

Characterization Of Limestone Waste for Use in Base and Sub-Base Layers of Flexible Pavements

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ABSTRACT

The present study comprises a comprehensive survey and experimental investigation carried out to quantify the limestone waste generation at quarry sites in two villages of Chittapur and Shahbad taluks, Kalaburagi district, and to assess its feasibility for application in flexible pavement construction. Survey findings indicate that approximately 20 lakh tonnes of limestone waste are produced annually in the region. To evaluate its suitability for road infrastructure, the collected limestone waste aggregates were subjected to detailed laboratory characterization. The experimental program included determining the physical properties of aggregates, developing Job Mix Formulae (JMF) for Granular Sub-Base (GSB) and Wet Mix Macadam (WMM) layers, conducting Modified Proctor Compaction tests to establish Maximum Dry Density (MDD) and Optimum Moisture Content (OMC), and performing California Bearing Ratio (CBR) and Direct Shear tests on GSB mixes. The performance of limestone waste aggregates was analytically compared with conventional basalt aggregates. Results confirm that limestone aggregates meet the MoRT&H (2001) specifications and can effectively serve as a complete replacement for basalt aggregates in both GSB and WMM layers. The utilization of limestone waste in pavement construction not only offers a sustainable solution for waste management but also helps address the aggregate demand-supply gap, conserves natural stone resources, and reduces environmental degradation caused by excessive quarrying. This study underscores the potential of limestone waste as an eco-friendly and cost-effective alternative material for road construction.

Keywords: Limestone, Pavements, Flexible Pavements.

I. INTRODUCTION

The rapid depletion of the nation's natural resources is being brought about by the excessive use of traditional construction materials in the construction of roads and buildings. The ongoing rate of construction will soon deplete the availability of these materials, which are non-renewable and hence cannot be replenished. Engineering professionals have been pushed to investigate alternative possibilities because of the limited availability of crushed rock aggregates and the high cost of these aggregates because of higher transportation costs. Because of this, attention is currently being turned toward non-traditional and waste materials. Some examples of these materials are quarry by-products from limestone, industrial waste, debris from building and demolition, lateritic soil, and other marginal resources that are present within the country.

Chittapur Villeges in Malgatti and Ravoor are well-known for their production of slabs and tiles in the Gulbarga region, particularly in the various talukas of Shahbad. The extraction of these slab sand tiles creates a significant amount of waste during the quarrying process. Large mounds of this waste have been generated because of the deposition of this trash, which has taken up a significant portion of the land surrounding the quarry sites. Both Shahbad and Chittapur contain several talukas that contain quarries that are comparable to one another. Taking all these factors into consideration, it is projected that the Gulbarga district alone might produce between around 20 and 25 lakh tonnes of garbage. In addition to this, it is anticipated that other limestone belts located throughout the country will produce significant quantities of waste limestone. Considering this, it is of the utmost importance to characterize the waste limestone and determine whether it is suitable for use in the building of base and sub-base layers of flexible pavements. This will allow for the problem of waste disposal to be resolved. In the current investigation, an attempt has been made to characterize two kinds of quarry wastes, namely muddy waste and non-muddy waste, by means of laboratory tests. The purpose of these investigations is to evaluate the possible potential of these wastes for application in the base and sub-base courses of flexible pavements.



Figure No.1: Limestone waste at quarry site.

II. LITERATURE REVIEW

The construction and demolition waste (CDW) has led to eco-friendly practices that promote recycling and reusing of the same material, as well as the valorization of various types of trash, as shown by Abukttle [1]. While reducing the amount of construction trash sent to landfills is obviously important, one of the long-term objectives should be to use as little borrowed materials as possible while building new infrastructure. This will help achieve green construction. Regarding this matter, reusing materials from construction and demolition waste (CDW) considerably reduces the environmental damage caused by construction activities. On a technical level, this study aims to examine the viability of using CDW as a substance in the base layers of road pavements. To get there, researchers evaluated the performance of pavements made from concrete, asphalt-mix, and ceramic waste aggregates in the field. The investigation tested how these recycled materials fared in a simulated road environment with real-life traffic circumstances. Results demonstrated that recycled CDW aggregates, as a final product, could be used to build pavements due to their high load bearing capacity.

