

Soil Stabilized Road

Birendra Kumar Singh*

Abstract

This research examines the suitability of soil-stabilized roadways for light vehicular movement, offering an economical and practical alternative for areas with limited infrastructure development. Stabilizing soil involves improving its engineering properties by incorporating additives such as cement, lime, or other binding materials. Through stabilization, the treated soil can achieve a compressive strength of approximately 5 N/mm², or 500 t/m², which is sufficient to support loads imposed by light vehicles. In road construction, it is crucial to account not only for the compressive strength but also for the ability of the material to resist bending or flexing under traffic loads. Since soil naturally tends to deform under pressure, flexural strength becomes a key factor in ensuring long-term performance. For this purpose, design calculations incorporate the load applied by vehicles, typically expressed in tonnes, and compare it with the soil's load-bearing capacity, measured in t/m². By evaluating both compressive and flexural strengths, the road design ensures stability and durability under expected service conditions. This method makes it possible to construct low-cost roads that remain functional and safe for daily use, particularly in rural and semi-urban settings where traffic consists primarily of lighter vehicles. Additionally, the use of locally available materials and simplified construction techniques reduces environmental impact and promotes sustainability. The findings support the broader implementation of soil stabilization as a viable method for improving transportation infrastructure in resource-constrained regions.

Keywords: Flexural strength, bearing capacity of soil, soil stabilization, soil-cement, load bearing capacity, pavement design, vehicle load, soil mechanics, tensile strength, road construction, soil reinforcement, flexural design, soil strength, soil-structure interaction, soil pressure

INTRODUCTION

In various types of civil engineering structures, the action of upward soil pressure plays a crucial role in the design and stability of the overall system. This principle is particularly relevant in applications such as road pavements, foundation bases (e.g., reinforced concrete slabs), industrial floors, railway embankments, and airfield runways. In each of these scenarios, the underlying soil exerts an upward reaction force in response to the loads imposed on it from above. Due to this upward pressure from the soil, the structural element in contact with the ground must be designed to resist flexural stresses. These stresses arise as the structure bends under the load, making flexural strength a critical design parameter. In practice, concentrated loads, typically expressed in tons, are considered during design calculations to simulate the effect of heavy vehicles or equipment acting over a relatively small contact area. When

*Author for Correspondence

Birendra Kumar Singh
E-mail: birendrasingh.civil@yahoo.co.in

Professor, Department of Civil Engineering, Birla Institute of Technology, Mesra, Ranchi, Jharkhand, India

Received Date: April 12, 2025

Accepted Date: May 25, 2025

Published Date: May 27, 2025

Citation: Birendra Kumar Singh. Soil Stabilized Road. Journal of Geotechnical Engineering. 2025; 12(2): 38–42p.

analyzing soil-stabilized roads, it is essential to ensure that the bearing capacity of the subgrade soil is sufficient to support the imposed load without failure or excessive settlement. Unlike foundations or slabs where loads may be distributed over a larger area, vehicular loads on roads act over specific areas defined by the dimensions of the vehicle's wheels or axles. Therefore, for design purposes, the load from a single wheel is often considered as a concentrated load, and the pressure distribution is evaluated in tons per square meter (t/m²). This ensures that the

design remains safe, effective, and within acceptable performance limits under real-world traffic conditions [1–8].

METHODOLOGY

Load Analysis

This study begins by identifying the loads imposed on soil-stabilized roads, focusing particularly on vehicle weights. A representative Class AA vehicle load of 70 t is assumed to act over a contact area measuring 3.5 m×1.2 m. In addition, the total footprint of the vehicle, with dimensions of 7 m in length and 4 m in width, is considered to evaluate the overall pressure distribution on the subgrade [9–12].

Evaluation of Soil Bearing Capacity

To ensure safety and durability, the subgrade soil's bearing capacity is assessed to confirm that it can withstand the applied loads without excessive deformation. A minimum bearing capacity value of 20 t/m² is chosen, providing a buffer above expected pressures. Soil stabilization methods are considered to enhance soil strength, raising it to approximately 5 N/mm² (or 500 t/m²), based on laboratory test data [14–17].

