EFFECTS OF SURKHI ON GSB LAYER OF FLEXIBLEPAVEMENT

Abstract

With the increasing demand of materials for road construction, the need has arisen to explore various alternatives to the conventional materials. Surkhi is a form of brick dust and has been collected from local brick kilns at nominal cost. The study tries to investigate whether locally available Surkhi can be used in road construction in the granular sub base (GSB) layer or not. The study has been conducted on four types of GSB trial mixes formed by partially and completely replacing the stone dust content with that of Surkhi. The proportion of Surkhi varies from 0 to 25% by weight of total mix in these GSB mixes. The study evaluates gradation and plasticity of fine aggregates used and OMC, MDD and CBR of various GSB mixes. The MDD is found to increase with increase in proportion of surkhi from 0 to 10% after which it decreases. The maximum MDD is found to be for GSB mix with 10% surkhi and 15% stone dust. The findings of the test results of the four GSB mixes indicate that they meet the requirements of MORTH in terms of gradation, CBR, and plasticity. Therefore, these combinations are suitable for utilization in the GSB construction of road works. The incorporation of locally available Surkhi in the construction of GSB layer of flexible pavement not only leads to cost-effectiveness in road projects but also reduces environmental degradation by decreasing pollution from mining and consumption of energy in the quarrying of sand/stone dust.

Key words: Optimum Moisture Content, Maximum Dry Density, CBR, GSB

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I. INTRODUCTION

In the case of a flexible pavement, a layer of granular sub-base is implemented between the sub-grade and the granular base course. When the base course thickness surpasses the standard due to an inadequate sub-grade, it is bifurcated into two layers: granular base course and GSB. The material utilized to fabricate the GSB layer is of inferior quality compared to that employed in constructing the granular base course, thus the implementation of the GSB layer results in cost savings during road construction. In addition, this layer plays a crucial role in acting as a drainage layer for the pavement, thereby preventing excessive saturation and deterioration of the sub-grade. In terms of strength, it surpasses that of the sub-grade. The sub-base course is constructed using various materials and methodologies. The Ministry of Road Transport and Highways (MORT&H) and the National Rural Roads Development Agency (NRRDA) have emphasized the use of locally available waste materials from industries in the construction of low-volume roads, including rural pavements. This approach effectively addresses the issue of disposing of large quantities of industrial waste.

One such locally available waste material is Surkhi, which is essentially brick dust from the brick kiln industry. It can be utilized as Granular Sub Base (GSB) material, replacing sand. India's brick sector is the second largest in the world, producing approximately 54% of the world's annual brick production with an annual growth rate of 10%, just behind China. The construction industry's growing demand for bricks is the main driver behind the continuous expansion of the sector. In India, the brick industry employs a considerable number of workers, estimated to be around 9 to 10 million, a significant portion of whom lack adequate skills. Despite possessing more brick units than China by over 50%, India's brick production only accounts for 27% of China's output. This can be attributed to deficiencies in organization, the immense scale of operations, lack of technological advancements, poor quality control, and unskilled labor. These factors collectively contribute to decreased brick production, heightened fuel consumption, and the generation of substantial waste in the form of broken, deformed, over-burnt, or dusty bricks, as well as fly ash or coal ash, depending on the type of fuel utilized. Various studies have demonstrated the recyclable nature of fly ash or coal ash, which finds application in diverse construction activities.The residual waste produced by brick kilns is often utilized for purposes of land filling or road side dumping, resulting in a detrimental impact on the environment. The brick industry bears responsibility for not only contaminating the surface of the earth but also exacerbating air pollution, thereby raising environmental concerns. In light of these concerns, it is imperative to implement effective waste management. This study aims to explore the potential for Surkhi to be utilized as GSB material in a manner that is both efficient and effective.

1. **Aim of the Study:** The goal of the present investigation is to determinethe suitability of brick dust on the GSB layer over stone dust.

2. **Objectives**

- The primary aim of the current investigation is to fabricate GSB blends employing Brick Dust, both with or without stone dust. Within the scope of this inquiry, stone dust shall be substituted by Brick Dust, in percentages of 0%, 10%, 15%, and 25%.
- The GSB mixtures, which encompass various proportions of Surkhi, undergo examination for the California Bearing Ratio (CBR) at the utmost level of compacted

density and optimal moisture content. This assessment serves to assess the efficacy of Surkhi and subsequently aid in the conservation of sand for other construction purposes. Additionally, it helps to minimize the waste produced by brick kilns, while promoting efficiency in road construction and reducing environmental pollution. This study thus seeks to achieve a dual objective of enhancing economic viability and environmental sustainability.

- In GSB blends, various materials such as natural sand, stone dust, moorum, gravel, crushed stone, or a combination thereof are employed. Nevertheless, in areas where there is a plentiful supply of Surkhi available at a low cost from brick kilns, it may be utilized alongside sand or in place of sand. Surkhi, however, is primarily used in the construction of roads for sub-grade and WMM constructions. The present study has chosen to evaluate the suitability of Surkhi, in conjunction with stone dust, in the GSB layer of road construction.