According to Shafi ullah, [2], a significant amount of marble waste is generated during the cutting operations in marble processing units. About 70% of the marble that is industrially produced goes to waste since it is not biodegradable, and only 30% of it is really turned into a marketable product. Thirty percent of the stress on our environment is caused by this recovery rate. Water logging and reduced soil porosity are issues that arise when marble manufacturers dispose of waste in an open field or pit. Soil productivity issues and soil alkalinity are both caused by marble waste. As a dimensional stone, marble is sold by size rather than weight by the marble industry. These businesses' goal is to stock up on marble slabs for sale; however, the massive proportions of these slabs cause even more marble to be wasted. Since the amount of waste is not so huge in other works, reusing the waste in civil works, especially roads, could be a solution to the problem of marble waste. The goal of this research is to find new uses for marble.

According to Ovidijus Sernas [3,] a tiny amount is deposited in Lithuania, and the mineral aggregates that are found there have a low to medium strength. These mineral aggregates include sand, gravel, and various types of dolomites. Lithuania is home to over 950 million miles. Even though there are significant granite reserves, they are not mined since they are in close vicinity to Dzuki National Park and are between 200 and 300 meters deep. Granites with erroneous characteristics are brought in from neighbouring nations such as Ukraine, Sweden, Poland, Norway, and

Finland, amongst others. When imported granite is received, it is in the form of coarse granites that measure 20/40 mm and 40/70 mm. Domestic manufacturing companies then purify the imported granite mass to produce broad and narrow granites. The separation of huge granite aggregates results in the production of a significant amount of secondary material, which in this case is granite fines, which consumes a significant amount of volume. This phenomenon creates an issue that is comparable in other countries. An investigation into the impact of quarry dust on highway construction was carried out by Sridharan and colleagues in 2005. The researchers found that the CBR and angle of shearing resistance values gradually decreased as the quantity of quarry dust increased. The use of cracker dust, which was published in 2001, demonstrates a high shear strength, which is an attribute that is suitable for use in geotechnical applications.

It has been suggested by Choudhary and Chandra (2008) that the incorporation of marble and granite dust into asphalt concrete can result in the attainment of qualities that are comparable to those of conventional asphalt concrete mixes, with stone dust serving as the typical filler. It was observed that they may be added into asphalt concrete mixes at a ratio of up to seven percent; however, it is recommended that they be introduced initially in the range of four to five percent to accurately evaluate how effective they are in the field. When filler-asphalt mastic was subjected to viscometric examinations, it was discovered that the granite dust exhibited the highest $G^* / \sin \delta$, which was indicative of its superior resistance to rutting. They found that there is no substantial difference between granite and basalt mineral filler in terms of their physical qualities, and that asphalt mix enlivened by granite or basalt mineral filler in terms of its mechanical resistance needs and satisfies requirements.

This was discovered by Ribeiro et al. (2008). As a result of the findings of Binici et al. (2008), it has been discovered that the aggregates of waste marble and granite can be utilized to improve the mechanical characteristics, workability, and chemical resistance of the conventional concrete mixture.

In the present environment, steel slag is not successfully used and instead it is deposited in costly lands adjacent to the factories. It came up with a research to determine whether it could be used in the different layers of road construction. As a less material of cohesion, the slag was combined with the local soil at varying ratios of 5-25 percent, and the geotechnical characteristics of the blend analyzed. Standards of technology use of steel slag were worked out on road pavement embankment layers of sub-grade and sub-base layers. More on that, the possibility of including slag in bituminous layers was also explored.

As Abukhettla [1] be it through the wet or dry treatment, the Crumbed shape of rubber applied in asphalt surfacing covering has numerous other merits besides the enhanced skid-resistant value. It also gives asphalt mixtures, which are high in shear strength that are preferable in the sustainability of the imposed traffic load and the elimination of rutting in the underlying pavement layers. Moreover, when able to freeze and thaw in cold weather, the disposal of scrap rubber in the bottom layer compositions are main factors that will ensure that the frost penetration level is decreased significantly. Other advantages of the crumbed rubber in the construction application of roads include but not limited to rendered temperature flammability, precipitated rutting and fatigue resistance, and heightened aptitude and lessening flow worth up to a level of 10 percent of crumb rubber Comprising enhancing stripping obstinacy. On addition to the asphalt binder to a percentage of up to 30, improvement in other properties like weathering and stripping resistance has been realised to a greater extent.

