternative to conventional aggregate in road works.	[6]
7	Ravindra Nagar and P. Kalla	2018	Quarry waste	Open-graded friction course / low-traffic roads	Replacement above 25% did not satisfy IRC and MoRTH requirements, whereas up to 25% replacement was found feasible for low-traffic roads and parking areas.	[7]
8	Pradeep Kumar Gautam and Pawan Kalla	2018	Kota stone waste	DBM Grade II and BC Grade II in hot mix asphalt	Kota stone waste was used at 25%, 50%, 75%, and 100% replacement levels. The study concluded that 50% replacement was feasible in BC and	[8]

S. No.	Author(s)	Year	Material Used	Layer/Application	Key Findings	Citation
					25% in DBM.	
9	Arun Pratap Singh Rathore and Karan Parbhakar	2018	Stone slurry waste	Black cotton soil stabilization / subgrade improvement	The addition of stone slurry improved compaction, direct shear strength, and CBR. Around 15% slurry reduced plasticity and significantly increased shear strength.	[9]
10	Surender Singh et al.	2017	Bagasse ash with reclaimed road material	Road material / pavement blends	Different blends were evaluated, and 10% bagasse ash replacement was found optimum, showing improved physical properties.	[10]
11	Virendra Singh Shekhawat and Bharat Nagar	2017	Marble dust waste	DBM layer as filler in asphalt pavement	Marble dust was found effective as filler. The highest density was achieved at about 5.5% marble dust with 4% bitumen content.	[11]
12	Ajay Singh Jethoo and Harshwardhan S.C.	2017	Kota stone waste	BM Grade II replacing natural fine aggregate	Full replacement of fine aggregate with crushed Kota stone waste improved rigidity and strength, but the mix was considered more suitable for low-traffic roads due to higher flow and VFB values.	[12]
13	Surender Singh, G.D. Ransinchung, and R.N.	2017	Demolition waste and bagasse ash	Asphalt mixes	The use of bagasse ash improved reinforcement behavior and reduced project cost significantly. About 10% replacement was found beneficial.	[13]
14	S. Faisal and Ibrahim A.	2017	Basalt with limestone fines	Black-top mixes	Full replacement adversely affected mechanical properties. The study also indicated the need for anti-stripping treatment due to basalt properties.	[14]
15	Huseyin Akbulut and Cahit Gurer	2007	Marble waste granules	Asphalt mixes / Marshall evaluation	Marble waste mixes showed acceptable abrasion and freeze-thaw resistance, although some other aggregate combinations exhibited higher Marshall stability.	[15]
16	Mustafa Karasahin and Serdal Terzi	2006	Marble waste dust	Bituminous concrete as filler	Lower marble dust contents improved	[16]

S. No.	Author(s)	Year	Material Used	Layer/Application	Key Findings	Citation
					dynamic modulus, whereas higher additive contents increased plastic deformation. The mixes were recommended for lightly loaded roads.	

3. Materials & Method

Waste Kota stone, marble stone waste, marble dust, natural aggregates, and VG-40 bitumen were used. Aggregate gradations for GSB, WMM, and BM were prepared in accordance with MoRTH recommendations. Compaction behavior was assessed through the Modified Proctor test, bearing resistance through the soaked CBR test, and bituminous performance through Marshall mix design and stability testing.

For GSB, the response variables were optimum moisture content (OMC), maximum dry density (MDD), and soaked CBR. For WMM, OMC and MDD were used to assess compaction response under different replacement levels. For BM, specimens were prepared at multiple binder contents to determine optimum binder content (OBC), Marshall stability, flow value, and Marshall quotient.

The thesis examined three substitution patterns in the granular layers: (i) Kota stone waste + marble dust, (ii) marble stone waste + marble dust, and (iii) combined Kota stone waste + marble stone waste + marble dust. In BM, marble stone waste and marble dust replaced conventional aggregates/filler at 0%, 20%, 40%, 60%, 80%, and 100% replacement.

4. Result & Discussion

4.1. Granular Sub-base (GSB)

Across both GSB gradations, OMC generally increased while MDD and soaked CBR decreased as the replacement percentage increased. Even so, the experimental results remained above the minimum soaked CBR requirement over a substantial part of the replacement range, indicating practical potential for controlled substitution.

