Study on Brick Dust for GSB Layer of Flexible Pavement

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ABSTRACT

This study investigates the potential of locally available Brick Dust as a partial replacement for sand in Granular Sub-Base (GSB) layers for road construction, following MORTH specifications. Brick Dust was incorporated at four replacement levels—**10%, 20%, 30%, and 40%**—and evaluated through gradation analysis, compaction testing, and California Bearing Ratio (CBR) assessment. While all mixes satisfied the gradation and non-plasticity requirements, significant variation in strength characteristics was observed. The mixes containing **10%, 20%, and 30% Brick Dust failed to achieve the minimum CBR value** required for GSB applications, indicating inadequate load-bearing capacity. Conversely, the **40% Brick Dust mix exhibited optimal performance**, achieving CBR values well within the acceptable range and demonstrating improved compaction behavior. The findings confirm that **40% Brick Dust can effectively replace sand in GSB layers**, offering a cost- efficient and environmentally sustainable alternative by reducing dependence on natural sand resources. This study supports the use of Brick Dust as a viable material for sustainable road construction practices.

1. INTRODUCTION

When pavements are built on a weak sub grade, granular sub base is used as a layer between the sub grade and the granular base course. When the base course thickness exceeds the norm due to a poor sub grade, it is divided into two layers: granular base course and GSB. Because the material used to produce the GSB layer is inferior that used to construct the granular base course, the GSB layer saves money during road construction. Another important role of this layer is to serve as a drainage layer for the pavement, preventing excessive wetting and sub grade deterioration. In terms of strength, it is superior to the sub grade. Sub-base course is built with a variety of materials and procedures.

2. OBJECTIVE OF STUDY

The primary objective of this study is to evaluate the feasibility of using ceramic waste powder and bagasse ash as partial replacements for cement in concrete. The specific objectives include:

- To evaluate the suitability of brick dust as a partial or complete replacement for conventional GSB materials such as crushed stone aggregates in flexible pavements.
- To analyse the physical and engineering properties (e.g., grain size distribution, compaction characteristics, strength, CBR value) of brick dust for use in the GSB layer.
- To develop a mix design or proportioning strategy for incorporating brick dust into the GSB layer while ensuring compliance with relevant standards
- To propose guidelines or recommendations for the practical implementation of brick dust in GSB layers for flexible pavement construction.

3. MATERIALS & METHODOLOGY

3.1.1 Technology used

Granular sub-base (GSB) layers are frequently used in flexible pavement technology to support and stabilize the pavement structure. Brick dust has occasionally been researched and used in the GSB layer of flexible pavement construction. Here are some details on the application of brick dust in the GSB layer:

3.1.1.1 Brick dust:

Brick dust is a by-product of brick production or can be obtained by crushing bricks, according to the material properties. Depending on the source and the processing techniques, its characteristics can change. Similar to sand or fine aggregate, brick dust typically consists of finely crushed particles in a variety of sizes.

3.1.1.2 Stability and Load-Bearing Capacity:

Loads from the pavement surface are predominantly transferred to the underlying layers via the GSB layer. When correctly compacted, studies have demonstrated that brick dust can offer sufficient stability and load-bearing capacity. Its strength is influenced by the distribution of particle sizes, angularity, and compaction properties.

3.1.1.3 Moisture Resistance:

It has been discovered that brick dust has strong moisture resistance qualities. It doesn't quickly absorb water, which aids in
preserving the GSB layer's stability and preventing excessive swelling or softening brought on by moisture content.

3.1.1.4 Cost and Availability:

Brick dust might be an affordable choice for GSB layers, particularly in regions with a high concentration of brick manufacture. Brick dust is a by-product that can be used to build structures more sustainably and lowers the need to extract raw materials.

3.1.1.5. Environmental Considerations:

Recycling waste materials, lowering landfill trash, and protecting natural resources are all benefits of using brick dust in pavement construction. It adheres to the concepts of waste reduction and environmentally friendly building.It's vital to keep in mind that the amount of brick dust used in the GSB layer may change depending on regional requirements, climate, and project parameters. A thorough geotechnical research and laboratory testing should be done before employing brick dust to determine its appropriateness and performance qualities for the particular application.To ensure compliance and ideal performance in the particular project context, it is advised to engage local authorities, pavement design specialists, and engineers knowledgeable with regional standards and recommendations.