As Abukhettla[1] notes, fly ash, bottom ash/boiler slag, pond ash, oil sand, petroleum-contaminated soil, oil slate ash, brake shoe fines could be considered in terms of their use in road construction. Utilizing a 40 percentage fly ash of a RAP-modified mix, sub-base and base course layers make use of fly ash suitable in the construction of light-traffic pavements. Ash eluted through blast furnaces is generally known as furnace bottom ash.. It has been shown in literature that fly ash can be applied mostly in the construction of roads as opposed to bottom ash. Indicatively, the City of Mississauga and Brampton generate nearly 30,000/year and 3,000/year of bottom ash and fly ash respectively, which are only allowable to be suitable for use in the hot mix asphalt (HMA) with a reporting percentage of 10%. The use of ash has however been reported to leech and suggested solution to this implication is vitrification. An asphalt pavement filter is designed to be used as an aggregate in asphalt pavements; a vitrified ash that is a glassy and repulsive to water texture. Its hydrophobic property greatly keeps the volume of asphalt cement needed to reach desirable performance traits at minimum levels. Moreover, it has been exhibit that addition of bottom ash has increased tensile strength and deformation resistance although more studies are required to access its resistance to stripping properties. Studies have also shown that an increase in the ratio of fiber and lime in consort with ash results in decreases in the vertical compressive strain and horizontal tensile strain on the bottom and sub-grade layers thus augmenting pavement stiffness. It is further suggested that the impact of pond ash on that of sub-base materials ratio in California be researched on.

III. OBJECTIVES

1. The objective is to analyse and characterize a waste material derived from limestone to assess its suitability for use in the base and sub-base layers of flexible pavement construction.
2. Calculate the mix design parameters, including proportioning, grading, and compaction parameters for GSB and WMM layers utilizing limestone waste.
3. The objective is to minimize dependence on traditional coarse aggregates in road construction by substituting them with waste limestone.
4. This document outlines the engineering and physical properties of limestone waste collected from quarry sites. Analysing the performance metrics of limestone waste in relation to traditional aggregates such as basalt.

IV. EXPERIMENTAL STUDY

In this project, there is an attempt to utilize the waste of limestone and traditional aggregate, and different tests should be performed.

- **Aggregates:** Aggregates provide shear strength and compression. With this they also offer interlocking capability and allow good permeability. Fractions (both fine and coarse aggregates) are mostly found in aggregates.
- **Filler:** Filler is mostly a fine divisive mineral material like rock dust, hydrated lime or cement. The filler material does not contain any organic impurity. When taking expected filler is cement, the index of plasticity need not be determined.
- **Grading:** The grading of aggregates for both the GSB and WMM layers is presented in Table No. 1, respectively. The material is suitable for use in the road construction of the sub-base and base layers as it meets the necessary grade requirements.

Table No. 1: Grading parameters of aggregate for Granular subbase layer (GSB)

Sl. No.	IS sieve designations	Percentage (%) of weight passing the IS sieve					
		Grading I	Grading II	Grading III	Grading IV	Grading V	Grading VI
1.	75.0mm	100	-	-	-	100	-
2.	53.0mm	80-100	100	100	100	80-100	100
3.	26.5mm	55-90	70-100	55-75	50-80	55-90	75-100
4.	9.5mm	35-65	50-80	-	-	35-65	55-75
5.	4.75mm	25-55	40-65	10-30	15-35	25-50	30-55
6.	2.36mm	20-40	30-50	-	-	10-20	10-25
7.	0.85mm	-	-	-	-	2-10	-
8.	0.425mm	10-15	10-15	-	-	0-5	0-8
9.	0.075mm	<5	<5	<5	<5	-	0-3

4.1 CALIFORNIA BEARING RATIO TEST (CBR)



Figure No. 2: CBR Test at Laboratory

- The California bearing Ratio (CBR) test represents the test that determines the strength of soil and base layers of the during road construction. It is the product of the California Department of Transportation developed prior to World War II.
- The tests involve how penetrative a plunger of standard size must be on soil or an aggregate, versus how the same plunger should be on a standard crushed rock specimen.
- CBR value - This value indicates the load support capacity of soil primarily on roads and can also be adequate with airstrips. The surfaces with stronger characteristics are better in terms of CBR rating.

