Effects of Surkhi on GSB Layer of Flexible Pavement

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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 roadconstruction 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 MDDis found to be for GSB mix with 10% surkhi and 15% stone dust. The test results on all the four GSB mixes are found to fulfill the MORTH requirements of gradation, CBR and plasticity indicating that these combinations can be used in GSB construction of road works. The use of locally available Surkhi in construction of GSB layer of flexible pavement 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.

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

1. Introduction

In case of flexible pavement, 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 to 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. The use of locally available and industrial waste materials in the construction of low-volume roads like rural pavements is emphasized by MORT&H and the National Rural Roads Development Agency (NRRDA), as it overcomes the problem of disposing of large amounts of industrial waste1.

Surkhi (Brick Dust), a waste of brick kiln industry, is one of the locally available waste materials which can be utilized as GSB material in place of sand. The brick sector of India is the second largest brick producer with 10% annual growth after China with annual brick production of 54%. It is continuously expanding due the rapid demand for bricks in construction industries. In India, about 9 to 10 million employees are working in the brick industry, but mostly of them are unskilled. India has about more than 50% brick units than China but still in India the production of bricks is about only 27% of that produced by China.Poorly organized and tremendous in size, lack of technology, poor quality control and unskilled labor are the reasons behind the less production of bricks in Indian brick industry. Because of above reasons there is less production, high consumption of fuel and large amount of waste is generated in the form of broken bricks, deformed bricks, over-brunt bricks, brick dust or Brick Dust, fly ash or coal ash depending on the type of fuel used. The various studies shows that fly ash or coal ash has its recycling value and are used in many construction activities. The rest of the waste of brick kilns is used for land filling or road side dumping, which causes environmental pollution. Brick industry is not only responsible for contaminating top earth surface but also causes the air pollution, causing environmental concern. Due to environmental concern effective waste management is required. In the present study an attempt is made for the effective utilization of Surkhi as GSB material.

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

1.2 Objectives of the Study:

a. The first objective of the present study is to develop GSB mixes by using Brick Dust with or without stone dust. In the present study stone dust is replaced by Brick Dust in proportion 0%, 10%, 15% and 25%.

b. GSB mixes with varying proportions of Surkhi are test for CBR at the maximum dry density and optimum moisture content, to evaluate the performance of Surkhi. This will facilitate in, saving of sand for other construction works, reducing waste from brick kilns, bring economy to the road construction and also reduce the environmental pollution, which is second objective of this study.

c. In GSB mixes, the materials, like, natural sand like stone dust, moorum, gravel, crushed stone, or combination of these are being used. But, in regions, where Surkhi, is available in abundant quantity at marginal/low cost from brick kilns, it can also be used along with sand or in place of sand. However, Surkhi finds its application in road constructions like sub- grade, WMM constructions. Accordingly, Surkhi along with stone dust has been selected for the present study to evaluate its suitability in GSB layer of road construction.

1.3 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 withthe 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.

1.4 Scope of the study:

- To achieve the desirable engineering properties of GSB mixes the project has been plannedto carry out in the following manner:
- The design and construction procedure for GSB trial mixes was according to MORTH specifications.
- Crushed aggregates of size 53mm, 20mm along with brick dust and stone dust wereprocessed.
- The proportion of SURKHI and STONE DUST varies between 0-25%
- The Maximum dry densities of all the GSB trial mixes are compared with their corresponding Optimum moisture content.

- The CBR values of all the trial mixes are determined at 98% dry density and compared withthe requirements of MORTH specification.

2 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 have liquid limit less than 21 % and are non-plastic in nature. They fulfil the requirement of plasticity for 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 test results on all six 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.

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 journal ***Laboratory Studies on Granular Sub Base*** published in 2014, Manjunatha H, (Asst. Professor, Dept. of Civil Engineering, Govt. Engineering College, Karnataka), conducted some laboratory tests on three different GSB mixes. The conclusion drawn from the laboratory studies was that gradation specifications are to be suitably changed so that locally available materials are to be used in the specified range of 75.00 to 2.36 mm with permeability criteria along with strength parameter - the CBR value. The co-efficient of permeability values obtained are 1.038×10^{-3} cm/sec, 2.50×10^{-3} cm/sec and 1.28×10^{-3} cm/sec.

In the year 2021, Karma Tempa of Civil Engineering Department, College of Science and Technology, Rinchending: Bhutan, conducted a study on "***Study on Riverbed Sediments as Road Construction Material: GSB and WMM.***" His study on the riverbed sediments of Toorsa river in Bhutan for suitability of use in road construction as GSB and WMM indicates that the mechanical properties are well up to the standard requirement with acceptable specific gravity ranges and water absorption potential of less than 2%. However, the flaky natural aggregates are in a substantial amount and hence initial screening and prior shape test are highly recommended. The mix proportion indicated in this paper however can also be used for batching purposes but gradation should be checked before execution or laying at the 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.

