International Journal of Scientific Research in Engineering and Management (IJSREM)
Volume: 09 Issue: 01 | Jan - 2025 SJIF Rating: 8.448 ISSN: 2582-3930

Stabilization of Soil Sub-grade Using GSB Material for Construction of Pavement

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Abstract - The construction of roads often necessitates soil stabilization in the sub-base and sub-grade regions when the soil exhibits poor strength due to softness, swelling, or low shear strength. While compaction can enhance many soils, it may not be sufficient for expansive soils, which necessitate the use of stabilizing agents, especially when dealing with weak or expansive soils. A crucial parameter in pavement design is the California Bearing Ratio (CBR), which measures soil strength. This study aimed to enhance CBR values by incorporating granular Sub-Base (GSB) material. Laboratory tests were conducted on various soil samples to determine their geotechnical properties, including Atterberg's limits, compaction characteristics, and CBR. The results indicated that increasing the percentage of GSB led to an increase in plasticity index and maximum dry density while decreasing optimum moisture content. Notably, CBR values significantly improved with higher GSB percentages. To achieve a CBR value exceeding 5, CL soils required 12-16% GSB, while CI soils needed 8-12%. This research provides valuable insights for optimizing GSB usage in pavement design, considering soil characteristics and traffic demands. Future research could explore the use of crushed demolition aggregates and fine marble powder, as well as evaluate permeability and consolidation characteristics for long-term performance and durability.
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Key Words: Granular Sub-base (GSB), Atterberg's Limit, Plasticity Index, Compaction, CBR, Expansive Soil.

1. Introduction

The construction of pavements requires a stable and load bearing soil sub-grade to ensure the longevity and performance of the pavement structure. Unstable or week sub-grade soils can lead to issues such as differential settlement, cracking, and premature failure of the pavement. One method to address this challenge is the stabilization of the sub-grade soil using geotechnical materials like Granular Sub-Base (GSB). GSB is a commonly used material in pavement construction, and its stabilizing properties can be used to improve the load-bearing capacity of sub-grade.

1.1. Soil Stabilization and Granular Sub-Base

Soil stabilization is the process of improving the engineering properties of soil, such as strength, volume stability, and durability, to make it more suitable for construction purposes (Akpila and Jaja 2019). This can be achieved through the use of various additives, including cement, lime, fly ash, and other materials. In the case of pavement construction, the stabilization of the sub-grade soil is crucial to ensure the long-term performance and stability of the pavement structure.

Granular Sub-Base is a material commonly used in the construction of pavements, typically consisting of crushed stone, gravel, or a combination of both. Granular Sub-Base provides a stable, load-bearing layer that helps distribute the loads from the pavement surface to the sub-grade, reducing the risk of differential settlement and other issues. The body of the paper consists of numbered sections that present the main findings. These sections should be organized to best present the material.

1.3. Mechanism of Stabilization

The stabilization of soil sub-grade using Granular Sub-Base material works by improving the physical and mechanical properties of the soil. The Granular Sub-Base acts as a protective layer, reducing the stresses transmitted to the sub-grade and improving the overall load-bearing capacity of the pavement structure.

Specifically, the stabilization process can involve the following mechanisms (Akpila and Jaja 2019):

- *Interlocking:* The angular and sharp edges of the Granular Sub-Base particles create a strong interlocking effect with the soil particles, enhancing the overall shear strength of the sub-grade (Nagaraj et al. 2014).

- *Drainage:* The coarse and permeable nature of the Granular Sub-Base material allows for improved drainage, reducing the risk of water accumulation and the associated problems of soil weakening and loss of bearing capacity.

- *Confinement:* The Granular Sub-Base layer acts as a confining layer, preventing the lateral movement of the sub-grade soil and increasing its load-bearing capacity.

1.4. Benefits of Stabilization

The stabilization of soil sub-grade using Granular Sub-Base material in pavement construction offers several benefits:

- *Improved Load-bearing Capacity*: The stabilization process enhances the load-bearing capacity of the sub-grade, allowing the pavement structure to support heavier loads without excessive deformation or failure (Skrzypczak, Radwański, and Pytlowany 2018).

- *Reduced Differential Settlement*: The stabilized sub-grade is less susceptible to differential settlement, which can lead to cracking and other pavement distresses.