The thesis conclusions recommend approximate upper practical replacement limits of about 70% for mixes with Kota stone waste plus marble dust, about 60% for mixes dominated by marble waste plus marble dust, and about 65% for combined Kota stone waste + marble stone waste + marble dust. These limits reflect the point beyond which CBR loss becomes too pronounced for safe field adoption.

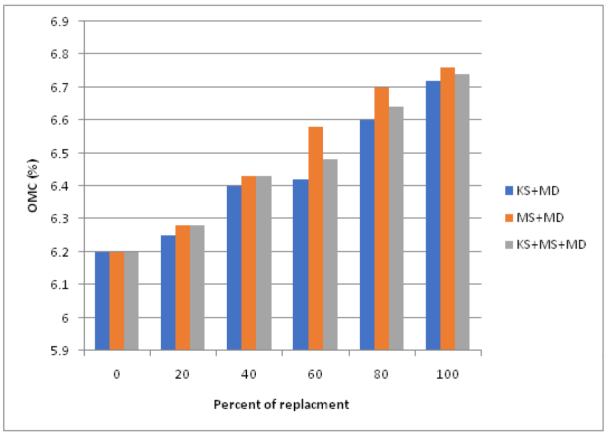

Figure 1: *Comparative OMC Value of GSB Grade-I with Various Wastes*

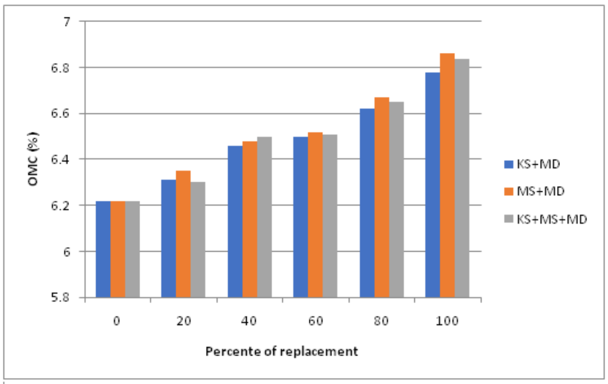

Figure 34: *Comparative OMC Value of GSB Grade-II with Various Waste*

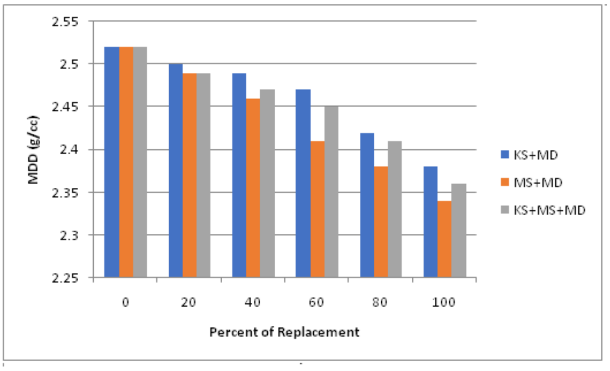

Figure 2: *Comparative MDD Value of GSB Grade-I with Various Waste*

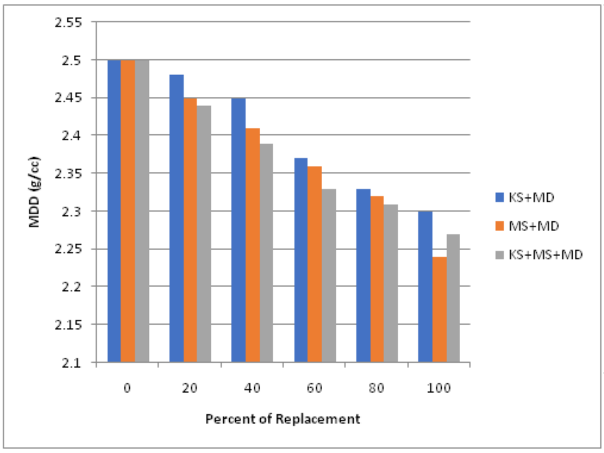

Figure 3: *Comparative MDD Value of GSB Grade-II with Various Waste*

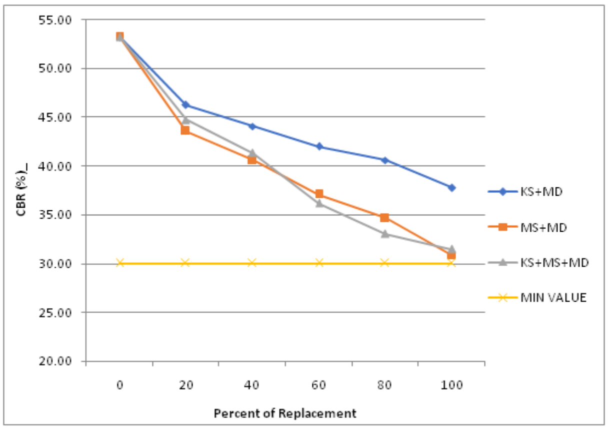

Figure 4*: GSB G-I Soaked CBR Value Comparison with Various Waste*

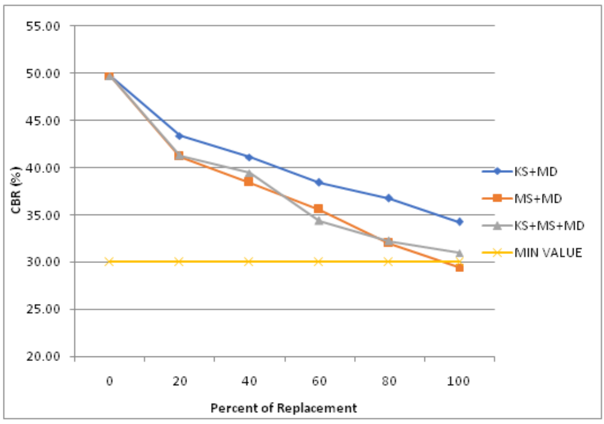

Figure 5: *GSB Grade-II Soaked CBR Value Comparison with Various Wastes*

Table 1: *GSB Grade-I Substitution Results*

S.No.	**Natural Material (Percent)**	**MW+KSW (Percent)**	**OMC (Percent)**	**MDD (g/cc)**	**Soaked CBR (Percent)**	**Soaked CBR (Percent)**	**Soaked CBR (Percent)**	**Soaked CBR (Percent)**	**Min. CBR (Percent)**