4. TEST & RESULTS

Before going ahead of our final test of this project, we need to do the necessary test on the materials. The following laboratory test to be conducted in the project

4.1 Test on Aggregate

- Specific gravity test.

SI NO	Description	Trail No 01	Trail No 02	Trail No 03
01	Empty Weight of Pycnometer (W1)	664	664	664
02	Weight of Pycnometer +1/3 of Soil (W2)	1077	1048	1093
03	Weight of pycnometer +1/3 of Soil +full of Water (W3)	1778	1750	1770
04	Weight of Pycnometer +full of water (W4)	1545	1534	1547
05	Specific gravity of soil =(W2-W1)÷(W2-W1)-(W3-W4)	2.94	2.28	2.08
06	Average Specific gravity		2.43%	

The specific gravity of the soil/aggregate sample = 2.71

This value indicates that the material has a specific gravity typical of natural aggregates/soil minerals, showing it is dense and suitable for civil engineering applications.

- Water absorption test.

SI NO	DISCRIPTION	Trail 01
01	Weight of saturated surface-dried sample in g(A)	3790
02	Weight of over-dried sample in g(B)	3776
03	Water absorption =A-B÷B×10	0.37%

The water absorption of the aggregate = 0.37%

This value is within the acceptable limit (generally < 2%), indicating that the aggregate has low water absorption and is of good quality for concrete and pavement applications

Flakiness and Elongation

Size of aggregate		Thickness gauge	Weight of fraction consisting 200 pieces (gm)	Weight of aggregate in each fraction retained on the thickness gauge
Passing through IS sieve (mm)	Retained IS sieve (mm)			
20	16	20 to 16	2000	76
16	12.5	16 to 12.5	2000	30
125	10	12.5 to 10	2000	21
10	6.3	10 to 6.3	2000	5
			Total	132 gm

W2÷W3×100 = 132÷ 2000 x 100 = 6.6%

The flakiness index of the given aggregate sample is 6.6%, which indicates that the sample contains a low proportion of flaky particles and is generally suitable for construction use.

- Aggregate crushing test

SINO	DISCRIPTION	Trail 01	Trail 02
01	Weight of aggregate sample in the cylindrical measure WI gm (excluding empty weight of cylindrical measure)	13615-11633 1982	13257-11633 1624
02	Weight of crushed aggregate after passing through 2.36mm sieve W2 gm	615	555
03	Aggregate crushing value W2÷W1x100	31.02	34.17
04	Average value crushing value÷no of trails	32.595	

Average value of aggregate crushing strength = 32.595

- Aggregate impact test

SINO	DISCRIPTION	Trail 01	Trail 02	Trail 03
01	Weight of aggregate sample in the cylindrical measure WI gm (excluding empty weight of cylindrical measure)	1347-1007 340	1328-1007 321	1343-1007 336
02	Weight of crushed aggregate after passing through 2.36mm sieve W2 gm	1225-1007 218	1098-1007 91	1121-1007 114
03	Aggregate Impact value W2÷W1x100	64.11	28.34	33.92
04	Average value Impact value÷no of trails	42.12%		

4.2 Test on Brick dust.

- Liquid limit

SINO	DISCRIPTION	Trail 01	Trail 02	Trail 03
01	Number of Blows	28	20	14
02	Container Number	Y	CD	X
03	Empty Weight of container (WT)	13	14	16
04	Weight of container + Wet Soil (W2)	25	28	37
05	Weight Container + dry Soil (W3)	24	24	32
06	Water Content W=(w2-w3)÷(w3-w1)×10	9.09	40	31.25

- Grain size analysis (Brick dust)