Table No. 2: CBR test for GSB mix.

Sl. No	Type of aggregate	Requirement as per MoRT&H-2001
1	lime stone	25%(minimum)
2	Basalt	

4.2 PROCTOR COMPACTION TEST

The Proctor compaction test is a test conducted in a laboratory to find out how much the parent soil contains in terms of moisture value, at which the soil faithfully yields its highest density in form of dry soil. This test is based on the property pioneered by R. R. Proctor in 1933 who established that the relationship between the dry density of a soil when compacted at a certain level of compactive effort depends on the moisture content of the soil at the compaction time.



Figure No. 3: Proctor Compaction Test at Laboratory

- The original system designed by Proctor and often trademarked as the standard Proctor compaction test, sometimes called standard Proctor test, was later improved to offer the modified Proctor compaction test. In such laboratory analyses, soil is pressed at standard moisture levels at controlled compactive inputs into a standard cylindrical mold.
- Equally stratified soil The soil is laid down in standard layers and each layer gets a defined number of blows on it, using some weighted hammer at a predetermined height. This process is carried out at a series of moisture content and the respective dry densities documented. Plotting between dry density and the moisture content will produce the compaction curve. Maximum point of the compaction curve indicates the maximum dry density (maximum weight of solids in the soil) and the optimum moisture content in the soil.

4.3 DIRECT SHEAR TEST

The shear strength of soil or rock is majorly considered by the direct shear test, including fractures or weak planes. Tests of direct shear can be done in varying conditions.



Figure No. 4: Direct Shear Test at Laboratory

- About the tests, they can be conducted on saturated specimen or at in-situ moisture content. Strain may be set to a drained or undrained regime by varying the strain rate either in the direction of slow strain (to allow the water to escape in the sample) stress to prevent pore-pressure development. An arduous shear machine will be required to perform the test.

4.4 TEST RESULTS & DISCUSSION

Table No. 3: Obtained Values of Physical Properties of Aggregates

			Requirements as per		
Sl. No.	Property	Material		MoRT&H-2001[3]	
1.		Limestone	Basalt	GSB	WMM
2.	Water Absorption (%)	0.10	0.50	2%(max)	-
3.	Specific gravity	2.63	2.89	2.5-3.2	2.5-3.2
4.	Impact value (%)	27.06	17.85	30%(max)	30%(max)
5.	Crushing value (%)	25.70	15.26	30%(max)	30%(max)
6.	Abrasion value (%)	19.96	22.56	30%(max)	30%(max)
7.	Combined Index (%)	41.19	32.88	30%(max)	30%(max)
8.	Liquid limit	19.64	20.00	25%(max)	-
	425μpassing(%)				
9.	Plasticity Index on 425μ passing(%)	Non Plastic	Non Plastic	6%(max)	-

Based on Table 3, it is possible to notice that limestone waste aggregates are lower porous than basalt. According to strength of coarse aggregates, basalt is stronger than limestone waste basing on specific gravity. Moreover, the joint index is larger than the one stated in MoRT&H 2001, which means that the material can also be applied to Granular Sub Base (GSB) and WMM layers of flexible pavements since it displays an acceptable CBR value. Its liquid limit as of limestone waste is lesser than that of basalt this shows that limestone waste is a freer draining material and that it may be used in sub base and base. As all the physical characteristics of limestone waste fit the MoRT&H 2001 standards, the aggregates may be applied in WMM and the GSB layers as an alternative to traditional products e.g. basalt.