II. SCOPE OF THE STUDY

1. To achieve the desirable engineering properties of GSB mixes the project has been plannedto carry out in the following manner:
2. The design and construction procedure for GSB trial mixes was according to MORTH specifications.
3. Crushed aggregates of size 53mm, 20mm along with brick dust and stone dust were processed.
4. The proportion of SURKHI and STONE DUST varies between 0-25%
5. The Maximum dry densities of all the GSB trial mixes are compared with their corresponding Optimum moisture content.
6. The CBR values of all the trial mixes are determined at 98% dry density and compared withthe requirements of MORTH specification.

III. LITERATURE REVIEW

Many tests conducted on SURKHI and STONE DUST show significant outcomes when it is used as subbase material. In a "***Laboratory study on Brick Dust for GSB layer of Flexible Pavement***" by Bhim Sen and Er. Shashi Sharma, found out that 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. Both stone dust and brick dust demonstrate a liquid limit that is below 21% and possess a non-plastic characteristic. Such attributes satisfy the requisite level of plasticity for their application in road construction. MDD (heavy compaction) for various GSB mixes is found to be varying between 2.194 gm/cc to 2.346 gm/cc. It is found to be maximum for GSB Mix – 3 with Brick Dust and stone dust in the ratio 10:15. OMC is found to increase with increase in proportion of Brick Dust from 0% to 25%. The findings of the test results on all six GSB mixes reveal that they are in compliance with the MORTH requirements for gradation, CBR, and plasticity. This indicates that these specific combinations are suitable for utilization in the construction of GSB for road works.

In 2014, Nishant Kumar, Vikas Kumar, Akash Priyadarshee and Anil Kumar Chhotu conducted a study on "***Impact of Surkhi on GSB Layer as Replacement to the Stone Dust***," The study evaluates gradations and plasticity of fine aggregates used and OMC, MDD and

CBR of various GSB mixes. OMC is found to increase with increase in proportion of surkhi from 0 to 25%. The MDD is found to increase with increase in proportion of surkhi from 0 to 10% after which it decreases. The maximum MDD is found to be for GSB Mix – 3 with 10% surkhi and 15% stone dust. The OMC is found to increase with increase in proportion of surkhi from 0% to 25%.

In his publication titled "Laboratory Studies on Granular Sub Base" in 2014, Manjunatha H, an Assistant Professor from the Department of Civil Engineering at the Government Engineering College in Karnataka, conducted a series of laboratory experiments on three different mixes of Granular Sub Base (GSB). The findings from these experiments indicate that it is necessary to appropriately modify the gradation specifications in order to utilize locally available materials within the specified range of 75.00 to 2.36 mm. This modification should also consider the permeability criteria and the strength parameter, which is measured by the CBR value. The obtained values for the coefficient of permeability are 1.038 x 10-3 cm/sec, 2.50 x 10-3 cm/sec, and 1.28 x 10-3 cm/sec.

In the year 2021, Karma Tempa, a member of the Civil Engineering Department at the College of Science and Technology in Rinchending, Bhutan, conducted a study entitled "An Examination of Riverbed Sediments as Materials for Road Construction: GSB and WMM." Tempa's research focused on the riverbed sediments of the Toorsa river in Bhutan and their suitability for utilization in road construction as GSB and WMM. The findings of the study indicate that the mechanical properties of these sediments meet the required standard, with specific gravity falling within an acceptable range and water absorption potential below 2%. However, a significant presence of flaky natural aggregates was observed, and as a result, it is highly recommended that preliminary screening and shape testing be conducted. Additionally, the mix proportions outlined in this paper can be employed for batching purposes, although it is essential to verify the gradation prior to execution or placement at the construction site.

In an experimental study in 2014 by K. V. Subrahmanyam, U. Arun Kumar and Dr. P.V.V. Satyanarayana on “***A Comparative Study on Utilization of Waste Materials in GSB Layer***”, they tried to establish the possibility of using Granulated Blast Furnace Slag (GBFS) and also with Waste Rubber Tyre (WRT) with various blended mixes of conventional aggregates in subbase layer with different percentages separately. They also studied the result of experimental investigation on the influence of Rice husk ash (RHA) on the index properties of red soil which is used as filler material in subbase layer. It was concluded that with the addition of RHA to the red soil, the Liquid limit of the soil decreases and Plastic limit of thesoil decreases and the plasticity index gets decreased. And it was also found that GBFS can be used for the partial replacement of unmodified aggregate upto 20-30% in the construction of granular sub base layer. Also, aggregates when partially replaced by 2% waste rubber tyre pieces showed considerable decrease in abrasion value, crushing value and impact value which proves them to be better composite material in the subbase layer of the pavement system.

In October 2013, Anil Sinha, Sudhir Mathur and Vashant G. Havanagi from CSIR Central Road Research Institute conducted a study on the “**S*teel slag waste material for the construction of road***,” to check the feasibility of using steel slag in different layers of road construction. The material was mechanically stabilized with the locally available soil in the range of 25-75%. The study of the geotechnical properties of the sub base layer was also thepart of the investigation. It was concluded that steel slag may be used for the construction of embankment and sub grade. It was also concluded that about 40 to 50 % of steel slag material may be replaced conventional aggregate for the construction of granular sub base layers and itis not suitable for the use in bituminous layers.