S.No.	**Natural Material (Percent)**	**MW+KSW (Percent)**	**OMC (Percent)**	**MDD (g/cc)**	**I**	**II**	**III**	**Avg.**	**Min. CBR (Percent)**
1	100	0	6.3	2.52	52.43	53.98	53.22	53.21	30
2	80	20	6.35	2.5	45.87	46.02	46.88	46.26	30
3	60	40	6.4	2.49	43.78	44.48	43.92	44.06	30
4	40	60	6.42	2.47	42.08	41.83	42	41.97	30
5	20	80	6.58	2.42	41.2	39.88	40.77	40.62	30
6	0	100	6.7	2.38	38.32	37.8	37.2	37.77	30

Table 2: *GSB Grade-II Substitution with KS+MD Waste*

S.No.	**Natural Material (Percent)**	**MW+KSW (Percent)**	**OMC (Percent)**	**MDD (g/cc)**	**Soaked CBR %**	**Soaked CBR %**	**Soaked CBR %**	**Soaked CBR %**	**Min. CBR (%)**
S.No.	**Natural Material (Percent)**	**MW+KSW (Percent)**	**OMC (Percent)**	**MDD (g/cc)**	**I**	**II**	**III**	**Avg.**	**Min. CBR (%)**
1	100	0	6.22	2.5	50.2	49.3	49.6	49.7	30

S. No.	Natural Material (Percent)	MW+KSW (Percent)	OMC (Percent)	MDD (g/cc)	Soaked CBR %	Soaked CBR %	Soaked CBR %	Soaked CBR %	Min. CBR (%)
								0	
2	80	20	6.31	2.48	42.9	44.1	43.2	43.40	30
3	60	40	6.46	2.45	41.3	40.98	41.12	41.13	30
4	40	60	6.5	2.37	38.7	38.3	38.2	38.40	30
5	20	80	6.62	2.33	36.9	37.1	36.3	36.77	30
6	0	100	6.78	2.3	34.1	34.5	34.08	34.23	30