3 Aims and Objectives of the Study

Aggregates used in GSB layers are of two types

1. Coarse Aggregate (CA)
2. Fine Aggregate (FA)

Coarse aggregate of size 53 mm and 20 mm 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

Dumping of Stone and other waste brick particles, flakes etc., not only occupy land but also create environmental problems. The problems could be reduced to a large extent by using these waste materials in highway construction as filler material. Dust of broken or pounded bricks graded to the required grading can be used as filler. We collected the Surkhi from the local Brick kiln 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

1. Characterising the materials.
2. Prepare the trial mixtures with different sizes of aggregates.
3. 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

Aggregate plays an important role in pavement construction. Aggregates influence, toa great extent, the load transfer capability of pavements. Hence, it is essential that they shouldbe thoroughly tested before using for construction. Not only that aggregates should be strong and durable, they should also possess proper shape and size to make the pavement permeable 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 for 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:

4. 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 decide the suitability of the aggregate for use in pavement construction, the following tests are carried out:

1) Tests performed on Coarse Aggregates-
    i) Impact Value Test
    ii) Water Absorption Test
    iii) Specific Gravity Test
2) Tests performed on Fine Aggregates-
    i) Liquid Limit Test
    ii) Gradation Test
    iii) Specific Gravity Test
3) Heavy Compaction Test
4) CBR Test

5. 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**, sothe aggregates have higher strength are suitable for road construction.

6. 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 cone penetration on the X-axis shall be prepared. The penetration corresponding to 20 % water content is 19 mm. So, the liquid limit of the stone dust is **19 %**.