SINO	Sieve Size	Empty weight of sieve (A)	Weight of sieve+ soil (B)	Weight of soil retained B-A=W2	%Weight of soil retained w2÷w1×100	Cumulative % of soil retained (X)	Cumulative % of soil passed 100-X
01	4.75 mm	429	724	295	29.5	29.5	70.5
02	2.36 mm	421	542	121	12.1	41.6	433
03	1.18 mm	414	565	151	15.1	56.7	58.4
04	600micron	374	446	72	7.2	63.9	36.1
05	300micron	393	554	161	6.1	50	20
06	150micron	320	443	123	12.3	923	7.7
07	75microns	294	353	59	5.9	98.2	1.8
08	Pan	318	339	21	2.1	100.3	03

4.3 Test on M-sand

- Grain sieve analysis
- Specific gravity

SINO	Sieve Size	Empty weight of sieve (A)	Weight of sieve+ soil (B)	Weight of soil retained B-A=W2	%Weight of soil retained w2÷w1×100	Cumulative % of soil retained (X)	Cumulative % of soil passed 100-X
01	4.75 mm	404	404	0	0	0	100
02	2.36 mm	349	355	6	0.6	0.6	99.4
03	1.18 mm	346	592	246	24.6	25.2	74.8
04	600micron	347	568	221	22.1	47.3	52.7
05	300micron	341	677	336	33.6	80.9	19.1
06	150micron	333	458	125	12.5	93.4	6.6
07	75microns	288	345	57	5.7	99.1	0.9
08	Pan	275	280	5	0.5	99.6	0.4

SI NO	Description	Trail No 01	Trail No 02	Trail No 03
01	Empty Weight of Pycnometer (W1)	664	664	664
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04	Weight of Pycnometer +full of water (W4)	1545	1534	1547
05	Specific gravity of soil =(W2-W1)÷(W2-W1)-(W3-W4)	2.94	2.28	2.08
06	Average Specific gravity		2.43%	

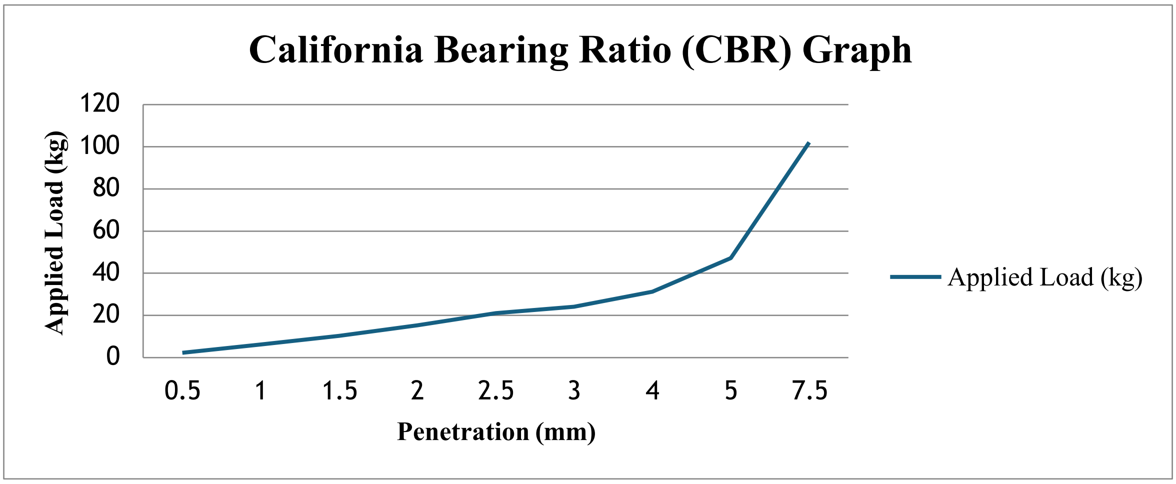
- Liquid limit

SINO	Description	Trail No 01	Trail No 02	Trail No 03	Trail No 04
01	Number of Blows	33	20	15	7
02	Container Number	A	B	C	D
03	Empty Weight of container (W1)	25	24	25	25
04	Weight of container + Wet Soil (W2)	37	36	39	40
05	Weight Container + dry Soil (W3)	35	33	36	37
06	Water Content W=(w2-w3)÷(w3-w1)×100	20	33.33	27.27	25