Table 3: *GSB Grade-I Substitution with MS+MD Waste*

S. No.	Natural Material (Percent)	MW+KSW (Percent)	OMC (Percent)	MDD (g/cc)	Soaked CBR %	Soaked CBR %	Soaked CBR %	Soaked CBR %	Min. CBR (%)
S. No.	Natural Material (Percent)	MW+KSW (Percent)	OMC (Percent)	MDD (g/cc)	I	II	III	Avg.	Min. CBR (%)
1	100	0	6.2	2.52	52.43	53.98	53.22	53.21	30
2	80	20	6.28	2.49	43.5	43.8	43.44	43.58	30
3	60	40	6.43	2.46	40.88	40.23	40.58	40.56	30
4	40	60	6.58	2.41	37.2	37.02	36.98	37.07	30
5	20	80	6.7	2.3	34.5	34.8	34.4	34.6	30

S. No.	Natural Material (Percent)	MW+KSW (Percent)	OMC (Percent)	MDD (g/cc)	Soaked CBR %	Soaked CBR %	Soaked CBR %	Soaked CBR %	Min. CBR (%)
				8	6	9	8	4	
6	0	100	6.76	2.34	31.02	30.8	30.78	30.87	30

Table 4: *MS+MD Waste Replacement in Grade-II GSB*

S.No.	GSB Material (%)	MS+MD (%)	OMC (%)	MDD (g/cc)	Soaked CBR %	Soaked CBR %	Soaked CBR %	Soaked CBR %	Min. CBR (%)
S.No.	GSB Material (%)	MS+MD (%)	OMC (%)	MDD (g/cc)	I	II	III	Avg.	Min. CBR (%)
1	100	0	6.22	2.5	50.2	49.3	49.6	49.70	30
2	80	20	6.35	2.45	41.2	40.98	41.32	41.17	30
3	60	40	6.48	2.41	38.68	38.23	38.44	38.45	30
4	40	60	6.52	2.36	35.8	35.12	35.75	35.56	30
5	20	80	6.67	2.32	32.02	31.93	31.98	31.98	30
6	0	100	6.86	2.24	29.5	29.44	29.3	29.41	30

Table 5: *KS+MS+MD Waste Substitution in Grade-I GSB*

S. No	Natural Material (%)	KS+MS+MD (%)	OMC (%)	MDD (g/cc)	Soaked CBR %	Soaked CBR %	Soaked CBR %	Soaked CBR %	Min. CBR (%)
S. No	Natural Material (%)	KS+MS+MD (%)	OMC (%)	MDD (g/cc)	I	II	III	Avg.	Min. CBR (%)
1	100	0+0	6.2	2.52	52.43	53.98	53.22	53.21	30
2	80	10+10	6.28	2.49	44.69	44.76	44.71	44.72	30
3	60	20+20	6.43	2.47	41.24	41.31	41.36	41.30	30
4	40	30+30	6.48	2.45	36.4	36.1	35.98	36.16	30
5	20	40+40	6.64	2.41	33.12	32.95	33.08	33.05	30
6	0	50+50	6.74	2.36	31.44	31.5	31.48	31.47	30

Table 6: *KS+MS+MD Waste Substitution CBR of GRADE-II GSB*

S. No.	Natural Material (%)	KS+MS+MD (%)	OMC (%)	MDD (g/cc)	Soaked CBR %	Soaked CBR %	Soaked CBR %	Soaked CBR %	Min. CBR (%)
S. No.	Natural Material (%)	KS+MS+MD (%)	OMC (%)	MDD (g/cc)	I	II	III	Avg.	Min. CBR (%)
1	100	0+0	6.22	2.5	50.2	49.3	49.6	49.70	30
2	80	10+10	6.3	2.44	41.22	41.34	41.28	41.28	30
3	60	20+20	6.5	2.39	39.5	39.46	39.43	39.46	30
4	40	30+30	6.51	2.33	34.3	34.4	34.36	34.35	30
5	20	40+40	6.65	2.31	32.27	32.21	32.19	32.22	30
6	0	50+50	6.84	2.27	30.98	31.02	30.95	30.98	30

4.2. Wet Mix Macadam (WMM)

WMM mixes displayed the same broad compaction trend observed in GSB: OMC increased and MDD declined with increasing replacement of natural materials by stone waste and marble dust. The thesis interprets this as a consequence of material texture, grading effects, and specific-gravity differences between natural aggregates and waste-derived particles.

Because the thesis primarily evaluated WMM through compaction rather than direct strength testing, the conclusions are more conservative. Recommended practical limits are approximately 75% for Kota stone waste + marble dust, 65% for marble stone waste + marble dust, and 70% for the equal combined waste mixture.