- *Enhanced Durability:* The stabilized sub-grade is more resistant to the damaging effects of environmental factors, such as moisture and freeze-thaw cycles, improving the overall durability of the pavement (Calvarano et al. 2017) (Skrzypczak, Radwański, and Pytlowany 2018).

2. Literature Review

Various researchers have investigated the use of Granular Sub-Base material for the stabilization of soil sub-grade in pavement construction.

One study examined the utilization of phosphogypsum and fly ash as soil stabilizers, finding that these materials can significantly improve the strength characteristics of sub-grade soils (Krishnan et al. 2016). Another study focused on the use of cement and polypropylene fibre to stabilize black cotton soil, demonstrating the effectiveness of chemical stabilizers in enhancing the unconfined compressive strength of weak soils. (Tripathi 2020)

In addition to these studies, researchers have also explored the potential of natural fibers, such as jute, as alternative soil stabilization agents. The stabilization of soil sub-grade using Granular Sub-Base material in pavement construction has been extensively researched, and the available literature highlights the various benefits of this approach. The research findings presented in the literature review corroborate the effectiveness of using Granular Sub-Base material for the stabilization of soil sub-grade in pavement construction.

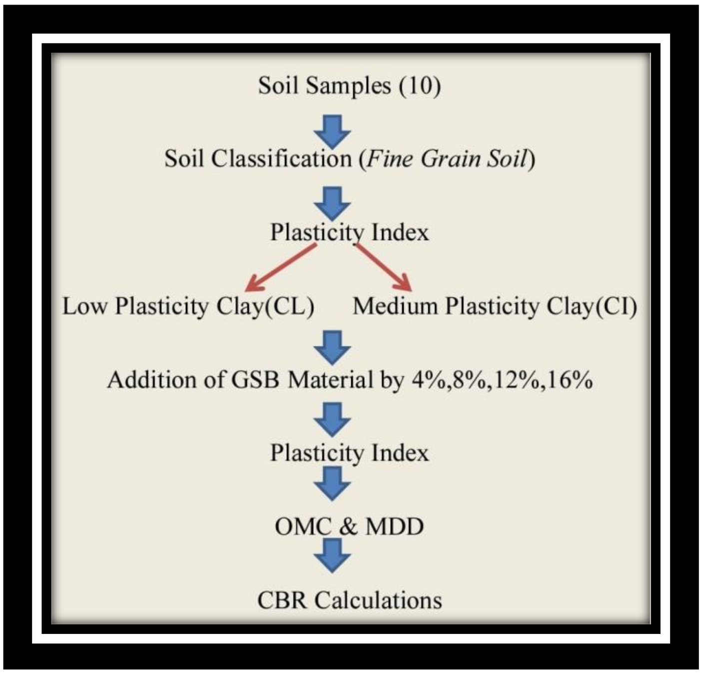
The stabilization of soil sub-grade using Granular Sub-Base material in pavement construction offers a promising solution to address the challenges associated with weak and unstable sub-grade soils

3. Methodology Adopted

The stabilization of soil sub-grade using Granular Sub-Base material in pavement construction involves the following key steps:

1. Site investigation and soil characterization: Evaluating the existing soil conditions, including soil type, strength, and bearing capacity, to determine the need for stabilization.
2. Alteration of existing soil condition based of CBR values by mixing GSB in various proportions.
3. Finding out the exact value of required GSB percentage based on maximum value of CBR.

Laboratory experiments were conducted following Indian Standard Codes to evaluate soil samples collected from a road project in Mirzapur district, Uttar Pradesh. Soil samples were obtained at one-kilometer intervals along the project stretch. Atterberg's Plasticity Limits tests were performed on these samples to determine their plasticity characteristics and classify them as either low plasticity clay (CL) or medium plasticity clay (CI). Subsequently, one representative soil sample from each plasticity group (CL and CI) was selected for further analysis. These samples were mixed with varying proportions of GSB (4%, 8%, 12%, and 16%). The impact of GSB addition on soil plasticity was investigated. Finally, compaction tests and California Bearing Ratio (CBR) tests were performed on the soil-GSB mixtures to assess their engineering properties at the respective GSB proportions.



