An approach to find the Suitability of Locally Available Brick Kiln Waste Surkhi as a Granular Sub Base Material for Indian Roads

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Abstract— for the pavements constructed on weak subgrade, Granular Sub-Base (GSB) layer became an important current construction practice of all the national highway projects in India. The recommended stringent specifications for the GSB material and its non-availability due to limited sources is one of the problem in road construction industry. Although in Indian road standards, there is provision for using the locally available materials in GSB layer, but most of these fail to satisfy the recommended specifications. Surkhi is one of the locally available brick kiln waste. This paper summaries the investigation carried out with an objective of developing the GSB mixes using the surkhi as partial replacement of stone dust. The laboratory tests like Grain Size Distribution, Atterberg Limits, Heavy compaction test, Soaked and Un-soaked California Bearing Ratio (CBR) tests were carried out for GSB mixes. Based on the tests results, it is found that Surkhi can be used as an alternative material in partial or full replacement of stone dust in GSB mix. This greatly encourages the utilization of locally available brick kiln waste Surkhi in the construction works of road pavements, this solves the problem of disposal of brick kiln industry waste and bring economy to road construction projects.

Key words: GSB, Surkhi, Soaked CBR

I. Introduction

Granular sub base is an intermediate layer between subgrade and granular base course, essentially provided when pavements are constructed on weak subgrade. In most of the practices where base course thickness more than standard, due to weak subgrade, it is divide into layer viz. granular base course and GSB. The material used for constructing GSB layer is inferior to granular base course material, thus GSB layer brings economy to road construction. The other main function of this layer is to act as a drainage layer for the pavement to avoid excessive wetting and weakening of subgrade. In strength it is more superior as compared to the subgrade. Various materials and techniques are used for construction of sub-base course. Ministry of Road Transport & Highways (MORT&H) and National Rural Roads Development Agency (NRRDA) emphasis the utilization of locally available and industrial waste materials in the construction works of low volume roads like rural pavements, as it also solves the problem of disposal of huge amount of industrial waste.

Surkhi, a waste of brick kiln industry, is one of the locally available waste material which can be utilised 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. The summarized data of brick production regarding brick industry is shown in Table.1.

Country	India	China	Nepal	Pakistan
No. of Brick Units	140000	80000	700	> 10000
Production in billion	240 - 260	800 - 1000	3.15	50
Labor in '000	9000	5000	NA	1500
Population in million	1210	1334	18.6	176.7
Brick use / Capita	215	750	169	283

Table 1: Brick Production in Asia

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[1]. Poorly organised and tremendous in size, lack of technology, poor quality control and unskilled labour 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 Surkhi, 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.

II. Objective of the Study

The first objective of the present study is to develop GSB mixes by using Surkhi with or without stone dust. In the present study stone dust is replaced by Surkhi in proportion 0%, 6%, 12%, 18%, 24% and 30%. 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. 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 subgrade, 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.

III. LITERATURE REVIEW

The research & development studies and successful field demonstration projects have proved that waste materials like fly ash, iron and steel industry slags, municipal waste, rice husk ash, marble slurry dust, brunt brick dust, recycled concrete etc. can be used for construction of roads. The studies carried out at central road research institute, India; reveal that, locally available low – grade materials like dhandla soil – gravel, kankar and stabilized soil can be used effectively and economically in pavement layers of rural roads [2]. Berthelot et al. [3] carried out investigation on cement modification of granular base and sub-base materials using Tri-axial Frequency Sweep Characterization and concluded with recommendation of adding cement to marginal quality aggregates for better performance. Carlos [4] reported that the brickbats in base course showed good record of use and performance in Bangladesh. Brick macadam bases become denser under traffic and develop high strength, while being flexible and insensitive to moisture at the same time.

Kazuhiko and Kuboi[5] based on their studies recommended that the effective utilization of the waste rock powder resources as a construction material could solve the problem of environmental pollution and disposal in Japan.

Based on the various researches, Indian road congress, publications, IRC: 63 – 1976, IRC: 68-1976, IRC: 74-1979, IRC: 88-1984 and IRC: SP: 58-2001 provides guidelines for the use of locally available waste material in road pavement construction.

IV. STANDARD SPECIFICATIONS FOR GSB MATERIAL

The specification [6] suggested by the MORT&H, has the provision for using two-types of GSB mixes, i.e. close-graded and coarse graded type. In Table 2.a and Table 2.b different gradations are shown recommended by MORT&H, based on the maximum nominal size of the aggregates with minimum CBR value required by mix. The material like natural sand, moorum, gravel, crushed stone, or combination thereof are recommended depending upon the grading required. The material shall be free from organic or other deleterious constituents and conform to one of the grading's given in Table 2.a and 2.b.