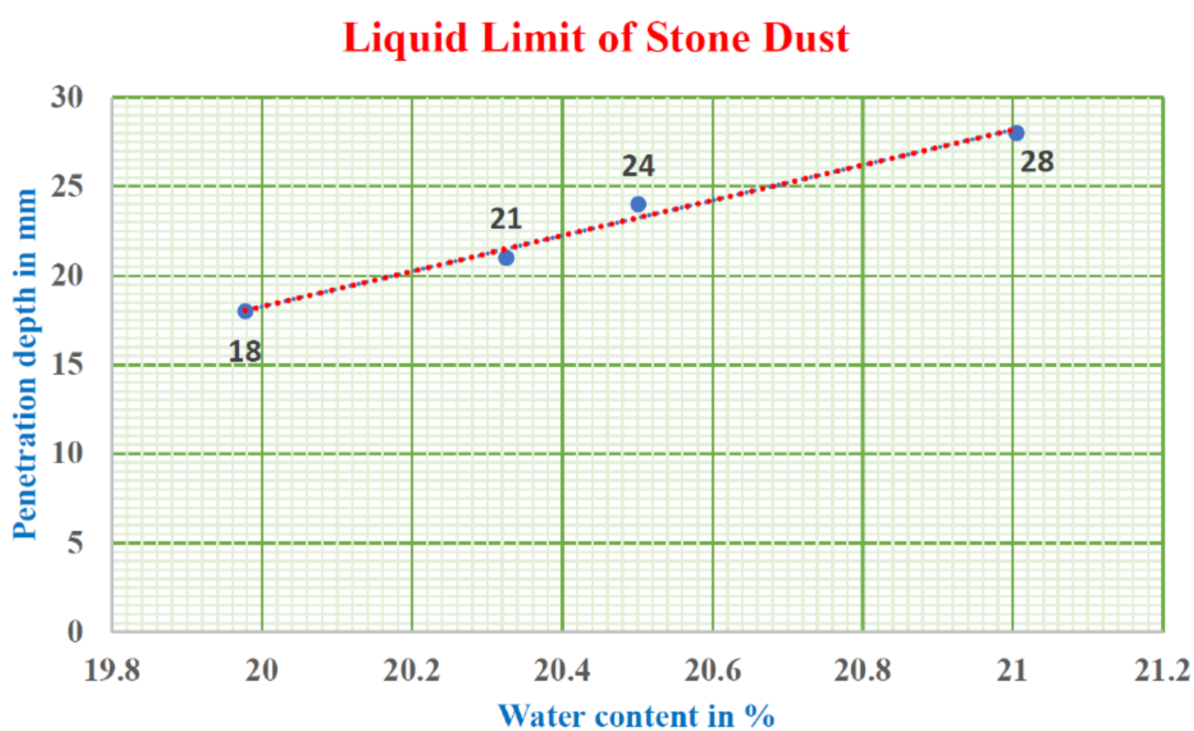

Fig 1: Liquid Limit test of Stone Dust

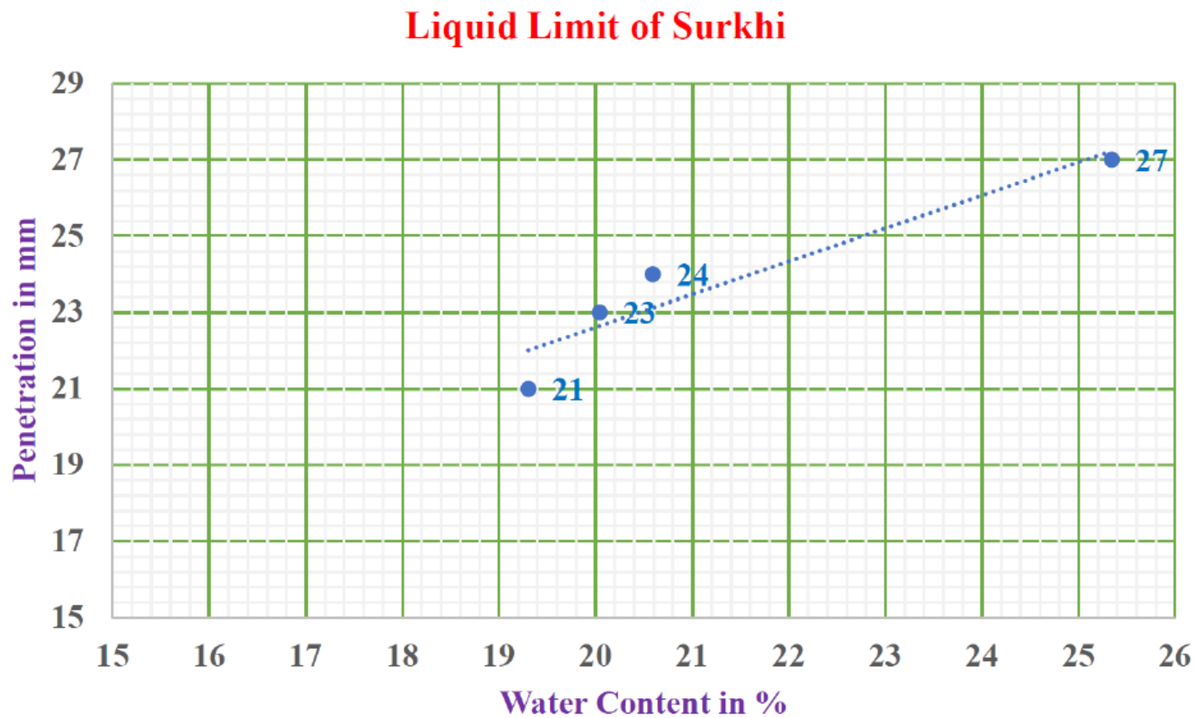

Fig 2: Liquid Limit of Surkhi

The penetration corresponding to 20 % water content is 22.5 mm.

So, the liquid limit of thestone dust is **22.5 %**.

<u>Gradation and Fineness Modulus Test:</u>

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)