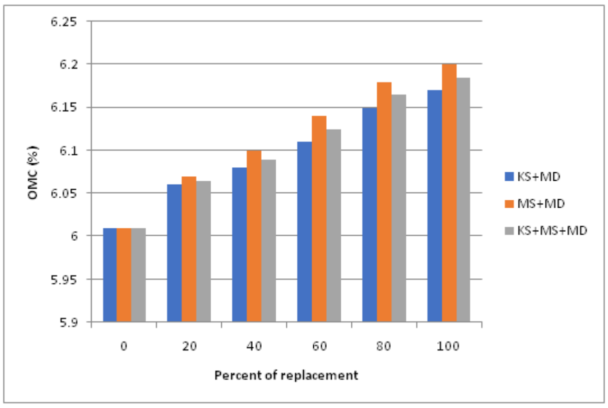

Figure 6: *Comparison in OMC Values of WMM with Different Waste*

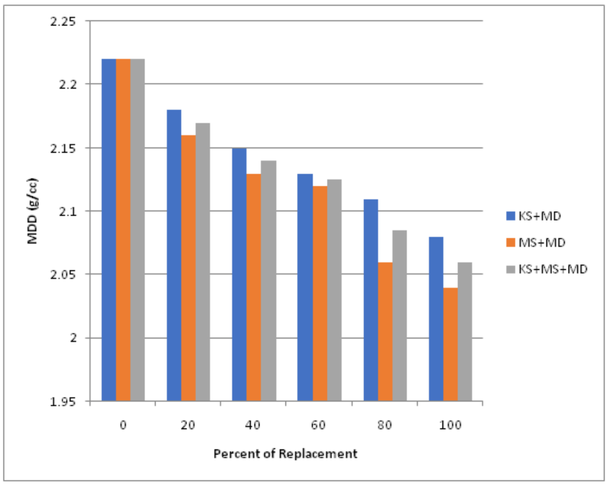

Figure 9: *Comparison in MDD Values of WMM with Different Waste*

Table 7: *Result of WMM Substitution with KS+MD Waste*

S.No.	Natural Material (%)	Kota stone + Mable dust (%)	OMC (%)	MDD (g/cc)
S.No.	Natural Material (%)	Kota stone + Mable dust (%)	OMC (%)	MDD (g/cc)
1	100	0	6.01	2.22
2	80	20	6.06	2.18
3	60	40	6.08	2.15
4	40	60	6.11	2.13
5	20	80	6.15	2.11
6	0	100	6.17	2.08

Table 8: *Results of WMM Substitution with MS+MD Waste*

S.No.	Natural Material (%)	Marble stone + Mable dust (%)	OMC (%)	MDD (g/cc)
S.No.	Natural Material (%)	Marble stone + Mable dust (%)	OMC (%)	MDD (g/cc)
1	100	0	6.01	2.22
2	80	20	6.07	2.16
3	60	40	6.1	2.13
4	40	60	6.14	2.12
5	20	80	6.18	2.06
6	0	100	6.2	2.04

Table 9: *Result of WMM Substitution with KS+MS+MD Waste*

S.No.	Natural Material (%)	KS+MS+MD (%)	OMC (%)	MDD (g/cc)
S.No.	Natural Material (%)	KS+MS+MD (%)	OMC (%)	MDD (g/cc)
1	100	0+0	6.01	2.22
2	80	10+10	6.07	2.17
3	60	20+20	6.09	2.14
4	40	30+30	6.13	2.125
5	20	40+40	6.17	2.085
6	0	50+50	6.19	2.06

4.3. Bituminous Macadam (BM)

Marshall design results showed that OBC remained relatively close to the control mix at moderate replacement levels, but Marshall stability declined and flow increased as marble stone waste and marble dust replacement became more aggressive. This indicates that the mixes remain technically usable up to an optimum range but progressively lose stiffness and load-carrying capacity at higher substitution percentages.

The thesis identifies an approximate feasible replacement window of 60% to 65% in BM. Beyond this range, the reduction in Marshall stability and the rise in flow make the mix less suitable for satisfactory pavement performance.