IS Sieve Designation (mm)	Per cent by weight passing the IS sieve		
	Grading I	Grading II	Grading III
75	100	--------	---------
53	80 – 100	100	---------
26.5	55 – 90	70 – 100	100
9.50	35 – 65	50 – 80	65 – 95
4.75	25 – 55	40 – 65	50 – 80
2.36	20 – 40	30 – 50	40 – 65
0.425	10 – 25	15 – 25	20 – 35
0.075	3 – 10	3 – 10	3 – 10
CBR Value (Min.)	30	25	20

Table 2(a): Grading for Close-Graded Granular Sub-Base Materials

IS Sieve Designation (mm)	Per cent by weight passing the IS sieve		
	Grading I	Grading II	Grading III
75	100	----	----
53		100	
26.5	55 – 75	50 – 80	100
9.50			
4.75	10 – 30	15 – 35	25 – 45
2.36			
0.425			
0.075	<10	<10	<10
CBR Value (Min.)	30	25	20

Table 2(b): Grading for Coarse Graded Granular Sub-Base Materials

The material shall have 10% fines value of 50 kN or more (for sample in soaked condition) when tested in compliance with BS: 812 (Pan 111). The water absorption value of the coarse aggregates shall be determined as per IS: 2386 (Pan 3); if this value is greater than 2%, the soundness test shall be carried out on the material as per IS: 383. For grading II and grading III materials, the CBR shall be determined at the density and moisture content likely to be developed in equilibrium conditions, which shall be taken as being the density relating to a uniform air voids content of 5%. In addition to the gradation and strength requirements, GSB material passing through 425-micron sieve [6, 7] has to satisfy the Atterberg limits i.e. the Liquid Limit (LL) and Plasticity Index (PI) should be less than 25 and 6 per cent respectively and the material shall conform to one of the grading zones [8] as recommended by IS: 383 – 1970 given in Table 3. For the road construction works, finer fraction belonging to the grading zone IV is not recommended by MORT&H.

IS Sieve Designation	Percentage Passing			
	Grading Zone I	Grading Zone II	Grading Zone III	Grading Zone IV
10 mm	100	100	100	100
4.75 mm	90 – 100	90 – 100	90 – 100	95 – 100
2.36 mm	60 – 95	75 –100	85 –100	95 – 100
1.18 mm	30 – 70	55 – 90	75–100	90 – 100
600 micron	15 – 34	35 – 59	60 – 79	80 – 100
300 micron	5 – 20	8 – 30	12 – 40	15 – 50
150 micron	0 – 10	0 – 10	0 – 10	0 – 15
75 micron	-----	-----	-----	-----

Table 3: Grading Zones Suggested by Is: 383 –1970

V. LABORATORY INVESTIGATION ON MATERIAL

A. *Coarser Fraction*

Normally in GSB material, quantity of coarser fraction is about more than 50%. The coarse aggregates used in this study were of size 53 mm and 20 mm, are shown in Fig. 1.

53 mm aggregates

20 mm aggregates

Fig. 1: Coarse Aggregates

Sr. No.	Physical Properties	Test Method	Recommended value as per IRC / MORT&H	Test Value
1	Aggregate Impact Value	IS: 2386 (Part 4) 1997	Shall not exceed 50%	17.53%
2	Aggregate Crushing Value	IS: 2386 (Part 4) 1997	Shall not exceed 45%	28.83%
3	Combined Flakiness and Elongation Indices	IS: 2386 (Part 1) 1997	Shall not exceed 40%	25.6%
4	Water Absorption	IS: 2386 (Part 3) 1997	Should not exceed 2%	0.85%
5	Specific Gravity	IS: 2386 (Part 3) 1997	2.5 to 3.0	2.79

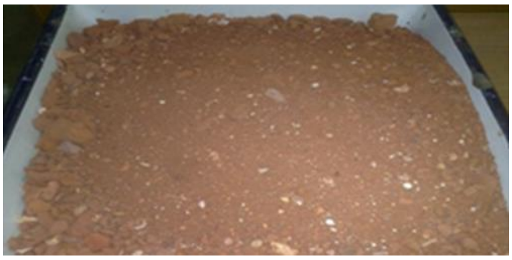
Table 4: Test Values for Coarse Aggregates

In the present study coarse aggregates are obtained from Yamuna Nagar quarry zone. The coarse aggregates of this quarry zone are strong enough and fulfil the requirements prescribed by MORT&H. The various tests[9,10,11] were conducted on 20 mm size coarse aggregates as per MORT&H /IS specifications[6,8] and found that selected coarse aggregates fulfil the requirements of MORT&H as given in Table 4.