4.4 Test on Sample

I. CALIFORNIA BEARING RATIO (WITHOUT BRICK DUST)

Penetration (mm)	Applied load (kg) load (kg)
0.5 0.5	2.32.3
11	6.3
1.5.5	10.3
2	15.3 15.3
2.5.5	21.1 21.1
3	24.2 24.2
4 4	31.3 31.3
5	47.2 47.2
7.5.5	102.1 102.1



CALCULATION :

LOAD AT 2.5 MM PENETRATION: 21.1
LOAD AT 5.0 MM PENETRATION: 47.2

CBR = TEST LOAD (KG) ÷ STANDARD LOAD(KG)

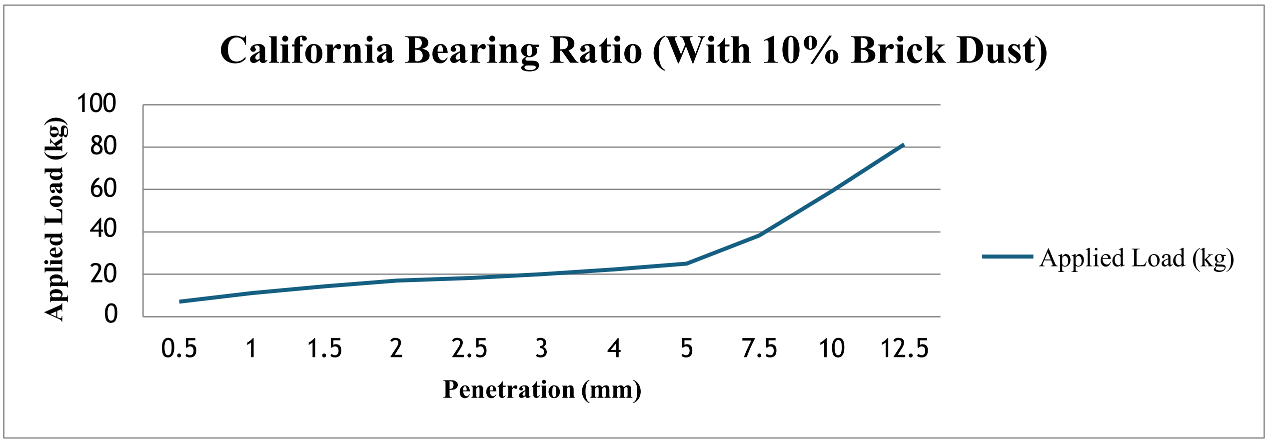
For 2.5 mm penetration:
CBR2.5 = 21.1÷1370×100 = 1.54%

For 5.0 mm penetration:
CBR5.0 = 47.2÷2055×100 = 2.30%

The California Bearing Ratio (CBR) values for a mix of M-sand, aggregate, and brick dust typically range from approximately 7% to over 80%,

II. CALIFORNIA BEARING RATIO (WITH 10% BRICK DUST)

Penetration (mm)	Applied load (kg) load (kg)
0.5 0.5	7.1.3
11	11.1
1.5.5	14.3
2	1715.3
2.5.5	18.321.1
3	20 24.2
4 4	22.3 31.3
5	25.1 47.2
7.5.5	38.4102.1
10	59.2
12.5	81.3