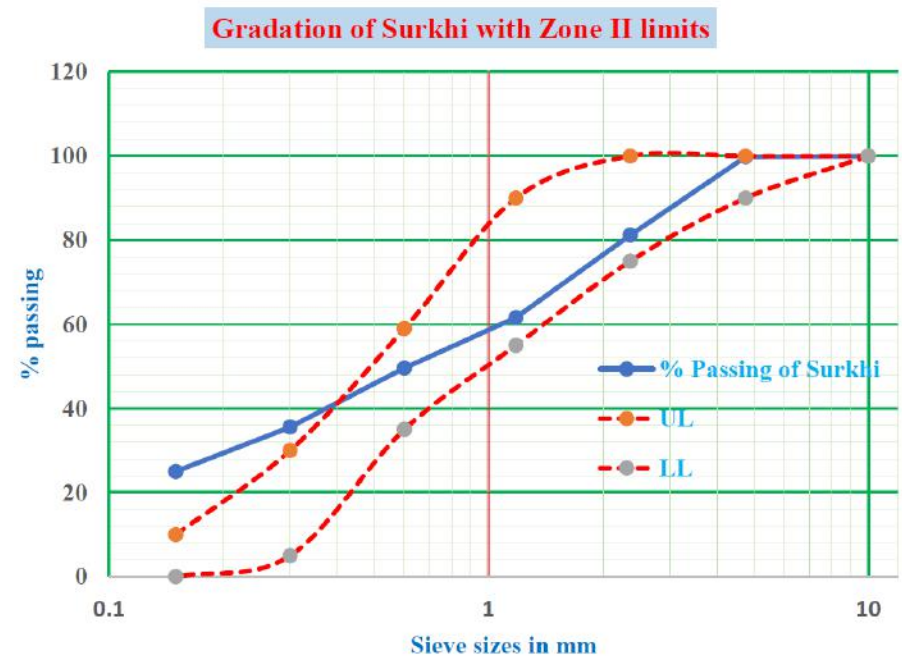

Fig 3: Gradation of Surkhi with Zone II limits

Fineness Modulus of Stone Dust = ∑Cumulative percentage weight retained/100

= 236.9/100

= **2.369 (Zone II)**

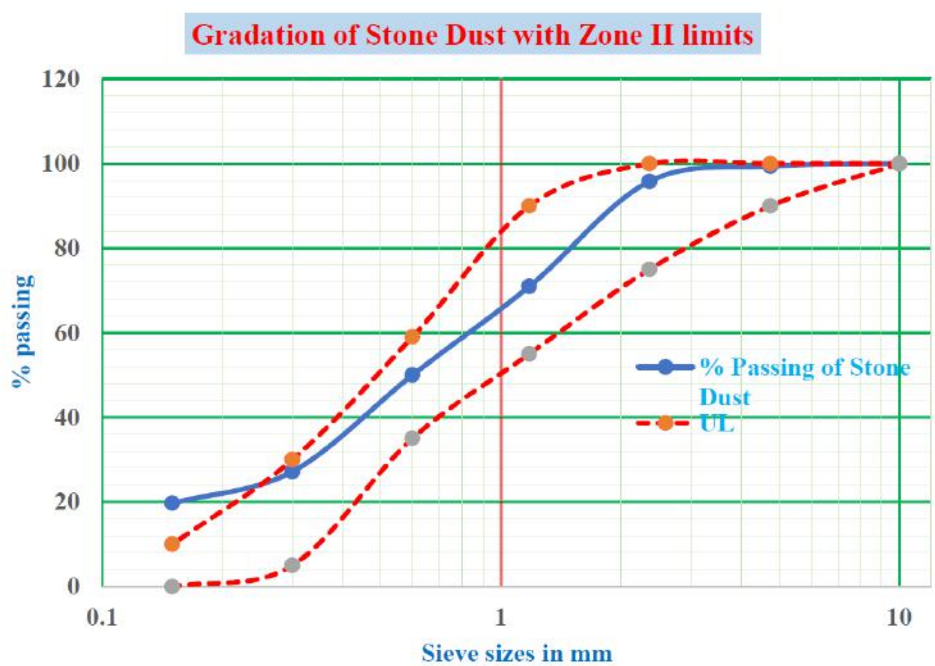

Fig 4: Gradation of Stone Dust with Zone II limits

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.

7. Modified Proctor Test:

Heavy Compaction Test

Heavy compaction test of soil is carried out using modified proctor test to understand the compaction characteristics of different types of soils with change in moisture content (water content). The Proctor compaction test (or heavy compaction test) is a laboratory test which is used for experimentally determining the optimal moisture content (O.M.C.) of soil at whichthe given type of soil specimen will become most dense and achieve its maximum dry density (by removal of air voids).

Test Description:

We have taken 5.7 kg of air dried soil passing the 19 mm IS test sieve and mixed thoroughly with 5% of water. The mixture is then compacted with a rammer of weight 4.9 kg in 5 layers, each layer being given 55 blows. The above step is repeated with an additional increment of water by 2% each time. 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