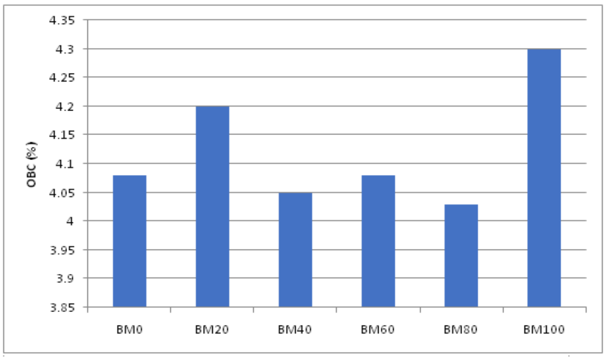

Figure 10: *OBC Value for BM at Different % of Substitution*

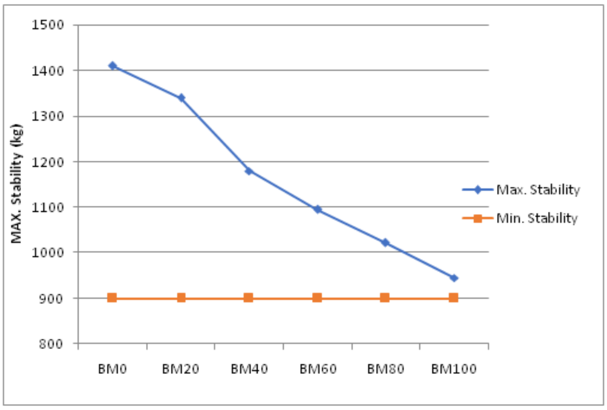

Figure 11: *Comparison of Marshall Stabiltiy at Different % of Substitution*

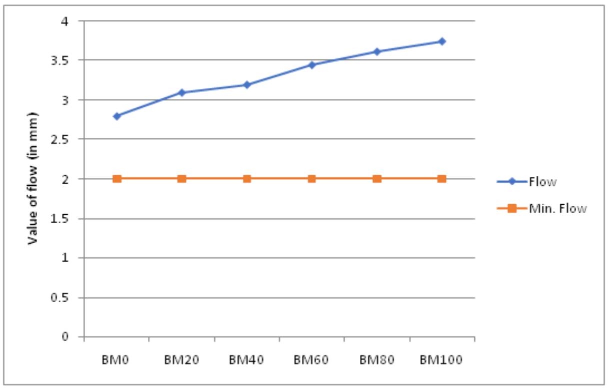

Figure 12: *Comparison of Flow Value at Different % of Substitution*

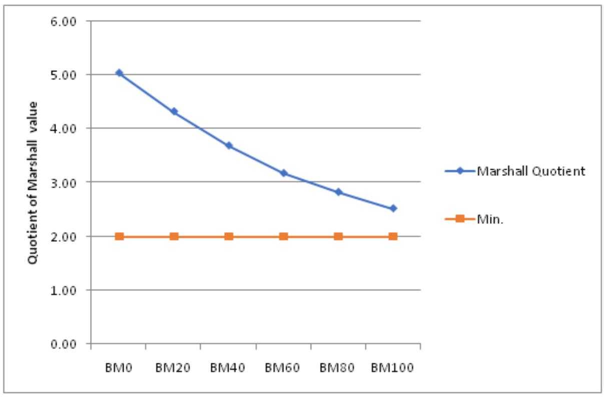

Figure 13: *Comparison of Marshall Quotient at Different % of Substitution*

Table 10: *Marshall Mix Results at Different Substitution Percentages*

Mix	Replacement (%)	BC-Optimum (%)	Stability - Maximum (kg)	Value of Flow (mm)	Quotient of Marshall value (kN/mm)
BM0	**0**	**4.08**	**1410**	**2.8**	**5.04**
BM20	20	4.2	1340	3.1	4.32
BM40	40	4.05	1180	3.2	3.69
BM60	60	4.08	1095	3.45	3.17
BM80	80	4.03	1022	3.62	2.82
BM100	100	4.3	945	3.75	2.52

4.4. Engineering Implication

The findings support the use of dimension stone waste as a partial substitute for conventional aggregates in pavement construction, especially in regions where Kota stone and marble waste are generated in large quantities. The most promising role is partial replacement rather than complete replacement, with performance-sensitive limits differing by pavement layer.

From a resource and sustainability perspective, the study demonstrates a route for converting a disposal problem into a construction input. This is especially relevant for low-cost or rural road projects where local sourcing can reduce transport demand and improve the circularity of road-building materials.