4 Experimental Work & Result

4.1 Geotechnical properties of Soil

Table 4.1 Geotechnical Properties of Soil Sample

Sr. No.	Properties	Value
1.	Colour	Brown
2.	Liquid Limit (%)	27-32
3.	Plastic Limit (%)	14-22
4.	Plasticity Index (%)	7-16
5.	Soil Type as per IS: 1498	CL-CI
6.	Optimum Moisture Content (%)	17-18
7.	Maximum Dry Density (g/cc)	1.76-1.77
8.	Soaked CBR (%)	3-3.2
9.	Specific Gravity	2.3-2.5

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4.2 Plasticity Index of all Soil Samples

Plasticity Index of all soil samples is performed with the help of Atterberg's limit test and it is found that the plasticity of all soil samples is in the ranges of 10-15.

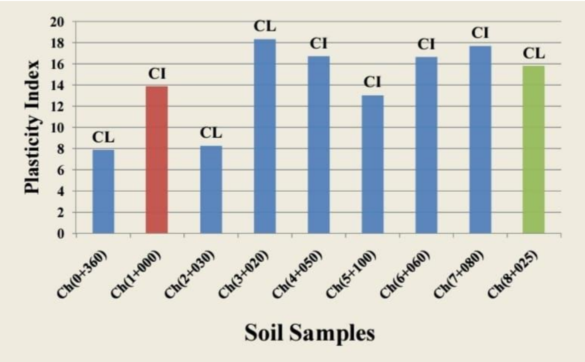


Fig 4.1. Plasticity Index of all Soil Samples

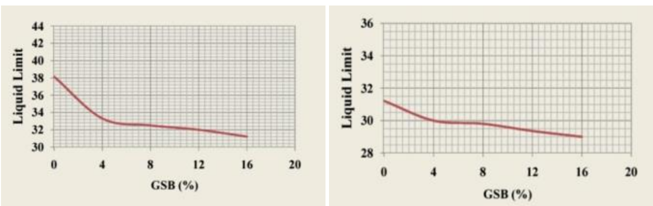
Based on the Plasticity Index, we selected two category soil one is Clay of Low Plasticty named Ch(1+000) and other is Clay of Medim Plastity named Ch(8+025). The Plasticity Index of these soil samples is 15.43 & 13.81 respectively. Further tests were performed by adding GSB in proportion of 4%,8%,12%,&16%. Results are follows with sub-sequential headings.

4.2.1 Liquid Limit Variations by Adding GSB

By addition of GSB in the soil For the Ch(1+000) sample (classified as CI soil), the liquid limit decreases from 38.13 for virgin soil to 31.2 with 16% GSB. The plastic limit also shows a slight reduction from 24.32 to 20.42, leading to a corresponding decrease in the plasticity index from 13.81 to 10.77.(Boru et al. 2022)(Maheshwari and Khatri 2012)(Tarefder, Saha, and Stormont 2010). These trends indicate that adding GSB reduces the soil's plasticity and improves its stability. For the Ch(8+025) sample (classified as CL soil), the liquid limit reduces from 31.22 for virgin soil to 29.01 with 16% GSB. Similarly, the plastic limit decreases slightly from 15.43 to 14.23, and the plasticity index reduces marginally from 15.79 to 14.78. This shows a more moderate reduction in plasticity compared to the CI sample, reflecting improved workability and reduced plastic characteristics.

Table 4.2 Plasticity Index of soil sample Ch(0+300) & Ch(8+025)

Ch(1+000) (CI)					
Virgin Soil		4% GSB	8% GSB	12% GSB	16% GSB
Liquid Limit	38.13	33.3	32.03	32	31.2
Plastic Limit	24.32	20.39	20.65	20.91	20.42
Plasticity Index	13.81	12.91	11.4	11.09	10.77
Ch(8+025) (CL)					
Liquid Limit	31.22	30.06	29.83	29.36	29.01
Plastic Limit	15.43	15.04	14.9	14.61	14.23
Plasticity Index	15.79	15.02	14.93	14.75	14.78



Ch(1+000) Ch(8+025)

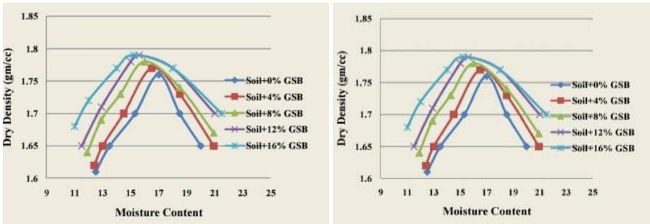
Fig 4.2. Liquid Limit Variations of soil samples