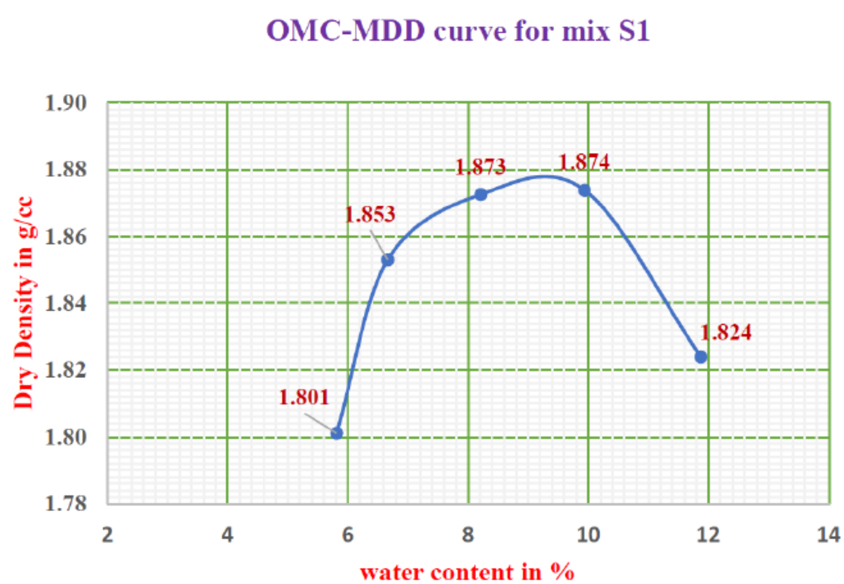

Fig 5: Compaction curve for mix S1

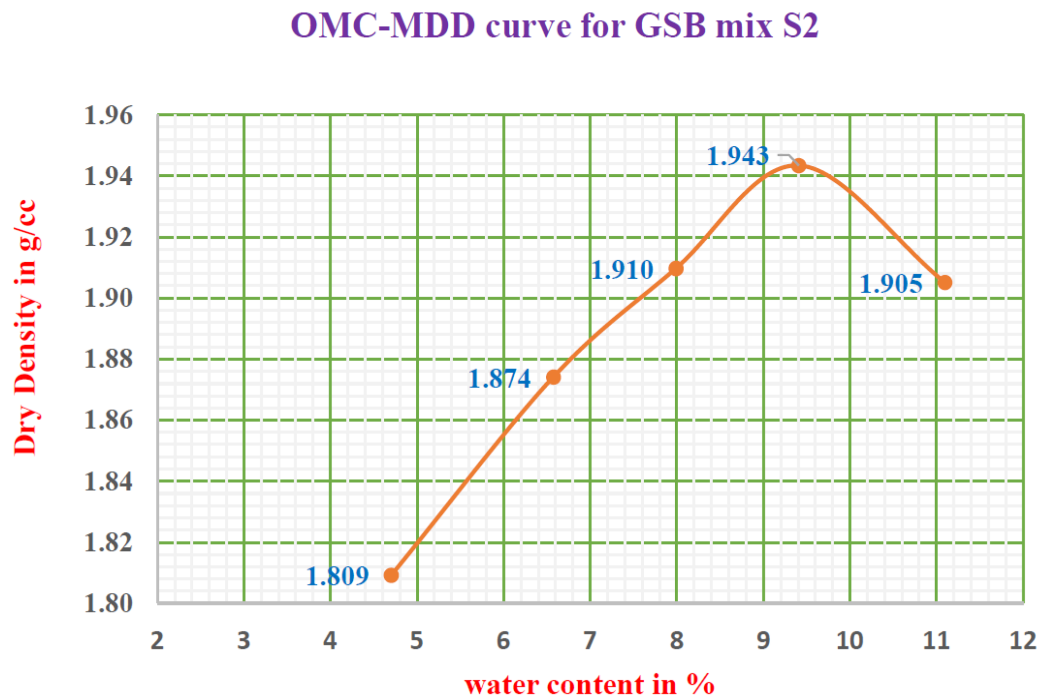

Fig 6: Compaction curve for mix S2