B. Finer Fraction

Generally, sands used for road construction include stone dust, crusher sand, natural sand obtained from river beds and local sands like tibba sand etc. In the present study stone dust (SD) is used as fine fraction to make the blend with coarser fraction. It is greyish in colour, has fewer fines and has better engineering properties. Besides stone dust, locally available brick kiln waste Surkhi was also used in the present study. Surkhi (S) is used in place of stone dust by replacing it in proportions 0%, 6%, 12%, 18%, 24% and 30% to find its suitability as GSB material in the road construction. The finer fractions used in the study are shown in Fig. 2.

Stone Dust



Brick Kiln Waste "Surkhi"

Fig. 2: Fine Aggregates

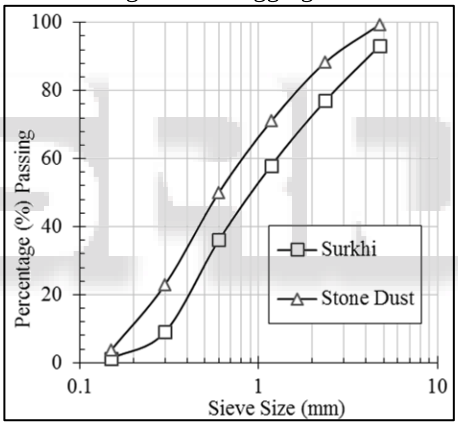


Fig. 3. Grain Size Distribution of Finer Fraction

The various tests were conducted to evaluate the properties of stone dust and surkhi. From grain size distribution curve[13] shown in Fig. 3, it is found that the size of finer fraction i.e. surkhi and stone dust lies in-between 4.75mm to 75 micron and both falls in grading zone II given in Table 3 with fineness modulus of 2.81 and 2.68 respectively. The specific gravity[12] of stone dust and surkhi is within limits and both are non – plastic [6, 14] in nature with liquid limit less 25%. The observed test values for different properties given in Table 5 ensures the suitability of surkhi in GSB material as a sand.

Properties		Test Method	Suggested Values by MORT&H / IS	Observed Test Values	
				Stone Dust	Surkhi
Specific gravity		IS: 2720 (P3 / Sec 2) 1963	2.65 to 2.85	2.68	2.81
Grain Size Analysis	Grading Zone	IS: 2720 (P4) 1985	Zones I, II & III	Zone II	Zone II
	Fineness Modulus (FM)		2 to 3.5	2.644	3.254
Atterberg Limits	Liquid Limit (LL)	IS: 2720 (P5) 1985	Max. 25%	17.89	20.08
	Plastic Limit (PL)		------	Non Plastic	Non Plastic
	Plasticity Index (PI)		Max. 6%	NA	NA

Table 5: Properties of Stone Dust and Surkhi

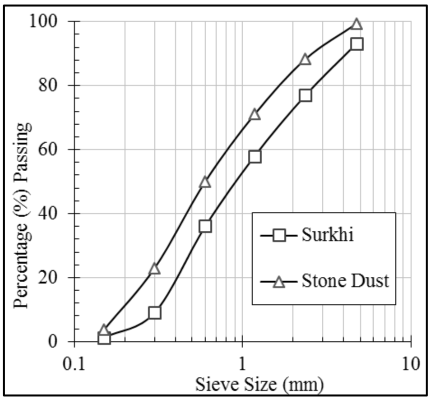


Fig. 3. Grain Size Distribution of Finer Fraction

VI. EXPERIMENTAL SETUP

The proportioning of materials was carried out to meet the specified graduation requirements of MORT&H. Job mix design is done for the combination and proportioning of aggregates to obtain the required gradation of GSB mix. The GSB mix consist of 70% coarse aggregates (CA) and 30% of finer aggregates (FA). The six samples (S1 to S6) of GSB mix were prepared with different proportions of sand and surkhi along with coarse aggregates. The observed grading of six GSB mix samples was conform to coarse graded granular sub-base material, grading – I, given in Table 2.b. The proportions of GSB mix samples are given in Table 6.

GSB Material		Material Proportioning (in %) of GSB Mix Samples					
		S1	S2	S3	S4	S5	S6
Coarser Fraction (CA)	53 mm	40	40	40	40	40	40
	20 mm	30	30	30	30	30	30
Finer Fraction (FA)	Stone Dust (SD)	30	24	18	12	6	0
	Surkhi (S)	0	6	12	18	24	30
Total Proportion		100	100	100	100	100	100

Table 6: Proportioning of GSB mix Samples

To evaluate the suitability of coarse graded GSB mix samples S1 to S6, Heavy Compaction Test [15] and CBR [16] (Soaked & Un-Soaked) test were conducted. The MDD and OMC for the GSB mix samples were obtained by test method, IS: 2720 Part 8, reaffirmed 1995. The CBR was determined at the MDD and OMC for each sample using test method, IS: 2720 Part16, reaffirmed 2002. The CBR test is conducted for both un-soaked and soaked (at 4 days soaking) conditions.