IV. METHODOLOGY

The above objectives could only be reached if acted upon with a planned approach. The first step towards a goal always starts with knowing everything about it. Thus, we began with the literature review. The books, journals, papers proved a rich source of knowledge in regard and were thoroughly studied and learned. This was followed by collection of samples from various sources. Samples were collected and brought to the laboratory for analysis and testing. The samples that include coarse aggregates, brick dust and stone dust. Various tests were undertaken to know about their properties as per the IS codes and compared with the MORTH specifications. Conclusions were drawn out from these results and recommendations for better safety were given.

Aggregates used in GSB layers are of two types

- Coarse Aggregate (CA)
- Fine Aggregate (FA)

  Coarse aggregate of 53 mm and 20 mm size are used in our project that is collected from Rani, Assam. Aggregates should be screened crushed rock, angular in shape, free from dust particles, clay, and vegetation. They should have following properties as per MORTH Specification:

  - The impact value should not be more than 40%
  - The water absorption should not be more than 2%.

    Fine aggregate should consist of crushed or naturally occurring mineral material, or a combination of the two, passing 4.75 mm sieve and retain on 75 micron sieve. It should be hard, durable, dry and free from clay, loam, vegetation or organic matter. Natural sand shall not be allowed in binder courses. Fine aggregate should have the following properties:
  - Liquid limit should not be more than 25%
  - Plasticity Index should not be more than 6

    The deposition of Stone and other discarded brick particles, flakes, and other similar materials not only occupies land but also gives rise to environmental issues. These problems can be significantly mitigated by utilizing these waste materials in the construction of highways as filler material. The dust resulting from the fragmentation or pulverization of bricks, which is appropriately graded, can be employed as filler. The Surkhi was acquired from the nearby Brick kiln located in Majir Gaon, Palashbari.

    Stone dust is a waste material obtained from crusher plants. It has potential to be used as partial replacement of natural river sand in concrete. Use of stone dust in GSB not only improves the quality of GSB but also conserve the natural river sand for future generations. In our project we used the stone dust collected form the stone crushing factory in Pamohi,Guwahati.

The work was divided into 3 stages

- Characterising the materials.
- Prepare the trial mixtures with different sizes of aggregates.
- Evaluate the suitability of use of Surkhi and Stone Dust for the GSB layer.

In the first stage the properties of aggregates i.e., Surkhi, Stone Dust and coarse aggregates were determined. Different tests like fineness modulus test, specific gravity test, plasticity test, impact value test, etc are done.

In the next stage different trial mixtures are prepared using trial and error method. The % passing of each of different sizes of aggregates are determined and trial mixtures are by mixing all these aggregates such that their overall gradation lies within the limit as describedby the MORT&H Table 400-1. The mixtures designed are such that the proportions of Stone Dust and Surkhi remain different in each mix.

Thirdly, the optimum moisture content and the maximum dry density of the trial mixtures are determined. Using these values of OMC, the CBR test is done for all the trial mixtures

Aggregates play a significant role in the construction of pavements. The influence of aggregates on the load transfer capability of pavements is substantial. Therefore, it is imperative that thorough testing is conducted prior to their utilization in construction. In addition to being robust and long-lasting, aggregates must also possess appropriate shape and size in order to facilitate the permeability of pavements for drainage.

In order to evaluate the effect of Surkhi as replacement of Stone dust on the GSB layer, a series of compaction tests and CBR tests were conducted. Different proportion of the aggregates, stone dust and surkhi were taken to prepare the specimen, Job Mix Design is done in order to combining the aggregates and proportioning of aggregates to obtain the required gradation. For the construction of Granular Sub Base, coarse aggregates of size 53 mm, 20 mm, stone dust and Surkhi are used as per the MORTH specifications. The various GSB mixes preparedfor the study are presented in the following table:

1. Constituents of Samples

Table 1: Material Constituents in % by weight

GSB mix	Material constituents in % by weight				
	53mm	20mm	Stone Dust	Surkhi	Total
S1	40	35	25	0	100
S2	40	35	15	10	100
S3	40	35	10	15	100
S4	40	35	0	25	100

In order to determine the appropriateness of the aggregate for utilization in the construction of pavement, the ensuing examinations are conducted.

- Tests performed on Coarse Aggregates-
  - Impact Value Test
  - Water Absorption Test
  - Specific Gravity Test
- Tests performed on Fine Aggregates-
  - Liquid Limit Test
  - Gradation Test
  - Specific Gravity Test
- Heavy Compaction Test
- CBR Test

2. Test Performed on Coarse Aggregates

- **Impact Value Test**
  AIV = 17.516 %

  As per Table 400-2 of MORTH 5th Revision (2013), the maximum Aggregate Impact Value of **40%** is allowed for GSB materials. In this test we found the impact value for the coarse aggregate as **17.516 %.** So the aggregates are considered as strong and can be used forconstruction.

- Water Absorption Test:
  Water Absorption = 0.75 %
  As per MORTH specification, maximum 2 % of water absorption for coarse aggregate is allowable for Dense Bituminous Macadam. So, the tested aggregates are goodenough to construct the DBM course.

- **Specific Gravity Test of Coarse Aggregates:**
  The specific gravity of aggregates normally used in road construction ranges from about 2.5 to
  3.0. Aggregates having low specific gravity are generally weaker than those with higher specific gravity values. As we have found the specific gravity of the aggregates as **2.614**, so the aggregates have higher strength are suitable for road construction.