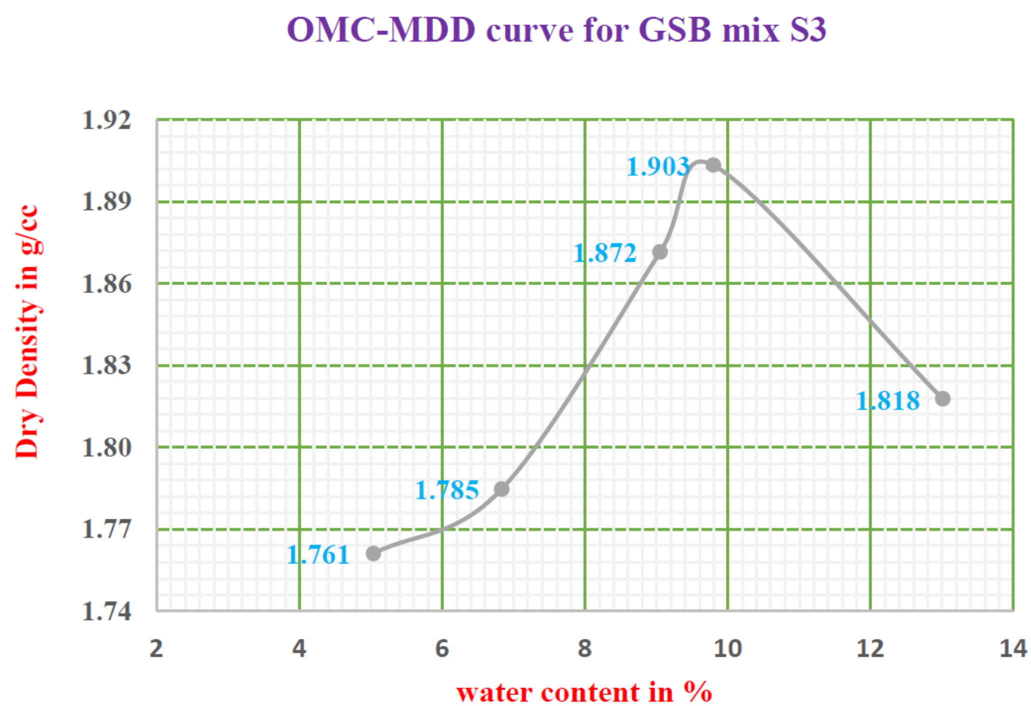

Table 7: Observation for GSB mix S3

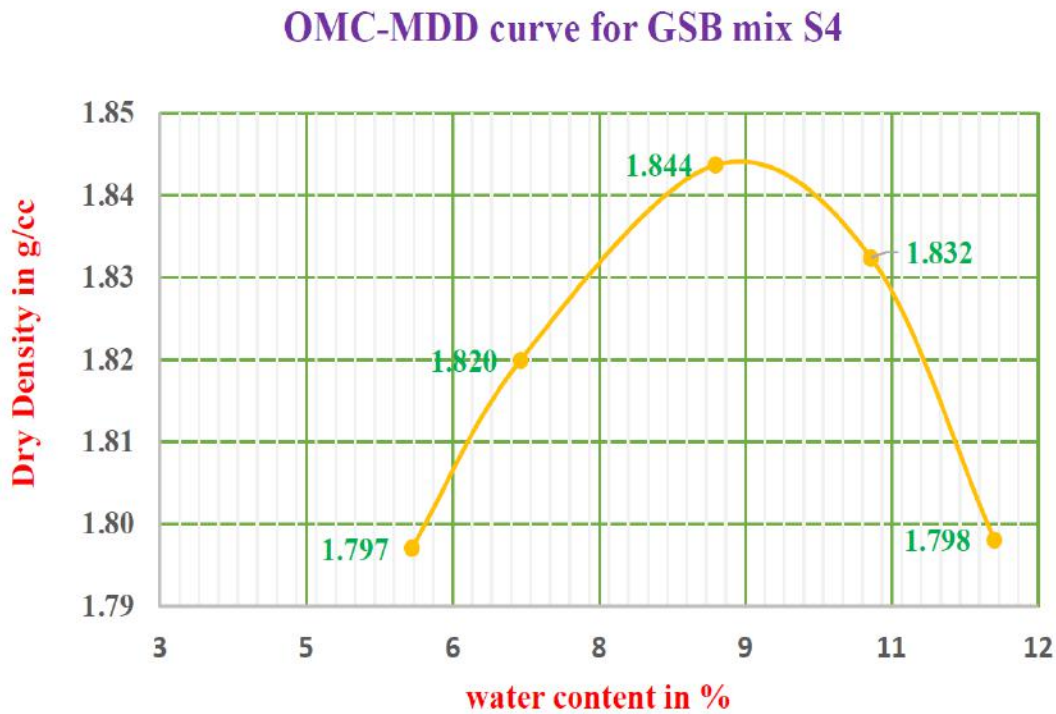

Table 8: Observation for GSB mix S4

CBR Test:

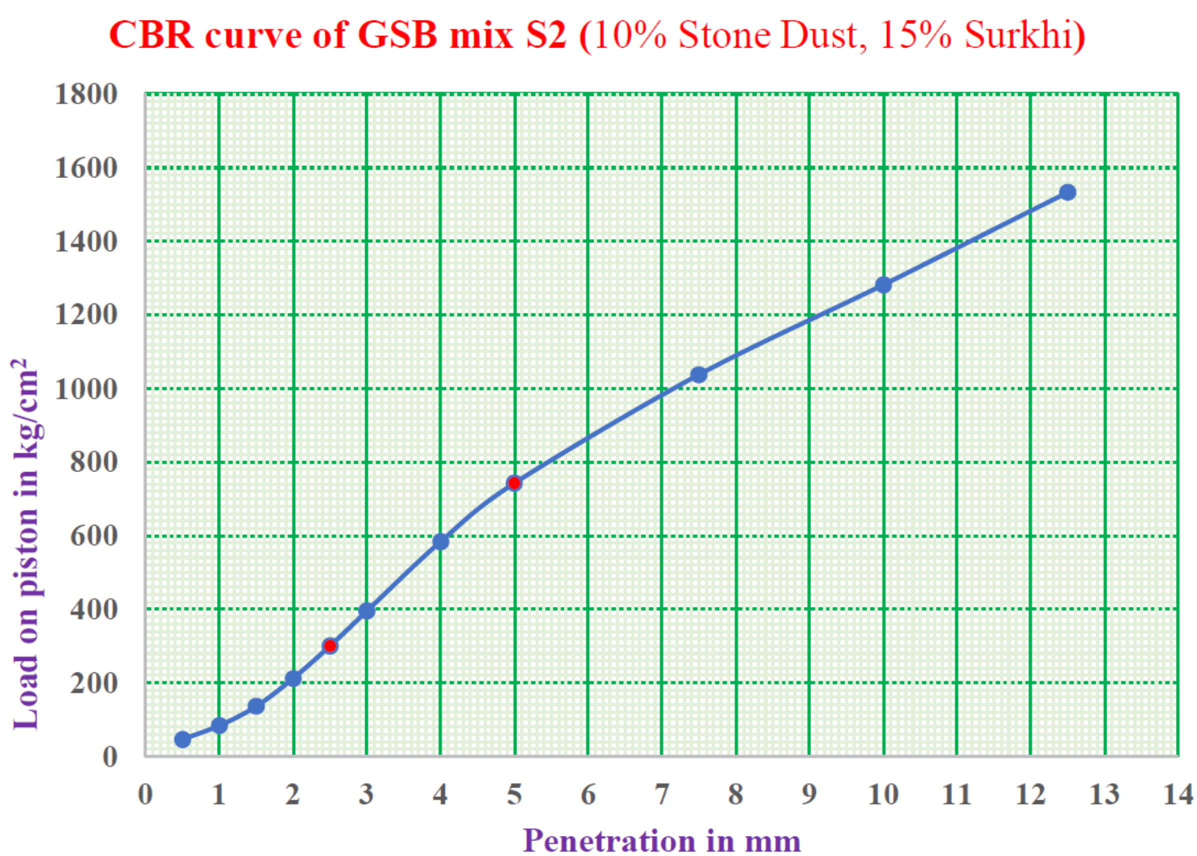

Fig 9: CBR curve for GSB mix S2

ANALYSIS OF RESULTS

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 (5th Revision). The result if presented in the graph as shown in fig 7.1

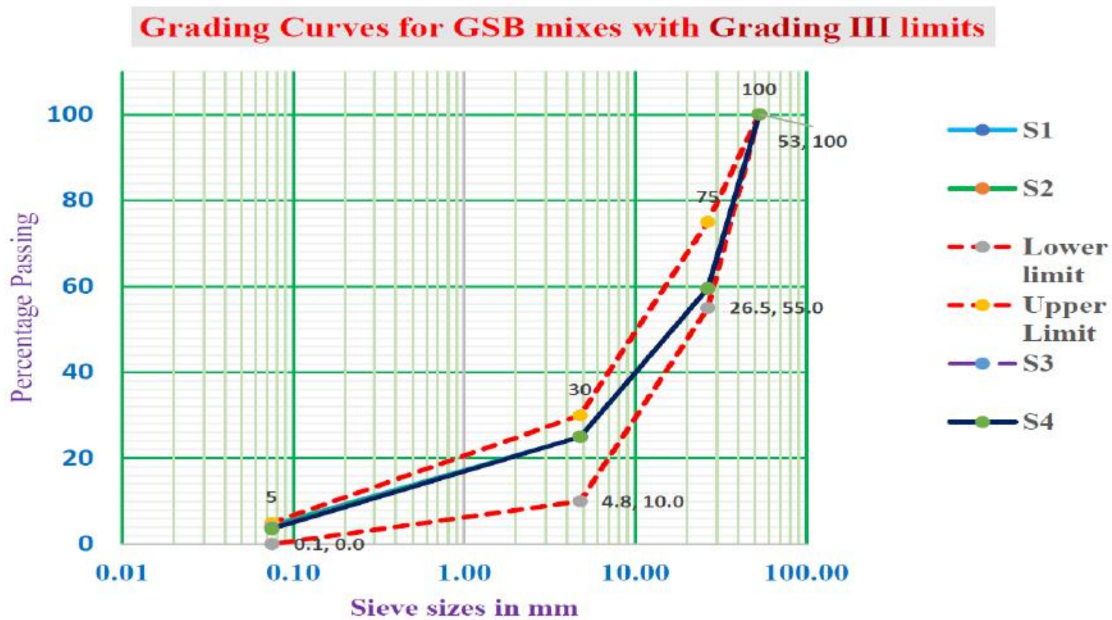

Fig 10: Grading Curves for GSB mixes with Grading III limits

Comparison of Maximum Dry Densities:

The results of all the four samples for the heavy compaction test are tabulated inTable 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

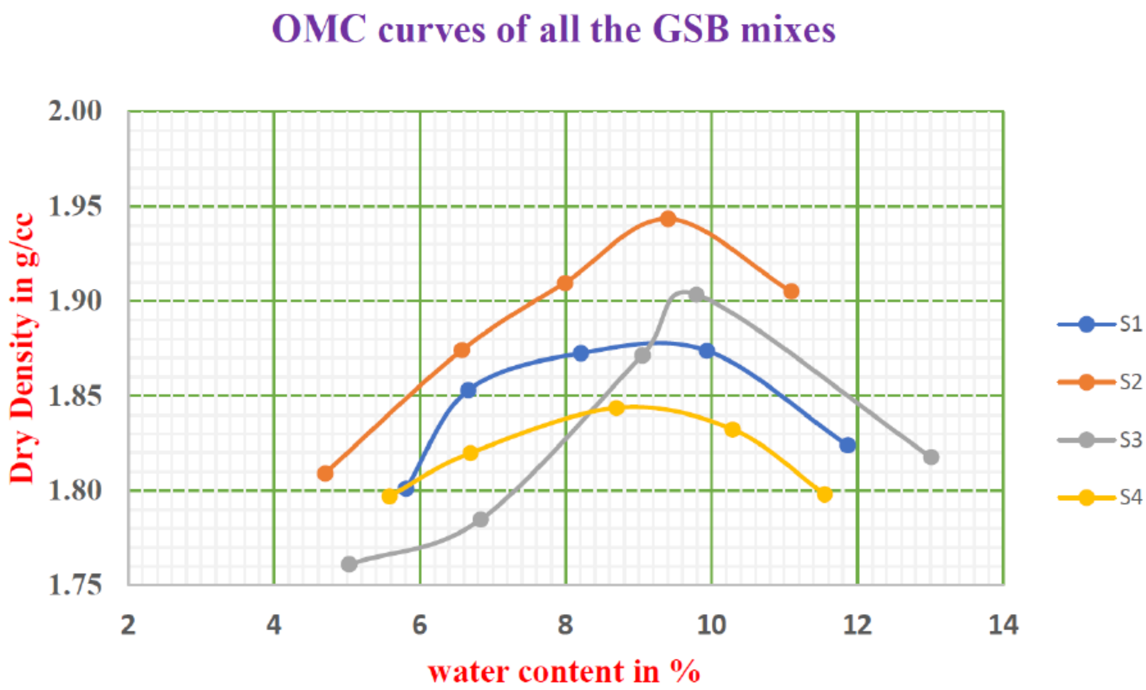

Fig 11: OMC curves of all the mixes

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 the specifications.
- The maximum MDD among all the mix samples is found to be 1.94 g/cc for the corresponding 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.

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 can be used for structural works.
2) The liquid limit of 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 test results on all six GSB mixes are found to fulfill the MORTH requirements of gradation, CBR and plasticity indicating that these combinations can be used in GSB construction of road works.
6) The CBR value of GSB Mix – S2 for unsoaked condition is found to be 36.14%.
7) The use of locally available surkhi in road construction in GSB will reduce the cost of construction of the GSB layer by 30% and also save on environmental degradation by minimizing mining pollution and energy used in the quarrying of sand/stone dust.

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 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. 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.

Statements & Declarations

The authors declare that no funds, grants, or other support were received during the preparation of this manuscript

Consent to Participate and Consent to Publish

We certify that we have participated sufficiently in the intellectual content, conception, design, analysis and interpretation of the data in this article, as well as the writing of the manuscript, to take public responsibility for it and have agreed to have my (or our) name(s) listed as the author(s). I (or we) believe that the manuscript represents valid work. Neither this manuscript nor one with substantially similar content under my (or our) authorship has been published or is being considered for publication elsewhere. Furthermore, all ethical guidelines have been followed in the conduct and reporting of this research.

Competing Interests

The authors have no relevant financial or non-financial interests to disclose.

Author Contributions

All authors contributed to the study. The first draft of the manuscript was written by Mrs. Rupjyoti Bordoloi, and all authors commented on previous versions of the manuscript. All authors have read and approved the final manuscript.

Ethics approval

This study did not require ethics approval.
The research did not involve human subjects

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