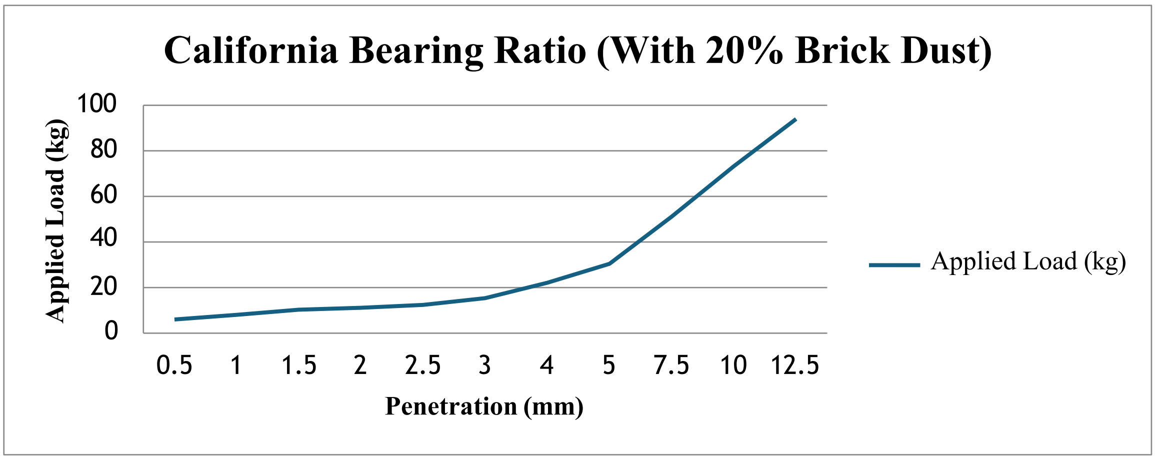
Result -

LOAD AT 2.5 MM PENETRATION: 18.3 = 1.336%

LOAD AT 5.0 MM PENETRATION: 25.1 = 1.221%

III. CALIFORNIA BEARING RATIO (WITH 20% BRICK DUST)

Penetration (mm)	Applied load (kg) load (kg)
0.5 0.5	6.3
11	8
1.5.5	10.3
2	11.215.3
2.5.5	12.421.1
3	15.3 24.2
4 4	22.1 31.3
5	30.4 47.2
7.5.5	51.2102.1
10	73.3
12.5	94



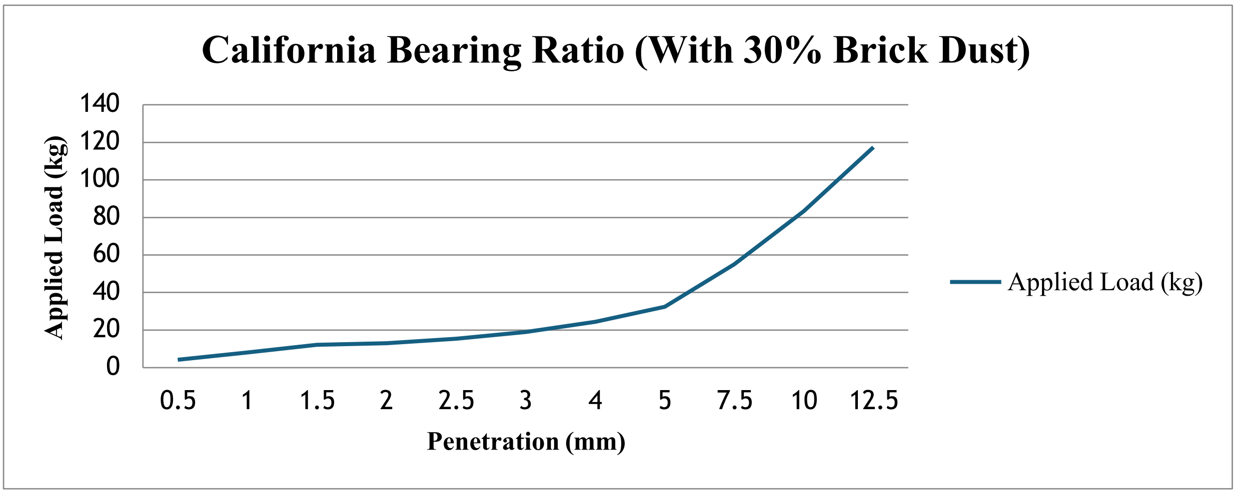
Result-

LOAD AT 2.5 MM PENETRATION: 12.4 = 0.905%

LOAD AT 5.0 MM PENETRATION: 30.4 = 1.479%

IV. CALIFORNIA BEARING RATIO (WITH 30% BRICK DUST)

Penetration (mm)	Applied load (kg) load (kg)
0.5 0.5	4.2.3
11	8.1
1.5.5	12.1
2	13.115.3
2.5.5	15.421.1
3	19 24.2
4 4	24.4 31.3
5	32.4 47.2
7.5.5	55102.1
10	83.4