Concentrated Wheel Load Assessment

For localized load evaluation, the load from an individual wheel weighing 8 t is analyzed. This load is assumed to act over a 0.5 m×0.5 m contact patch, resulting in an increased load intensity. This localized pressure is checked against the soil's enhanced bearing capacity to ensure it remains within safe limits [18, 19].

Flexural and Bending Stress Calculation

Due to the comparable dimensions of the wheel contact area, the loading is treated as lateral, causing bending in the soil-stabilized layer. Bending stress is calculated over the shorter span of 0.5 m using established flexural formulas. The calculated bending stress is then compared with the flexural strength of the stabilized layer, which is about 5 N/mm², to verify structural adequacy.

Determining Soil-Stabilized Layer Thickness

Based on the flexural and tensile stress requirements, the thickness of the stabilized soil layer is determined to prevent structural failure due to bending or tensile stresses from upward soil pressure. A thickness of 150 mm is adopted, ensuring the layer's strength and longevity.

Application to Related Structures

The design principles and calculations outlined are applicable to other structures subjected to upward soil reaction forces, including reinforced concrete foundations, floors, railway embankments, and airport runways. Ensuring sufficient bearing capacity and flexural strength in these cases is essential for maintaining structural stability and performance.

RESULTS AND DISCUSSION

- In pavement and foundation engineering, ensuring that the soil beneath a structure can safely carry imposed loads is a fundamental design requirement. For a soil-stabilized road to perform effectively under vehicular traffic, it must possess adequate bearing capacity and flexural strength to resist vertical and lateral stresses caused by wheel loads.
- A typical Class AA vehicle load is approximately 70 t, which is assumed to be distributed over a contact area of 3.5 m by 1.2 m, giving an average pressure of around 16.67 t/m². To avoid settlement or structural failure, the soil's bearing capacity must exceed this value. In this analysis, the required soil bearing capacity is taken as 20 t/m², providing a safety margin against potential deformation.
- For a full vehicle footprint, assumed as 7 m long and 4 m wide, the total loaded area becomes 28 m². The total vehicle weight of 467 t distributed over this area results in a pressure of

approximately 16.7 t/m^2 , which is well within the strength of stabilized soil, typically rated at 5 N/mm^2 or 500 t/m^2 . This confirms the soil is adequately strong under compressive loads.

- To evaluate localized effects, a single wheel load of 8 t is considered over a contact patch of $0.5 \text{ m} \times 0.5 \text{ m}$, giving a load intensity of 32 t/m^2 . As this is still far below the soil's capacity of 500 t/m^2 , the design is confirmed as safe.
- Given the similarity in length and width of the load area, this scenario is treated as a lateral load condition, where bending becomes critical. The wheel load induces bending along the shorter span of 0.5 m , and calculations show the resulting stress to be around 3 N/mm^2 , which is less than the available 5 N/mm^2 flexural strength of the stabilized layer.
- To ensure structural performance under such conditions, the thickness of the stabilized layer is taken as 150 mm . This dimension is determined based on bending and tensile stress analysis, ensuring that the layer can distribute upward soil pressure effectively without cracking or failure.
- The same method of checking flexural and compressive performance is applicable to structural foundations, floors, and similar surfaces where upward soil pressure is a critical design factor.

$3.5 \text{ m} \times 1.2 \text{ m} = 70 \text{ t}$ (class AA loading)

$$1 \text{ m}^2 = \frac{70}{4.2} = 17 \text{ t/m}^2$$

- Hence bearing capacity of soil should be 20 t/m^2 .
- Always, bearing capacity of soil should be more than the load so that settlement should not occur (hence tension is avoided to avoid failure of the structure).

$$1 \text{ m}^2 = \frac{70}{4.2}$$

$$\text{for } 7 \text{ m (Length of vehicle)} \times 4 \text{ m (width of vehicle)} = \frac{70 \times 7 \times 4}{4.2} = 467 \text{ tonne.}$$

- Since strength of soil stabilized road $= 5 \text{ N/mm}^2$ (500 t/m^2) greater than 467 t .

Hence OK.