4.5 OBSERVATIONS AND CALCULATIONS: (BASIC PROPERTIES OF LIMESTONE)

Specific Gravity of Limestone Waste

Observation:

- Weight of material = $W_1 = 3000$ (gm)
- Empty weight of wire basket under water = $W_2 = 2380$ (gm)
- Weight of wire basket + material under water = $W_3 = 4240$ (gm)



Figure No. 5: Specific Gravity Wire Basket Test at Laboratory

Calculation: Specific gravity (sg) of limestone = 2.63

$$\frac{W_1}{((W_1 - (W_3 - W_2)))}$$

$$\frac{3000}{((3000 - (4240 - 2380)))}$$

Comment: The specific gravity (sg) is (2.63). According to MoRT&H requirements the acceptable range is 2.5 to 3.2. Hence, value of obtained is clear of the specific gravity requirement.

Impact Value

Observation:

- | | | | |
|---|-----------------------|--------------|------------|
| 1. Weight of empty cylinder | = W_1 | = 794 (gm) | |
| 2. Weight of cylinder + sample full in cup | = W_2 | = 1101 (gm) | |
| 3. Weight of material | = $W_3 = (W_2 - W_1)$ | = 1101 - 794 | = 307 (gm) |
| 4. Weight of material passing through 2.36 mm sieve | = $W_4 = 83$ (gm) | | |



Figure No. 6: Impact Value Test at Laboratory

Calculation:

$$\text{Impact value} = \frac{W_4}{W_3} \times 100$$

$$= 27.03\%$$

Comment: The value obtained of Impact is 27.03 as per MorT&H Impact value should not exceed 30, therefore, the value obtained satisfies Impact value requirements.

Crushing Value

Observations:

- | | |
|---|---------------------------------|
| 1. Empty weight of cylindrical mould with plate | = $W_1 = 10034$ (gm) |
| 2. Weight of cylindrical mould + material | = $W_2 = 13629$ (gm) |
| 3. Weight of material | = $W_3 = W_2 - W_1 = 3595$ (gm) |
| 4. Weight of material passing through 2.36 mm sieve | = $W_4 = 924$ (gm) |



Figure No. 7: *Crushing Value Test at Laboratory*

Calculation:

$$\text{Crushing value} = \frac{W_4}{W_3} \times 100$$

$$= (924/3595) \times 100 = 25.7\% < 30\%$$

Comment: The resultant value of crushing is 25.7 percent. According to the MoRTH requirements, the crush value is not to be higher than 30. Therefore, the outcome is adequate to the prescribed standards.

Abrasion Test

Observations:

- | | |
|--|-------------------|
| 1. Weight of material | $W_1 = 5000$ (gm) |
| 2. Weight of material passing through 1.7 mm sieve | $W_2 = 998$ (gm) |
| 3. No. of steel balls taken = 12 Nos. | |



Figure No. 8: *Abrasion Test at Laboratory*

Calculation:

$$\text{Abrasion value} = \frac{W_2}{W_1} \times 100$$

$$= (998/5000) \times 100$$

= 19.96%

Comment: The received Abrasion Value is 19.96 percent. According to the MoRTH guidelines the Abrasion Value must not be greater than 30%. Therefore, the value obtained is adequate.

4.5 DEVELOPMENT OF JOB MIX FORMULA FOR GSB MIX

Determination of Proportions of Grade II, Coarse Grading This involves determination of the following parameters:

1. Blend proportion of aggregates
2. Modified Proctor compaction test
3. CBR test

Table No. 4 Obtained gradation per cent by weight of GSB materials

Sieve size in (mm)	Percentage passing finer (%)			Obtained gradation (% by weight passing)	Grading II As Per MoRT&H-2001 (% by weight passing)
	40mm (A) (0.6)	12mm (B) (0.15)	6mm (C) (0.25)		
75	100	100	100	100.00	-
53	100	100	100	100.00	100
26.5	47.44	100	100	68.46	50-80
4.75	3.32	32.5	61.7	22.29	15-35
75u	1.8	0.34	3.3	1.96	<10

Blend proportion of Limestone:

On coarse Aggregates sieve analysis was performed, Percentages passing was calculated on various sieves. The blend percentage was ascertained utilizing Rothfutch and trail and error approach. Table 2 indicates the obtained blend proportion gradations and targeted gradation according to specifications of MoRT&H- 2001.