3. Test Performed on Fine Aggregates

Liquid Limit Test: (Cone Penetration Method)

- **Result and discussion:** A graph representing water content on the Y-axis and the conepenetration on the X-axis shall be prepared. The penetration corresponding to 20 % water contentis 19 mm. So, the liquid limit of the stone dust is **19 %**.

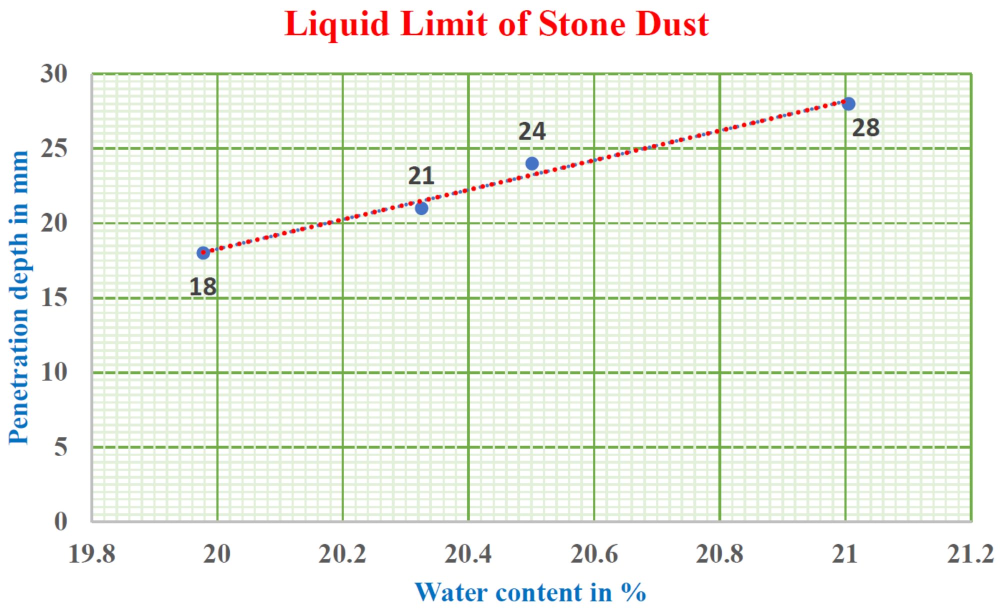

Figure 1: Liquid Limit test of Stone Dust

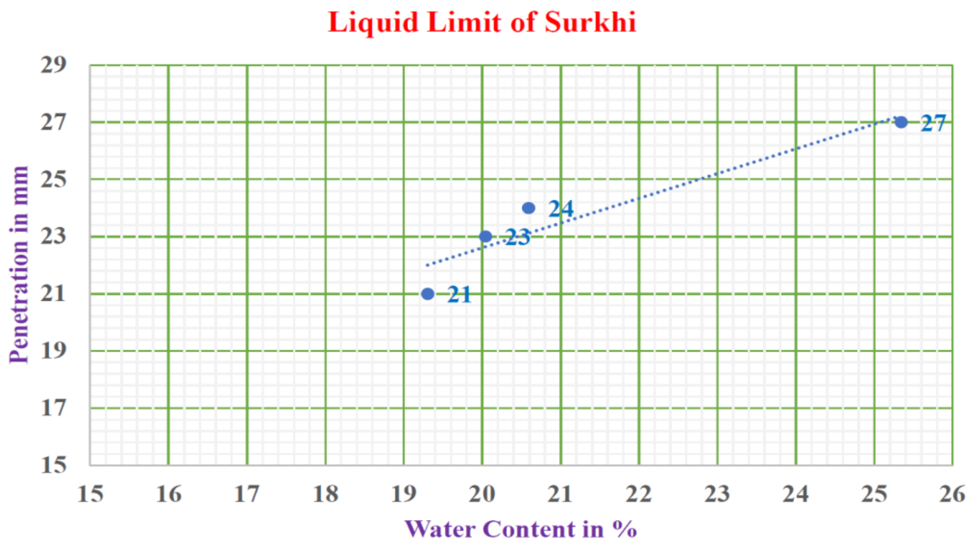

Figure 2: Liquid Limit of Surkhi

The penetration corresponding to 20 % water content is 22.5 mm.
So, the liquid limit of thestone dust is **22.5 %**.

- **Gradation and Fineness Modulus Test:** The gradation and fineness modulus test is done to find out the zone to which the aggregates belongs, This is because their sizes influence the drainage properties of the Granular Sub Base layer.
  This test is done as per the **IS code : 383-1970**. **Gradation of Surkhi:**
  FM of Surkhi = **2. 472** (Zone II)