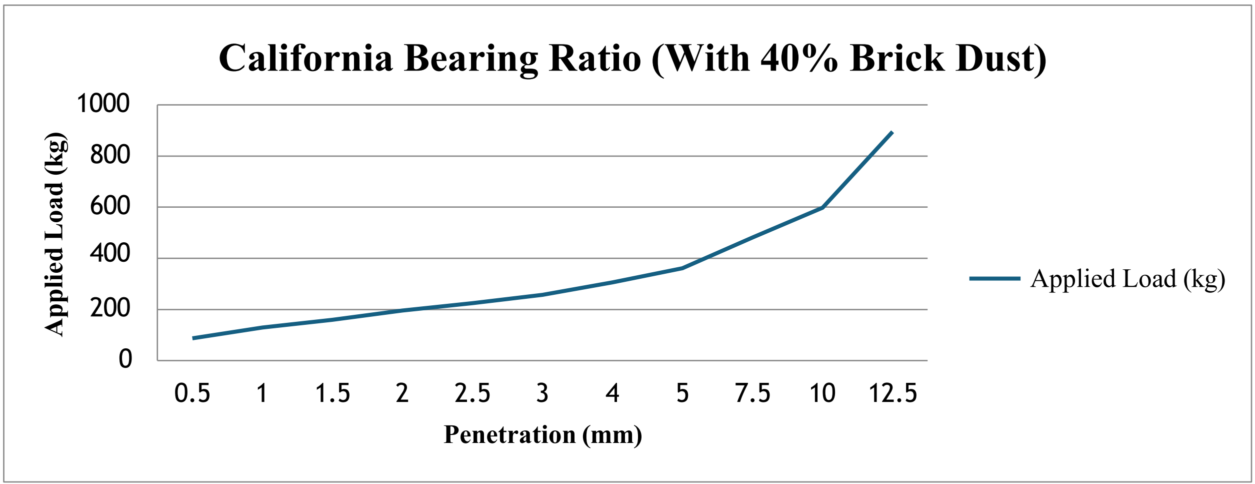
Result :

LOAD AT 2.5 MM PENETRATION: 15.4 = 1.12%

LOAD AT 5.0 MM PENETRATION: 32.4 = 1.58%

V. CALIFORNIA BEARING RATIO (WITH 40% BRICK DUST)

Penetration (mm)	Applied load (kg) load (kg)
0.5 0.5	873
11	129
1.5.5	160
2	19615.3
2.5.5	22421.1
3	25724.2
4 4	306 31.3
5	361 47.2
7.5.5	481102.1
10	598
12.5	895



Result :

LOAD AT 2.5 MM PENETRATION: 224 = 16.35%

LOAD AT 5.0 MM PENETRATION: 361 = 17.57%

5. Results & Discussion

The study investigated the performance of Granular Sub-Base (GSB) mixes prepared by partially replacing sand with locally available Brick Dust at four proportions: **10%, 20%, 30%, and 40%** by weight. All mixes were evaluated in accordance with **MORTH specifications** for gradation, plasticity, and California Bearing Ratio (CBR).

Gradation and Plasticity

Brick Dust exhibited a Zone-II particle size distribution and non-plastic behavior, consistent with MORTH requirements for GSB materials. While all replacement levels satisfied the basic gradation and non-plasticity criteria, gradation alone did not ensure satisfactory mechanical performance in lower replacement mixes.

Compaction Characteristics

An increase in Brick Dust content resulted in a gradual rise in **Optimum Moisture Content (OMC)** due to the finer texture and higher water absorption capacity of the material. Maximum Dry Density (MDD) showed a slight reduction at higher replacement levels; however, the values remained within acceptable limits for GSB applications.

California Bearing Ratio (CBR)

The CBR test results demonstrated a clear trend across the four replacement levels:

- **10% Brick Dust:** CBR values did not meet the minimum MORTH requirement for GSB layers, indicating insufficient load-bearing capacity.
- **20% Brick Dust:** Slight improvement was observed, but the mix still failed to satisfy the required CBR threshold.
- **30% Brick Dust:** Although closer to the acceptable limit, the CBR value remained marginal and did not fulfill the MORTH standard.
- **40% Brick Dust:** This mix achieved a **significantly higher CBR**, exceeding the minimum requirement and demonstrating superior load resistance compared to the other mixes.