Blend proportion of Limestone = $0.60A + 0.15B + 0.25C$

4.6 MODIFIED PROCTOR COMPACTION TEST FOR GSB LAYER

Determination of MDD and OMC of Limestone Waste

Observations:

1. Diameter of mould (d) = 15 cm
2. Height of mould (h) = 12.5 cm
3. Volume of mould = $(3.14 \times d^2 \times h)/4 = 2208.93 \text{ cm}^3$.

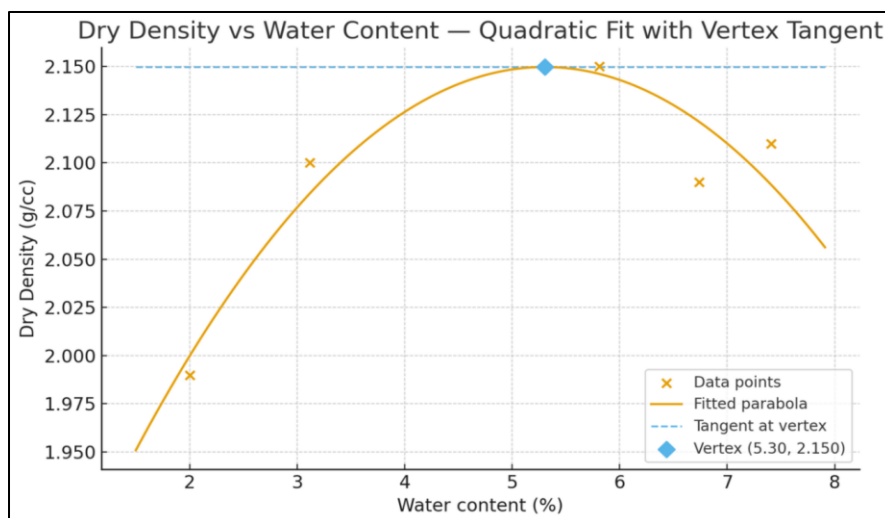
Total weight of limestone waste = Density x volume
= 2.5×2208.9
= 5522.33 gm, say 5600gms Weight of different sizes of materials

(A) 40mm = $0.60 \times 5600 = 3360 \text{ (gm)}$

(B) 12mm = $0.15 \times 5600 = 840 \text{ (gm)}$

(C) 06 mm = $0.25 \times 5600 = 1400 \text{ (gm)}$

A graph between moisture content (w%) along the X-axis and dry density along the Y-axis to determine the Maximum Dry Density (MDD) and Optimum Moisture Content (OMC).



Graph No. 1: Determination of Maximum dry density (MDD) and optimum moisture content (OMC) for GSB layer material grade II.

MDD = 2.15 gm/cc and OMC = 5.81%.

This was conducted as per IS:2720 Part 8[4], by mixing aggregates as per job mix formulae and different percentage of water is mixed and compacted in 5 layers by giving 56 blows on each layer from 4.8 kg rammer.

Table No. 5: Results of modified proctor compaction test for GSB

Sl. No.	Type of Aggregate	Optimum Moisture Content (%)	Maximum Dry Density (gm/cc)
1.	Limestone	5.81	2.15
2.	Basalt	6.10	2.47

Using the results obtained, one can notice that the maximum possible dry density of limestone waste is satisfactory. MDD obtained using basal this 11.34 percent higher than that of the limestone material. limestone material has provided a smaller maximum dry density; it is because that material contains more flaky and long material.