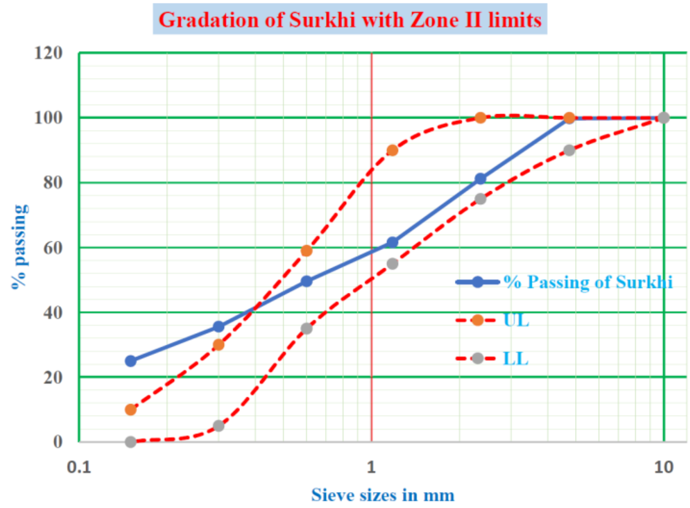

Figure 3: Gradation of Surkhi with Zone II limits

Fineness Modulus of Stone Dust = ∑Cumulative percentage weight retained/100
= 236.9/100
= **2.369 (Zone II)**

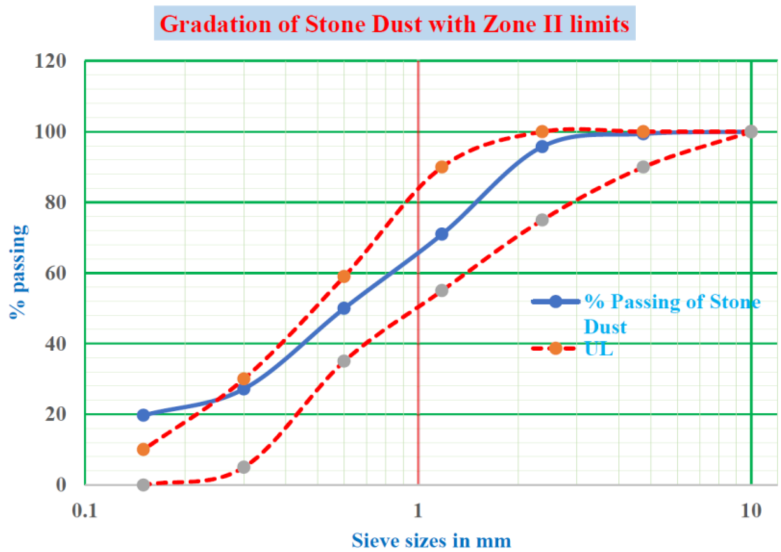

Figure 4: Gradation of Stone Dust with Zone II limits

- **Specific Gravity Test of fine aggregates:**

  Specific gravity Test (by using density bottle)

  Specific Gravity of stone dust = **2.786**

  Specific Gravity of Surkhi = **2.599**

  The specific gravity of aggregates normally used in road construction ranges from about 2.5 to

3.0. As we have found the specific gravity of the aggregates as 2.786 and 2.599, so the specificgravity of both the stone dust and Surkhi are within the required limits.

- **Modified Proctor Test:**

➢ **Heavy Compaction Test:** The modified Proctor test is employed to conduct a rigorous compaction analysis of soil, with the aim of comprehending the compaction characteristics of diverse soil types, vis-à-vis alterations in moisture content. This laboratory test, commonly referred to as the Proctor compaction test or heavy compaction test, is utilized to ascertain the optimal moisture content (O.M.C.) of soil, at which point a given soil specimen will attain maximum dry density by eliminating air voids.

➢ **Test Description**: We have utilized a total of 5.7 kilograms of air-dried soil that has successfully passed through the 19 millimeter IS test sieve. After which, we have diligently mixed this soil with 5 percent water, ensuring complete and thorough blending. The resulting mixture was then compacted with a rammer weighing 4.9 kilograms, employing a five-layer approach, with each layer subjected to precisely 55 blows. Following the aforementioned process, we have proceeded to repeat all steps, incrementally increasing the amount of water by 2 percent on each occasion. The weight of the soil along with the mould is measured for each compaction. The soil sample is taken from three different layers for determining the water content