Optimal Replacement Level

Among all the tested proportions, the **40% Brick Dust mix** delivered the **best overall performance**, meeting all MORTH criteria for:

- Gradation
- Non-plasticity

- CBR
- Compaction suitability

This indicates that **Brick Dust can effectively replace up to 40% of sand in GSB layers**, providing adequate strength for road construction.

Practical Implications

Using Brick Dust at the optimal 40% replacement level can contribute to:

- Reduced reliance on natural sand
- Lower material costs
- Environmentally sustainable use of locally generated brick waste

This makes Brick Dust a viable and eco-friendly alternative for GSB applications in road projects.

6. Market & Economic Outlook

The capstone project you mentioned focuses on the use of brick dust for the Granular Sub-base (GSB) layer of flexible pavement. This section will provide a brief overview of the market and economic outlook for such a project in the industry.

Growing Demand: The market for flexible pavements is expected to witness steady growth due to increasing road infrastructure development projects globally. This presents an opportunity for alternative materials, such as brick dust, to be explored for GSB layers.

Sustainability Factors: There is an increasing emphasis on sustainable construction Practices, which includes the use of recycled or waste materials. Brick dust, derived from construction and demolition waste, aligns with these sustainability goals, making it an attractive option for the industry.

Cost Considerations: Cost is a significant factor in construction projects. Utilizing brick dust as a replacement for traditional materials in the GSB layer may offer potential cost advantages, depending on the availability and cost of brick dust in the specific region.

Cost Savings: One of the primary drivers for adopting brick dust in the GSB layer is potential cost savings. If brick dust is readily available and affordable, it can help reduce material procurement costs for pavement construction projects

Reduced Environmental Impact: The use of brick dust as a recycled material aligns with environmental regulations and sustainability goals. This factor can positively influence the economic outlook by minimizing the disposal costs associated with construction and demolition waste.

Performance and Durability: The long-term performance and durability of pavement constructed using brick dust need to be thoroughly assessed. If the capstone project proves that brick dust is a reliable and durable alternative, it can lead to wider adoption in the industry, potentially driving economic growth.

It is important to note that the specific market and economic outlook will vary depending on the region, local regulations, availability of brick dust, and other factors. Conducting a detailed feasibility study and cost analysis specific to your project location will provide a more accurate assessment of the potential benefits and economic impact.

7. CONCLUSION

The study" Study on Brick Dust for GSB layer of Flexible Pavement has been carried out with a view to judge the suitability of locally available Brick Dust in rond construction works as per MORTH Specifications. For this purpose, six types of GSB mixes were formed by partially and completely replacing sand with that of Brick Dust. The main conclusions drawn from the study are:

Gradation of the fine aggregates indicates that both stone dust and Brick Dust fall in grading Zone-II. The fineness modulus for stone dust and Brick Dust are found to be 2.22 and 3.05 respectively. The gradation and fineness modulus indicate that both can be used for structural works.Both stone dust and Brick Dust have liquid limit less than 21% and are non-plastic in nature.

They fulfil the requirement of plasticity for road constructionMaximum dry density (heavy compaction) for various GSB mixes is found to be varying 2.25 gm/cc. It is found to be maximum for GSB Mix-5 with Brick Dust and stone dust in the ratio 40:10

OMC is found to increase with increase in proportion of Brick Dust from 0% to 40 %. The test results on all five GSB mixes are found to fulfil the MORTH requirements of gradation, CBR and plasticity indicating that these combinations can be used in GSB construction of road works. The CBR value of GSB Mix-5 (Brick Dust: STONE: 40:10) shows maximum values for both Unsoaked. conditions. A saving in the cost of sand in GSB can be achieved by replacing sand with that of Brick Dust 7. The use of locally available Brick Dust in road construction in GSB will not only result in achieving economy in the road projects, but also save on environmental degradation by minimizing mining pollution and energy used in the quarrying of sand stone dust.

8. ACKNOWLEDGEMENT

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