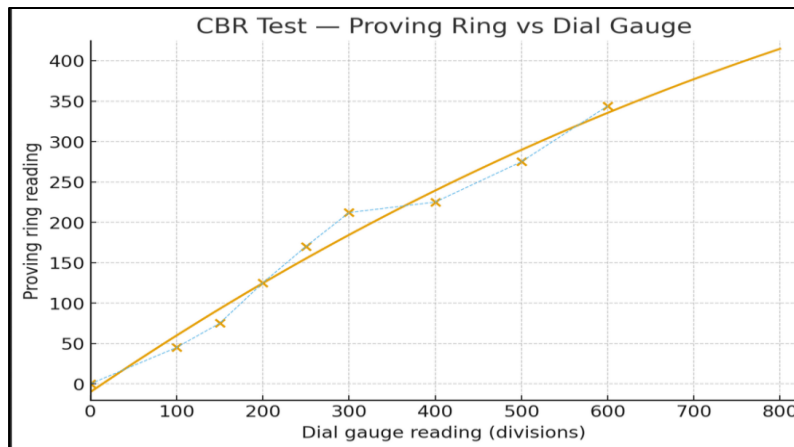
4.7 CALIFORNIA BEARING RATIO TEST

Buyers agency applied this test in accordance with IS: 2720-Part-16 [5], by mixing the aggregates within the CBR mould to the job mix formula. Moisture level where 98 percent of the maximum dry density was reached was utilized due to the maintenance of a constant airvoids content of 5 percent.

Table No. 6: CBR values obtained for GSB mix

Sl. No.	Type of aggregate	CBR values (%)	Requirement as per MoRT&H 2001
1.	Limestone	91	25%minimum
2.	Basalt	115	

From the table, it can be observed that limestone material has exhibited a satisfactory CBR value; therefore, these aggregates sample are suitable for use in heavy traffic volume pavements.



Graph No. 2: Determination of California bearing ratio test for GSB layer material grade II.

4.8 DIRECT SHEAR TEST

In conducting the test, the mixture of the aggregates sample was prepared in accordance with the mix ratios as up to date. In the large direct shear apparatus, the test was to be conducted by prepping of the aggregate mixture. The experiment was performed on the dry mix and it proved hard to obtain the maximum dry density (MDD). Therefore, height of aggregate sin of shear box maintained in such a way that we can compare the test results of limestone waste with the Basalt.

Table No. 7: Results of direct shear test for GSB mix

Sl. No.	Type of aggregate	Angle of internal friction(Φ) in degrees	Cohesion C, (kN/m ²)
1.	Limestone	41	0
3.	Basalt	58	0

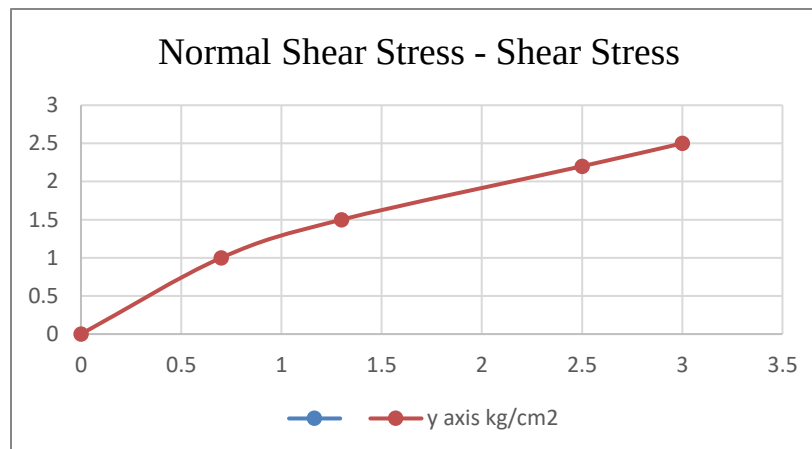


Figure No. 3: Determination of CBR test for GSB layer material grade II.

By examining the table, it is possible to note that this mix is non-cohesive and has an excellent angle of internal friction that implies a good interlocking among the aggregates and creates good grain to grain contact that is desirable and may have good dispersion properties.

4.9 PERMEABILITY TEST ON LIMESTONE WASTE (BY FALLING HEAD METHOD)



Figure No. 9 Permeability Test at Laboratory

Observation:

1. Die of standpipe = 2 cm
2. Area of standpipe (a) = $(3.142 \times (2)^2/4) = 3.142 \text{ cm}^2$
3. Diameter of sample = 10 cm
4. Height of sample = 13 cm
5. Length of sample = 13 cm
6. Area of cross section of sample = $(3.142 \times (10)^2/4) = 78.54 \text{ cm}^2$

Table No. 7: Permeability Test

Sl. No.	Time in (seconds)	Initial head (h_1) in (cm)	Final head (h_2) in (cm)	Permeability (k) in (cm/s)
1.	5	99	37	0.1005
2.	5	99	39	0.0968
3.	5	99	33	0.1142
4.	5	99	31	0.1207

$$\text{Permeability} = (k) = (k_1 + k_2 + k_3 + k_4)/4 = 0.1080 \text{ (cm/s)}$$

4.10 MODIFIED PROCTOR COMPACTION TEST FOR WMM LAYER

This test was done in combination of aggregates according to the formula of job mix. Various water content percentages were applied and the mix was pressed into 5 layers subjecting 56 blows per layer at 4.8 kg rammer. MDD and OMC of limestone waste were determined.