4.3 Compaction Characteristics (OMC&MDD)

The addition of GSB reduces the OMC due to the granular material's lower water absorption compared to the clay content in virgin soil. GSB also increases the MDD by improving the soil structure, creating a denser packing and reducing voids. For the Ch(1+000) sample (classified as CI soil), the OMC decreases from 17.4% for virgin soil to 14% with 16% GSB. Concurrently, the MDD increases from 1.75 g/cc to a peak of 1.87 g/cc with 12% GSB. (Tarefder, Saha, and Stormont 2010) (Zhang, Yang, and Zhang 2018) (Wu, Gautreau, and Zhang 2011). This indicates an enhancement in soil compaction characteristics with the addition of 12% GSB. For the Ch(8+025) sample (classified as CL soil), the OMC reduces from 17% for virgin soil to 15.2% with 16% GSB. The MDD remains relatively stable, fluctuating between 1.76 g/cc and 1.77 g/cc across all GSB percentages. This suggests that addition of 8% GSB will enhance the compaction characteristics of soil.

Table 4.3 OMC & MDD of soil sample Ch(0+300) & Ch(8+025)

Ch(1+000) (CI)					
Virgin Soil		4% GSB	8% GSB	12% GSB	16% GSB
OMC	17.4	15.2	14.6	14.2	14
MDD (gm/cc)	1.75	1.77	1.79	1.87	1.86
Ch(8+025) (CL)					
OMC	17	16.2	16	15.86	15.2
MDD (gm/cc)	1.76	1.77	1.76	1.77	1.77



Ch(1+000) Ch(8+025)

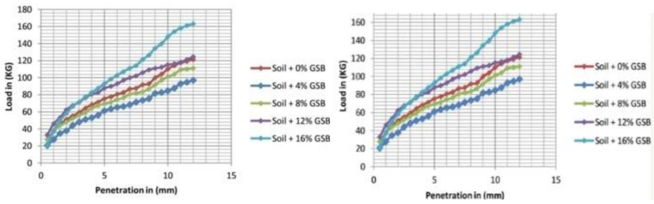
Fig 4.3. Liquid Limit Variations of soil samples

4.4 CBR Value Variations

The increase in CBR values with GSB addition is attributed to the improved compaction and interlocking of granular particles with finer soil particles, which enhances load-bearing capacity. The subsequent decline in CBR at higher GSB percentages occurs due to the excessive granular material disrupting the soil matrix's cohesion, reducing its structural stability(Amulya, Shankar, and Panditharadhya 2019) (Tarefder, Saha, and Stormont 2010). For the Ch(1+000) sample (classified as CI soil), the CBR value at 2.5 mm penetration increases from 3.2% for virgin soil to a peak of 6.32% with 12% GSB and reduction thereafter. The highest soil strength is achieved with 12% GSB for this sample followed by a slight reduction beyond the optimal GSB content. For the Ch(8+025) sample (classified as CL soil), the CBR value at 2.5 mm penetration increases significantly from 3.05% for virgin soil to 6.02% with 8% GSB and reduction thereafter This indicates the highest soil strength is achieved with 8% GSB for this sample followed by a slight reduction beyond the optimal GSB content.

Table 4.4 CBR Values of soil sample Ch(0+300) & Ch(8+025)

Ch(1+000) (CI)					
Virgin Soil		**4% GSB**	**8% GSB**	**12% GSB**	**16% GSB**
2.5(mm)	3.2	3.79	4.01	6.32	4.83
5(mm)	2.97	3.33	3.67	5.1	4.61
Ch(8+025) (CL)					
2.5(mm)	3.05	4.91	6.02	5.13	3.72
5(mm)	2.72	4.2	5.6	4.26	3.22



Ch(1+000) Ch(8+025)

Fig 4.4. CBR Values Variations of soil samples

5. CONCLUSION

The experimental study has yielded several key insights on the efficacy of using Granular Sub-Base material to stabilize the soil sub-grade for pavement construction. The addition of GSB significantly enhances the engineering properties of both CI and CL soils, making them more suitable for construction and load-bearing applications. The degree of improvement varies with soil type and GSB percentage. CI soils, with higher initial plasticity, benefit more from stabilization, while CL soils show moderate but consistent improvements. Optimal percentages of GSB addition are crucial to achieving the best results, as excess GSB may disrupt the soil matrix and reduce its cohesion. These findings emphasize the importance of tailored stabilization strategies based on soil type and desired application. (Zhang, Yang, and Zhang 2018) (Borku 2022) (Santoni, Tingle, and Webster 2002).