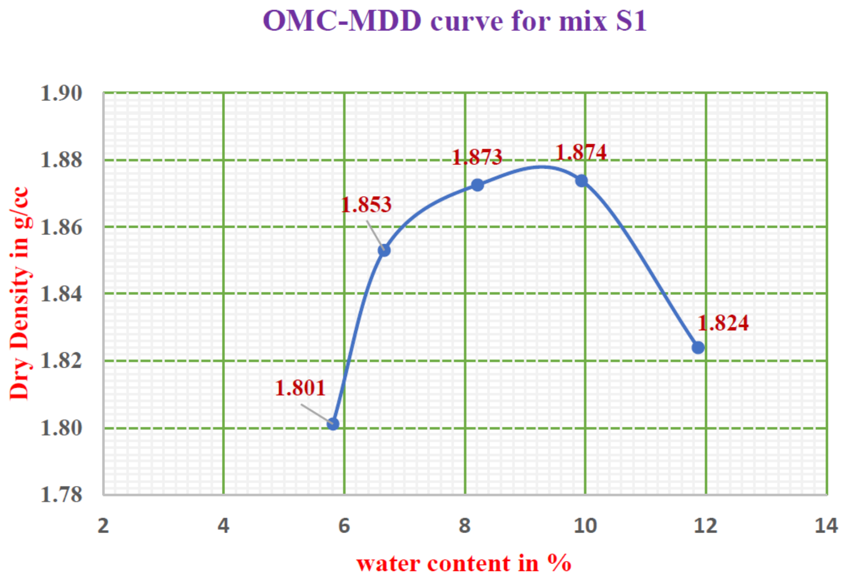

Figure 5: Compaction curve for mix S1

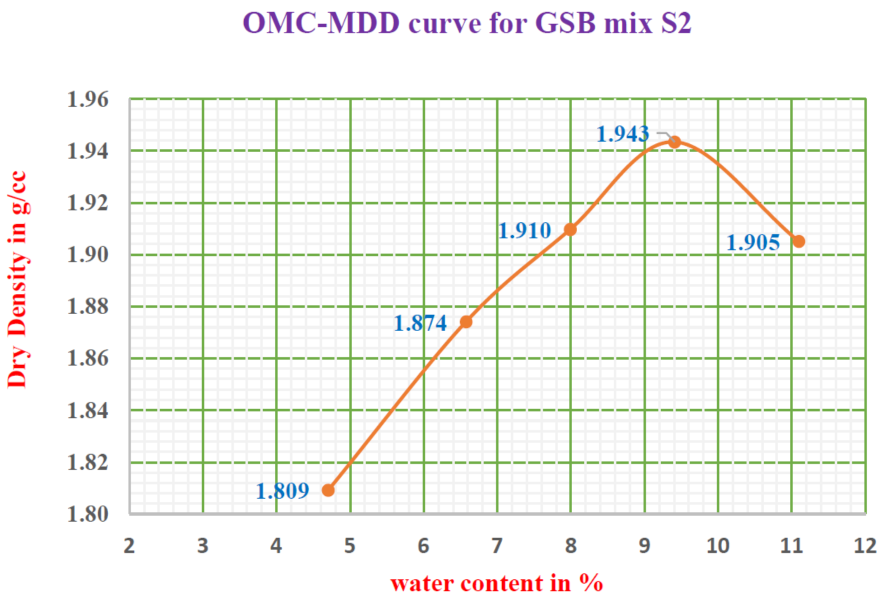

Figure 6: Compaction curve for mix S2

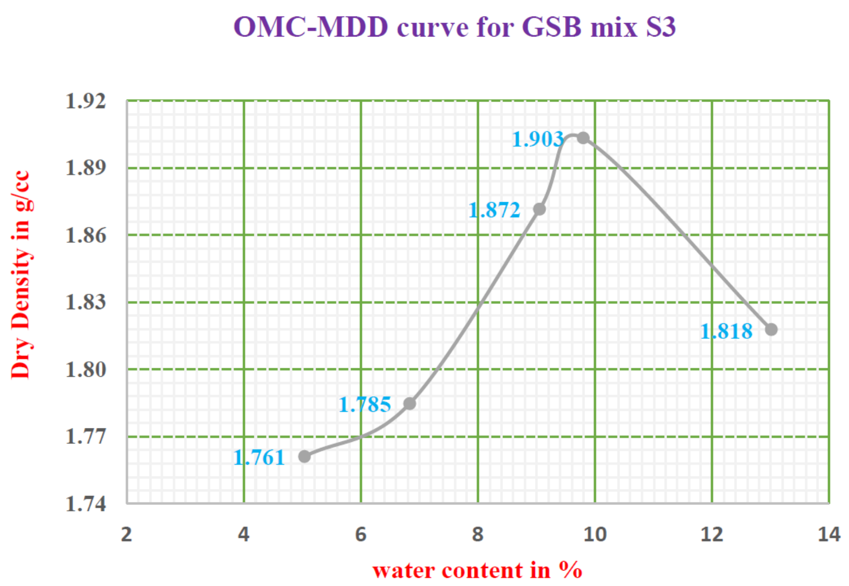

Figure 7: Observation for GSB mix S3

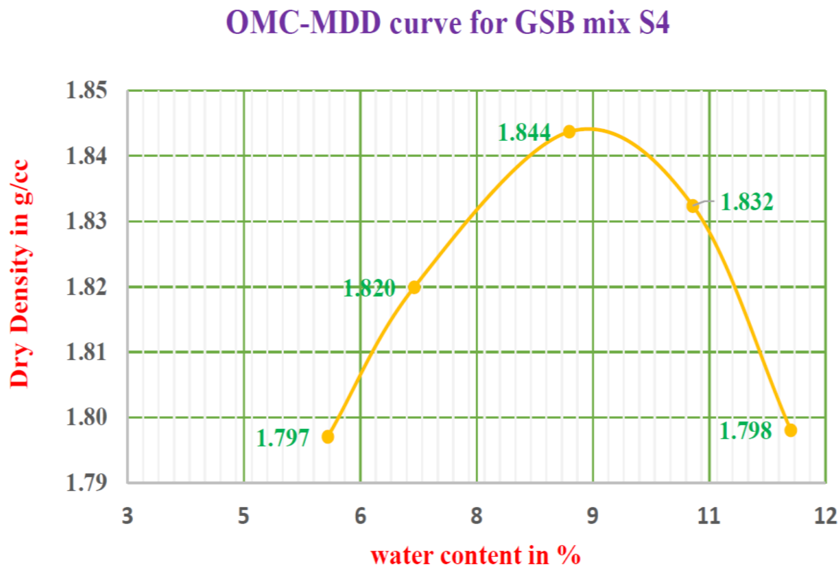

Figure 8: Observation for GSB mix S4

CBR Test:

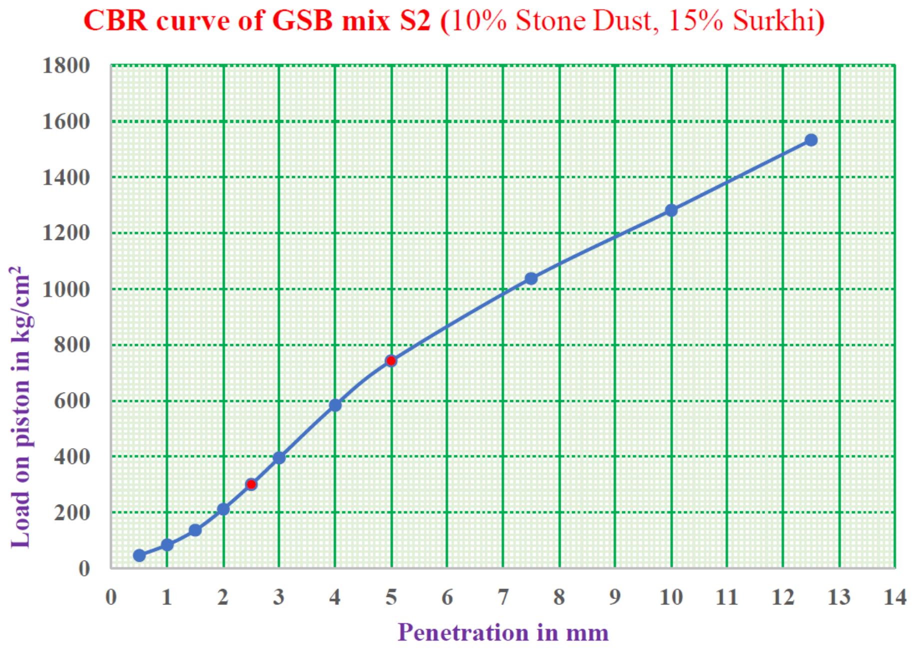

Figure 9: CBR curve for GSB mix S2

V. ANALYSIS OF RESULTS

1. **Grading Results of GSB mixes:** The grading results of all the four GSB mixes are compared with the limits of Grading III of the Table 400-1 of section 400 of the MORTH guidelines (5^{th} Revision). The result if presented in the graph as shown in fig 7.1

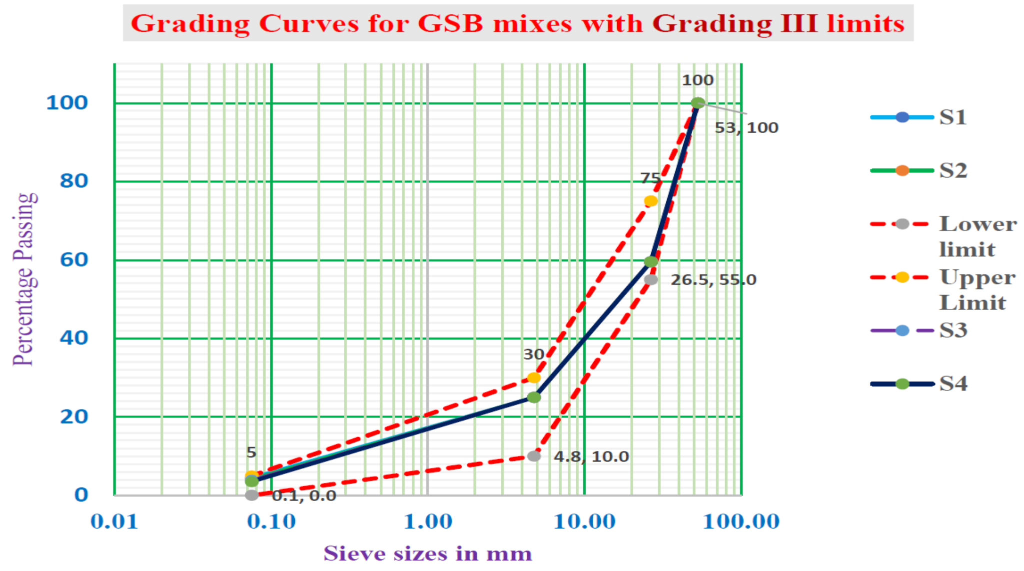

Figure 10: Grading Curves for GSB mixes with Grading III limits

2. **Comparison of Maximum Dry Densities:** The results of all the four samples for the heavy compaction test are tabulated in Table 7.2 and presented their compaction curves in the fig 7.2.