Figure No. 10: Modified Proctor Test at Laboratory

Observations:

- 1) Diameter of mould (d) = 15 cm

2) Height of mould (h) = 17.5 cm

3) Volume of mould = $(3.124 \times d^2 \times h)/4 = 3092.5 \text{ cm}^3$.

Total weight of limestone waste = Density $\times$ volume
= 2.5×3092.5
= 7731.25 (gm), say 8000 (gm)

Weight of different sizes of materials

(A) 40 mm = $0.35 \times 8000 = 2800 \text{ gm}$

(B) 20 mm = $0.10 \times 8000 = 800 \text{ gm}$

(C) 12 mm = $0.10 \times 8000 = 800 \text{ gm}$

(D) 6 mm = $0.45 \times 8000 = 3600 \text{ gm}$

A graph between moisture content (w%) along the X-axis and dry density along the Y-axis to determine the Maximum Dry Density (MDD) and Optimum Moisture Content (OMC).

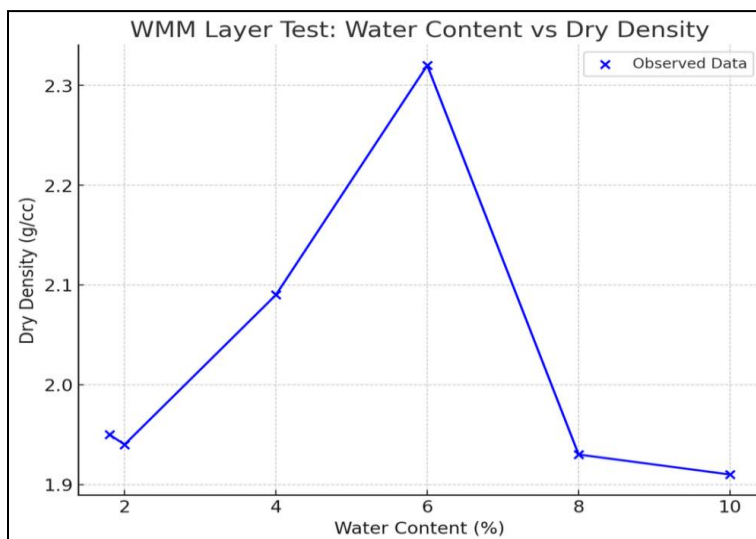


Figure No. 11: Determination of Maximum dry density (MDD) and optimum moisture content (OMC) for WMM layer material. MDD = 2.32 gm/cc and OMC = 8.25%.

Table No. 8: Results of Modified Proctor (Compaction) Test for WMM Materials

Sl. No.	Type of Aggregate	Optimum Moisture Content (%)	Maximum Dry Density (gm/cc)
1.	Limestone	8.25	2.32
2.	Basalt	7.60	2.47

Based on table no. 8, we find that limestone waste has collected a desirable maximum dry density. The MDM attained using basalt is 6.07 percent above that of muddy material. The muddy substance had lesser MDD that can be explained by the fact that more proportions of flaky and elongated particles were present in it.

VI. CONCLUSION

1. Limestone waste exhibits good interlocking ability as compared to the basalt aggregates and therefore it can display wonderful dispersion properties sought in base and subbase courses.
2. Limestone waste exhibits superior interlock characteristics vis-a-vis basalt aggregates and thus may offer good load dispersion characteristics necessary in a base and subbase.
3. Limestone waste proves high cost effective than basalt that involves simply the transportation costs and processing costs. This is free material, which also assists in solving the disposal challenge of limestone waste.
4. The granular sub-base (GSB) and wet mix macadam (WMM) may be successfully implemented with limestone waste condensed in their sub footfalls and facilitate sustainable and economical construction of the pavements.

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