REFERENCES

1. Akpila, S. B., and G. W. T. Jaja. 2019. "Reliability of Soil and Ground Improvement Techniques on Peaty Clay Soil – A Review." International Journal of Trend in Scientific Research and Development. Rekha Patel. https://doi.org/10.31142/ijtsrd22909.
2. Amulya, S., A. U. Ravi Shankar, and B. J. Panditharadhya. 2019. "Durability Studies on the Lateritic Soil Stabilized with GGBS and Alkali Solutions." Airfield and Highway Pavements 2019. https://doi.org/10.1061/9780784482469.056.
3. Borku, Wondimagegn Tadesse. 2022. "Index And Engineering Properties Of Subgrade Soils: A Study In Areka Town, Wolaita Zone, Southern Ethiopia." Journal of University of Shanghai for Science and Technology. https://doi.org/10.51201/jusst/22/0145.
4. Boru, Yada Tesfaye, Adamu Beyene Negesa, Gianvito Scaringi, and Wojciech Puła. 2022. "Settlement Analysis of a Sandy Clay Soil Reinforced with Stone Columns." Studia Geotechnica et Mechanica. De Gruyter Open. https://doi.org/10.2478/sgem-2022-0020.
5. Calvarano, Lidia Sarah, Rocco Palamara, Giovanni Leonardi, and Nicola Moraci. 2017. "3D-FEM Analysis on Geogrid Reinforced Flexible Pavement Roads." IOP Conference Series Earth and Environmental Science. IOP Publishing. https://doi.org/10.1088/1755-1315/95/2/022024.
6. Hasan, Murtaza, and N. K. Samadhiya. 2017. "Performance of Geosynthetic-Reinforced Granular Piles in Soft Clays: Model Tests and Numerical Analysis." Computers and Geotechnics. Elsevier BV. https://doi.org/10.1016/j.compgeo.2017.02.016.
7. Maheshwari, Priti, and Shubha Khatri. 2012. "Generalized Model for Footings on Geosynthetic-Reinforced Granular Fill-Stone Column Improved Soft Soil System." International Journal of Geotechnical Engineering. Taylor & Francis. https://doi.org/10.3328/ijge.2012.06.04.403-414.
8. Nagaraj, H. B., Sravan Muguda, T.G. Arun, and K. S. Jagadish. 2014. "Role of Lime with Cement in Long-Term Strength of Compressed Stabilized Earth Blocks." International Journal of Sustainable Built Environment. Elsevier BV. https://doi.org/10.1016/j.ijsbe.2014.03.001.
9. Santoni, Rosa L., Jeb S. Tingle, and Steve Webster. 2002. "Stabilization of Silty Sand with Nontraditional Additives." Transportation Research Record Journal of the Transportation Research Board. SAGE Publishing. https://doi.org/10.3141/1787-07.
10. Skrzypczak, Izabela, Wojciech Radwański, and Tomasz Pytlowany. 2018. "Durability vs Technical - the Usage Properties of Road Pavements." E3S Web of Conferences. EDP Sciences. https://doi.org/10.1051/e3sconf/20184500082.
11. Tarefder, Rafiqul A., Nayan Saha, and John Stormont. 2010. "Evaluation of Subgrade Strength and Pavement Designs for Reliability." Journal of Transportation Engineering. American Society of Civil Engineers. https://doi.org/10.1061/(asce)te.1943-5436.0000103.
12. Wu, Zhong, Gavin Gautreau, and Zhongjie Zhang. 2011. "Performance Evaluation of Lime and Cement Treated Soil Layers under Laboratory and Full Scale Accelerated Pavement Testing." https://doi.org/10.1061/41167(398)76.
13. Zhang, Faru, Deguang Yang, and Liujun Zhang. 2018. "Research on Filling Scheme and Deformation Properties of Wide Subgrade of Foamed Lightweight Soil on Soft Ground." IOP Conference Series Earth and Environmental Science. IOP Publishing. https://doi.org/10.1088/1755-1315/108/2/022051.