- Since load of one wheel load i.e. 8 t taken and bearing capacity of soil $= 20 \text{ t/m}^2 > 8 \text{ t}$. Hence, OK.
- This wheel load is acting on some contact area of wheel ($0.5 \text{ m} \times 0.5 \text{ m}$ taken).
- Since dimensions are comparable to each other hence it is the case of lateral load hence load

intensity $w = \frac{\text{Load}}{\text{Area}}$ taken.

$$w = \frac{8}{0.5 \times 0.5} = \frac{8}{0.25} = 32 \text{ t/m}^2$$

- Bending takes place along 0.5 m
- Hence bending moment $M = \frac{32 \times (0.5)^2}{8} = 1 \text{ t-m}$
- Using bending equation:

$$\frac{M}{Z} = f$$

$$\frac{10000000}{\frac{1}{12} \times 1000 \times (150)^3 \times \frac{2}{150}} = 3 \text{ N/mm}^2 < 5 \text{ N/mm}^2$$

Hence OK.

- Where, $b = 1000 \text{ mm}$ taken since it is the case of lateral load.

- 150 mm= thickness of soil stabilized road found by tensile strength of soil stabilized. (Since upward soil reaction is acting).

- $\frac{Load}{SurfaceArea} = \text{Tensile strength of soil stabilized road.}$

$$\frac{467 \times 1000 \times 10}{7000 \times t} = 5$$



Length of one vehicle

$$35000 \text{ t} = 4670000$$

t = thickness of soil stabilized road

$$t = \frac{4670000}{35000} = 133 \text{ mm}$$

- Hence thickness of soil stabilized road =150 mm taken.
- In this way flexural strength check is made for foundation base, floor etc. also where upward soil pressure is acting.

CONCLUSION

The evaluation of soil-stabilized road structures under light vehicle loads has shown that this method is both technically sound and practical. A key factor in the structural behavior of such roads is their ability to resist bending, especially under concentrated wheel loads. In this context, the flexural strength of the stabilized soil was calculated to be around 3 N/mm², and for design purposes, a conservative value of 5 N/mm² was considered. This provides sufficient safety against bending and cracking during service.

- The bearing capacity of the stabilized soil was estimated at 20 t/m², which comfortably supports the applied vehicle loads, including a single wheel load of 8 t and a total Class AA vehicle load of 70 t over a typical contact area. These values indicate that the soil has adequate strength to resist settlement and maintain structural stability.
- When considering localized pressure from individual wheels, which act on smaller areas such as 0.5 m×0.5 m, the resulting stress was found to be within safe limits. The calculated bending stress did not exceed the design strength, confirming the ability of the pavement to handle flexural demands.
- A layer thickness of 150 mm was selected for the stabilized soil base, based on both compressive and flexural strength considerations. This thickness ensures that the pavement can adequately spread loads and resist deformation under repetitive loading conditions.
- In summary, soil stabilization is a viable solution for constructing light-duty roads, offering strength, durability, and cost efficiency. The principles applied in this study can also be extended to other applications like floor slabs, foundations, and similar surfaces, where upward soil pressure and bending must be carefully accounted for in design.

Flexural strength of soil stabilized road =3 N/mm²≈5 N/mm² taken.

REFERENCES

1. Wang L, Shao G. Test research on flexural strength of soil-cement reinforced with carbon fibers. *Case Stud Constr Mater.* 2023; 19: e02280. Available from: <https://doi.org/10.1016/j.cscm.2023.e02280>.
2. Czerniak A, Grajewski SM, Kurowska EE. Bearing capacity standards for forest roads constructed using various technologies from mechanically and chemically stabilised aggregate. *Croat J For Eng.* 2017; 42(3): 14. Available from: <https://doi.org/10.5552/crojfe.2021.996>.
3. Linares-Unamunzaga A, Pérez-Acebo H, Rojo M, Gonzalo-Orden H. Flexural Strength Prediction Models for Soil-Cement from Unconfined Compressive Strength at Seven Days. *Materials (Basel, Switzerland).* 2019; 12(3): 387. <https://doi.org/10.3390/ma12030387>.