Table 2: Compaction Result for all the GSB mixes

GSB mix	Proportion of FA		OMC (%)	MDD (g/cc)
	Stone Dust	Surkhi		
S1	25	0	9	1.88
S2	**15**	**10**	**9.4**	**1.94**
S3	10	15	9.8	1.92
S4	0	25	8.7	1.845

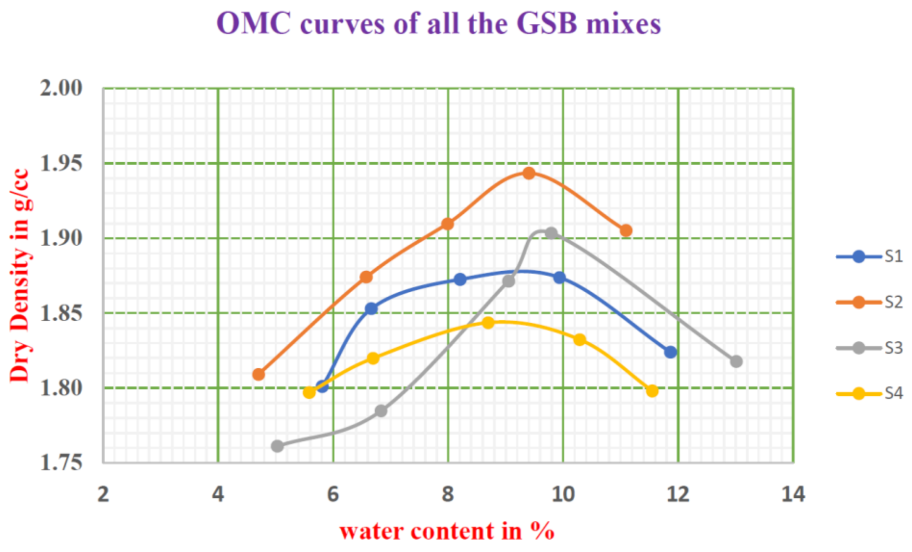

Figure 11: OMC curves of all the mixes

The maximum MDD is found to be **1.94 g/cc** for the corresponding to GSB trail mix **S2** having the mixture of Stone Dust to Surkhi in the proportion of **15:10**. So, the S2 sample is adopted for cost analysis.

From the study of the effect of Surkhi on the GSB layer, we summarize the following:-

- As per the MORT&H specification for GSB materials, the aggregate impact value(AIV) should be less than 40 which is fulfilled by the aggregates.
- The Liquid Limit test results of fine aggregates done according to IS 2720 (Part 5)satisfy the MORT&H specifications.
- The gradation curves of all the trial mixes were within the limits as mentioned in thespecifications.
- The maximum MDD among all the mix samples is found to be 1.94 g/cc for thecorresponding to GSB mix S2 (10% Surkhi and 15% Stone Dust).
- OMC is found to increase with increase in proportion of Surkhi.
- There may be slight error in the results obtained because of the following reasons-

➢ Instruments and machine were very old.
➢ Machines had to be operated manually.
➢ Observation error due to parallax.
➢ Oven is not operated continuously.
➢ Lack of proper maintenance of instruments due to which they were rusted.

VI. CONCLUSION

The present study has been carried out with a view to judge the suitability of locally available Surkhi in GSB road construction works as per MORTH Specifications. For this purpose, four types of GSB mixes were prepared by partially and completely replacing stone dust with that of Surkhi. The main conclusions drawn from the study are:

1. Gradation of both Stone Dust and Surkhi fall in grading Zone-II. The fineness modulus for Stone Dust and Surkhi are found to be 2.472 and 2.369 respectively, and are suitable for structural works.
2. Liquid limit values for Stone Dust and Surkhi are 19 % and 22.5% respectively, and both are non-plastic in nature.
3. Maximum dry density (heavy compaction) for various GSB mixes is found to be varying between 1.845 gm/cc to 1.940 gm/cc. It is found to be maximum for GSB Mix – S2 with 10% Surkhi and 15% Stone Dust.
4. OMC is found to increase with increase in proportion of surkhi from 0% to 25%
5. The results of the tests conducted on all six GSB mixes have demonstrated that they satisfy the MORTH specifications with respect to gradation, CBR, and plasticity. This indicates that these particular combinations are suitable for employment in the construction of roadworks utilizing GSB.
6. The CBR value of GSB Mix – S2 for unsoaked condition is found to be 36.14%.
7. The utilization of surkhi, which is readily accessible in the local area, in the construction of roads in the Granular Sub-Base (GSB) will result in a notable reduction, up to 30%, in the expenses associated with GSB construction. Moreover, this approach will also contribute towards environmental preservation by mitigating the adverse effects of mining pollution and reducing the energy consumption involved in the extraction of sand and stone dust from quarries.

VII. FUTURE SCOPE

A trial section of a pavement with the mixture of Surkhi and Stone Dust in required proportion as GSB filler materials be prepared and investigated. This trial filler can be evaluated and analysed based on their performance and can be compared with conventional fillers such as lime, sand and cement.

Dumping of Surkhi is of great concern for the society, hence use of Surkhi as filler in road construction can solve the problem as well as economic. Stone dust is a residual substance derived from the process of crushing plants. Its utilization as a substitute for natural river sand in concrete has the potential to be highly advantageous. Incorporation of stone dust in the construction of GSB not only enhances the quality of the material, but also serves to preserve the finite resource of natural river sand for posterity. Since Surkhi and Stone Dust are already in use in different engineering fields it is no threat to the environment.

Hence the present and future scenario is demanding use of non-conventional fillers in place of conventional fillers. At last, we would like to recommend that more studies should be carried out on this topic taking different types of fillers.

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