5. CONCLUSIONS

The present study was undertaken to examine the feasibility of utilizing Kota stone waste, marble stone waste, and marble dust as alternative materials in different layers of flexible pavement construction. The investigation was carried out for Granular Sub-Base (GSB), Wet Mix Macadam (WMM), and Bituminous Macadam (BM) layers by replacing conventional natural materials at different percentages and evaluating their performance through standard laboratory tests. The results of the experimental programme clearly indicate that these waste materials possess potential for use in pavement construction, though their suitability depends upon the layer of application and the extent of replacement.

The use of such waste materials is significant not only from the engineering point of view but also from the environmental and economic perspectives. Rajasthan generates large quantities of stone waste from marble and Kota stone industries, and its proper utilization in road construction can help reduce disposal problems, conserve natural aggregates, and promote sustainable development. However, the test results also show that complete replacement of conventional materials is not always desirable, as excessive substitution may adversely affect the engineering properties of pavement materials. The major conclusions drawn from the present investigation are discussed below.

The performance of waste materials in the Granular Sub-Base layer was evaluated primarily through compaction and soaked CBR tests. The results showed that the strength characteristics of the GSB mixes were influenced by the percentage of replacement of natural aggregate and stone dust with Kota stone waste, marble stone waste, and marble dust.

It was observed that the CBR values of both G-I and G-II gradations decreased gradually with the increase in replacement percentage of conventional materials by stone waste. This indicates that although the waste materials can be incorporated into the GSB layer, their excessive use reduces the load-bearing capacity of the mix. When full replacement was adopted, a severe reduction in CBR value was observed, which clearly indicates that complete substitution is not suitable for GSB applications.

In the case of mixes containing Kota stone waste and marble stone waste, the results suggest that replacement may be adopted up to about 70% without causing unacceptable deterioration in performance. Beyond this percentage, the reduction in CBR becomes substantial and the mix no longer remains suitable for effective use in the Granular Sub-Base layer.

Similarly, for mixes involving marble waste as the primary replacement material, the CBR values showed a decreasing trend with increasing replacement. The test results indicate that the practical upper limit for marble waste replacement is about 60%, as higher percentages result in a considerable loss in strength.

For the combined use of marble waste, Kota stone waste, and marble dust, the results were comparatively satisfactory up to around 65% replacement. Beyond this level, the engineering properties of the mix declined to an extent that makes the material unsuitable for pavement use. Therefore, it may be concluded that controlled use of these waste materials in the GSB layer is possible, but only within optimum replacement limits.

The suitability of waste materials in the Wet Mix Macadam layer was studied mainly through the Modified Proctor Compaction Test. The analysis of results shows that the inclusion of Kota stone waste, marble stone waste, and marble dust has a considerable effect on the compaction characteristics of the WMM mixes.

REFERENCES

[1] Ubani et al., 2025. Study on quarry dust with cement-stabilized tropical clay for pavement applications.

[2] Bardini et al., 2025. Study on waste foundry sand in pavement base and sub-base layers.

[3] Ohm, Lee, and Le, 2025. Study on crushed recycled marble stone powder in SBS-modified asphalt mixtures.

[4] de Medeiros et al., 2024. Study on marble and granite industry waste as filler in hot asphalt mixtures.

[5] Ali et al., 2024. Study on marble dust as filler in asphalt concrete.

[6] Benjeddou et al., 2022. Study on crushed marble waste as aggregate in road construction.

[7] Ravindra Nagar and P. Kalla, 2018. Study on quarry waste in open-graded friction course mixes.

[8] Pradeep Kumar Gautam and Pawan Kalla, 2018. Study on Kota stone waste in hot mix asphalt.

[9] Arun Pratap Singh Rathore and Karan Parbhakar, 2018. Study on stone slurry waste in black cotton soil stabilization.

[10] Surender Singh et al., 2017. Study on bagasse ash with reclaimed road material.

[11] Virendra Singh Shekhawat and Bharat Nagar, 2017. Study on marble dust waste as filler in DBM layer.

[12] Ajay Singh Jethoo and Harshwardhan S.C., 2017. Study on Kota stone waste as fine aggregate in BM Grade II.

[13] Surender Singh, G.D. Ransinchung, and R.N., 2017. Study on demolition waste and bagasse ash in asphalt mixes.

[14] S. Faisal and Ibrahim A., 2017. Study on basalt in black-top mixes.

[15] Huseyin Akbulut and Cahit Gurer, 2007. Study on marble waste granules in asphalt mixes.