VII. RESULTS AND DISCUSSION

A. *Moisture – Density Relationship*

The relationship between the dry density and moisture content was obtained by IS Heavy compaction test as per IS: 2720 (Part 8). The materials passing 20 mm sieve were used for the test, and the coarser size fractions (i.e. more than 20 mm) are suitably adjusted by lower size fractions. The variations in moisture-density values of GSB mix samples with different proportions of surkhi and stone dust are shown in Fig. 5. The heavy compaction tests results shows that the MDD and OMC for different coarse graded GSB mixes obtained by blending surkhi and stone dust in different proportions are in range of 2.275 to 2.371 g/cc and 4.895 to 7.731 per cent respectively. It is found that GSB mix sample S4 with 18% surkhi have the highest MDD and OMC among the samples with values 2.371 g/cc and 6.205 per cent respectively.

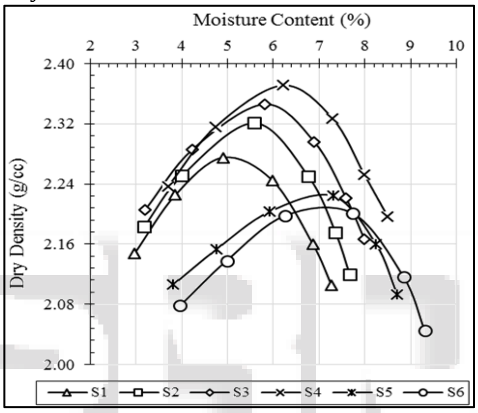


Fig. 5: Moisture – Density Curves

B. *Strength Property of Coarse Graded GSB Mix Samples*

The strength of GSB mix samples was evaluated in terms of un-soaked and soaked CBR values as per IS: 2720 part 16. The soaked CBR values were evaluated at the density and moisture content likely to develop in equilibrium condition, which shall be taken as density relating to a uniform air voids content of 5 per cent, for soaking CBR test the samples were soaked for 4 days period. The samples S1 to S6 for CBR test were remoulded at OMC and MDD. It is observed that the CBR values corresponding to MDD and OMC under heavy compaction were more than 30 per cent as required by MORT&H specifications, tabulated in Table 7.

GSB Mix Samples	S1	S2	S3	S4	S5	S6
Proportions of Stone Dust : Surkhi	30:0	24:6	18:12	12:18	6:24	0:30
OMC (%)	4.895	5.575	5.805	6.205	7.305	7.731
MDD (g/cc)	2.275	2.321	2.346	2.371	2.224	2.201
Un-Soaked CBR (%) at 2.5 mm	47.94	49.53	52.44	54.43	44.21	38.31
Soaked CBR (%) at 2.5 mm	37.24	39.07	40.79	42.85	35.81	32.16

Table 7: Test Results for MDD and CBR

The test results shows that the un-soaked and soaked CBR values ranges from 38.31 to 54.43 per cent and 32.16 to 42.85 per cent respectively, at 2.5 mm penetration. The GSB mix sample S4 with 18 % surkhi and 12% stone dust, have the maximum un-soaked and soaked CBR values of 54.43 and 42.85 per cent respectively. The Fig 6 & 7 shows the variation in CBR values for both soaked and un-soaked at 2.5 mm and 5.0 mm penetration.

VIII. CONCLUSION

The present investigation was aimed to develop an approach for developing GSB mixes to find the suitability of locally available brick kiln waste surkhi as GSB material. The test were carried out and following conclusions were made on the basis of test results:

1) The grain size analysis shows that the surkhi lies in grading zone II with fineness modulus of 3.254 which is in required range of fine aggregates i.e. 2 to 3.5. The specific gravity of surkhi 2.81 is within required range of 2.65 to 2.85. Thus surkhi can be used for road construction work.
2) The liquid limit of surkhi is less than 25% and non – plastic in nature, thus satisfies the plasticity requirement of MORT&H for road construction material.
3) The OMC increase from 4.895% to 7.731% as the content of surkhi increases from 0% to 30%. The value of MDD is found to be maximum 2.371 g/cc at 6.205% of OMC with 18% surkhi content of total fine aggregates in GSB mix.
4) The un-soaked and soaked CBR values of all six GSB mixes are more than 30% as required by MORT&H, indicating that these combinations can be used in GSB construction of road works. The sample S4 with – 18% surkhi and 12% stone dust have the maximum CBR values both.

Thus it can be concluded that surkhi is suitable as a GSB material for GSB layer construction and cab be used along with sand. The use of locally material in road construction like surkhi will achieve the economy in the road construction projects and also saves the sand for other construction works, thus minimize the mining pollution and energy used in the quarrying of sands.

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