4. Mallikarjuna V. Soil Stabilization Using Plastic Waste. *Int J Res Eng Technol*. 2016; 05(05): 391–394. <https://doi.org/10.15623/ijret.2016.0505074>.
5. Bell F. Lime stabilization of clay minerals and soils. *Eng Geol*. 1996; 42(4): 223–237. [https://doi.org/10.1016/0013-7952\(96\)00028-2](https://doi.org/10.1016/0013-7952(96)00028-2).
6. Zhang P, Wei XH. Study on flexural strength and flexural modulus of elasticity of cement stabilized aggregate. *Adv Mater Res*. 2011; 287–290: 990–993. <https://doi.org/10.4028/www.scientific.net/amr.287-290.990>.
7. Rasal RM, Janorkar AV, Hirt DE. Poly(lactic acid) modifications. *Prog Polym Sci*. 2009; 35(3): 338–356. <https://doi.org/10.1016/j.progpolymsci.2009.12.003>.
8. Wang DX, Abriak NE, Zentar R, Xu W. Solidification/stabilization of dredged marine sediments for road construction. *Environ Technol*. 2012; 33(1): 95–101. <https://doi.org/10.1080/09593330.2011.551840>.
9. Espinosa AB, Revilla-Cuesta V, Skaf M, Serrano-López R, Ortega-López V. Strength performance of low-bearing-capacity clayey soils stabilized with ladle furnace slag. *Environmental Science and Pollution Research*. 2023; 30(45): 101317–101342. <https://doi.org/10.1007/s11356-023-29375-y>.
10. Csanyi LH. Foamed Asphalt In Bituminous Paving Mixtures. *Highway Research Record*. 1957; 160: 00211354. <https://trid.trb.org/view/101130>.
11. Pedroso GOM, Santos RDD Junior, Da Silva JL, Motta MFB, Félix EF. Flexural strength characteristics of Fiber-Reinforced cemented soil. *Materials*. 2023; 16(11): 4185. <https://doi.org/10.3390/ma16114185>.
12. Lindh P, Lemenkova P. Laboratory experiments on soil stabilization to enhance strength parameters for road pavement. *Transp Telecommun J*. 2023; 24(1): 73–82. <https://doi.org/10.2478/tj-2023-0008>.
13. Anggraini V, Asadi A, Huat BB, Nahazanan H. Effects of coir fibers on tensile and compressive strength of lime treated soft soil. *Measurement*. 2014b; 59: 372–381. <https://doi.org/10.1016/j.measurement.2014.09.059>.
14. Gardete D, Luzia R, Carronda S, Simão A. Analysis of the Bearing Capacity of a Clayey Sand Stabilized with Waste Tire Fibers. *Airfield and Highway Pavements*. 2019; 03: 541–548. <https://doi.org/10.1061/9780784482469.054>.
15. Biswal DR, Sahoo UC, Dash SR. Fatigue characteristics of Cement-Stabilized Granular Lateritic soils. *J Transp Eng B Pavements*. 2019; 146(1): 04019038. <https://doi.org/10.1061/jpeodx.0000147>.
16. Tiwari N, Satyam N, Puppala AJ. Strength and durability assessment of expansive soil stabilized with recycled ash and natural fibers. *Transp Geotech*. 2021; 29: 100556. <https://doi.org/10.1016/j.trgeo.2021.100556>.
17. Yadav K, Tiwari P, Singh P. A review: Soil stabilisation using agricultural waste and cementitious material. *Int J Res Appl Sci Eng Technol*. 2024; 12(2): 212–216. <https://doi.org/10.22214/ijraset.2024.58303>.
18. Ali AB, Rashid M, Rahman Z, Talukder T, Joy IA. A comparative study on soil stabilization techniques. *Journal of Advances in Geotechnical Engineering*. 2023; 6(2): 19-25. <https://doi.org/10.5281/zenodo.8088722>.
19. Del Pilar Bustamante Sánchez R, Gallardo LMM. Stabilization of Clay Soils applying PET at 2%, 4% and 6% on Unpaved Roads. *Proceedings of the 20th LACCEI International Multi-Conference for Engineering, Education and Technology: Education, Research and Leadership in Post-pandemic Engineering: Resilient, Inclusive and Sustainable Actions*. 2022. <https://doi.org/10.18687/laccei2022.1.1.45>.