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FLEXIBLE PAVEMENT DESIGN USING INDUSTRIAL WASTE FOR SUBGRADE SOIL STABILIZATION

[1] K Veda Samhitha, [2] P Vasanthi, [3] M Sri Vasavi, [4] N Manoj
[1]AssistantProfessor, [234]Students
Department of CIVIL
Siddhartha Institute of Technology & Sciences, Narapally
sits.vedasamhitakadukoori@siddhartha.co.in, 24TQ5A0104@siddhartha.co.in,
23TQ1A0101@siddhartha.co.in, 24TQ5A0121@siddhartha.co.in,

Abstract

The project "Flexible Pavement Design Using Industrial Waste for Subgrade Soil Stabilization" focuses on improving the engineering properties of weak subgrade soil by utilizing suitable industrial waste materials. The strength and stability of subgrade soil play an important role in the performance and service life of flexible pavements. Weak or expansive soils may undergo excessive deformation under repeated traffic loading, resulting in pavement failures such as rutting, cracking, and uneven settlement. Therefore, stabilization of weak subgrade soil is necessary to improve its load-bearing capacity and reduce pavement deterioration.

The study investigates the use of selected industrial waste materials as stabilizing agents for subgrade soil. Materials such as fly ash, steel slag, cement kiln dust, or other suitable industrial by-products can be incorporated into the soil in different proportions. Laboratory tests are conducted on untreated and stabilized soil to evaluate properties such as moisture content, specific gravity, Atterberg limits, compaction characteristics, and California Bearing Ratio (CBR). The results are compared to determine the improvement achieved through stabilization.

The stabilized soil is then considered for flexible pavement design based on the improved subgrade strength. Different percentages of industrial waste can be evaluated to identify an optimum content that provides adequate strength and stability. The improved CBR value can be used as an important input for determining suitable pavement layer thickness. This approach can reduce the requirement for conventional soil improvement materials while providing a useful application for industrial waste.

Overall, the project demonstrates the potential of industrial waste-based soil stabilization as a sustainable approach to flexible pavement construction. The study aims to improve subgrade performance, reduce pavement thickness where technically appropriate, and promote the beneficial reuse of industrial by-products. The proposed approach provides an economical and environmentally responsible solution for developing durable flexible pavements over weak subgrade soils.

I. Introduction

Flexible pavement is one of the most commonly used pavement systems for roads and highways because of its flexibility, ease of construction, and ability to distribute traffic loads through different pavement layers. The performance of a flexible pavement depends greatly on the strength and stability of the underlying subgrade soil. Weak subgrade soils may undergo excessive deformation when subjected to repeated

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wheel loads, which can lead to rutting, cracking, settlement, and premature pavement failure. Therefore, improving the engineering properties of weak subgrade soil is an important part of pavement construction.

Soil stabilization is a technique used to improve the strength, stiffness, bearing capacity, and durability of soil by adding suitable stabilizing materials. Traditionally, materials such as cement, lime, and other conventional additives have been used for soil stabilization. However, the increasing generation of industrial waste has created environmental and disposal challenges. Industrial by-products such as fly ash, steel slag, cement kiln dust, and other suitable waste materials have the potential to be used in soil stabilization. Their utilization can reduce waste accumulation while providing useful construction applications.

The effectiveness of industrial waste for subgrade stabilization can be evaluated through laboratory testing. Properties such as Atterberg limits, compaction characteristics, moisture content, and California Bearing Ratio (CBR) can be determined for untreated and stabilized soil. Different percentages of industrial waste are added to the soil to study changes in its engineering properties. An improvement in CBR and other strength characteristics can indicate better subgrade performance and may influence the required thickness of the flexible pavement layers.

The present project focuses on flexible pavement design using industrial waste for subgrade soil stabilization. Weak subgrade soil is treated with selected industrial waste materials in different proportions, and its engineering properties are evaluated through laboratory investigations. The improved subgrade strength is then considered in the flexible pavement design to determine a suitable pavement structure. The study aims to identify an effective stabilization method that improves pavement performance while promoting the beneficial reuse of industrial waste. Overall, the approach provides a sustainable and economical solution for constructing durable flexible pavements over weak subgrade soils.

II. Literature Survey

Several studies have investigated the stabilization of weak subgrade soils using industrial waste materials to improve their engineering properties for pavement construction. Researchers have reported that materials such as fly ash, steel slag, cement kiln dust, and other industrial by-products can modify soil behavior by improving its strength, stiffness, compaction characteristics, and bearing capacity. The effectiveness of stabilization depends on the type of soil, chemical composition of the waste material, quantity added, moisture condition, and curing period. These studies indicate that industrial waste can provide an alternative to conventional soil-stabilization materials when appropriately selected and processed.

Fly ash has been widely studied as a stabilizing material for weak and expansive soils. Research has shown that adding suitable quantities of fly ash can modify the plasticity characteristics of soil and improve its compaction and California Bearing Ratio (CBR). The improvement is generally associated with the interaction between the soil particles and the reactive components present in fly ash. Several investigations have

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therefore considered fly ash stabilization for pavement subgrades, particularly where locally available soils have inadequate bearing capacity.

Researchers have also examined the use of steel slag and other steel-industry wastes for soil and pavement applications. Steel slag contains mineral components that can contribute to improved strength and stiffness when incorporated into suitable soils. Studies have evaluated changes in CBR, unconfined compressive strength, compaction characteristics, and durability after stabilization. However, researchers have emphasized that the physical and chemical characteristics of slag should be evaluated before use because different sources of industrial waste can exhibit significantly different properties.

Other studies have investigated combinations of industrial wastes with conventional stabilizers to achieve better subgrade performance. Laboratory investigations commonly compare untreated soil with soil containing different percentages of stabilizing material and evaluate parameters such as Atterberg limits, maximum dry density, optimum moisture content, CBR, and strength. The results generally show that an optimum stabilizer content exists beyond which additional waste material may not provide further improvement and can sometimes reduce desirable properties. This emphasizes the importance of laboratory testing and proper proportion selection before field application.

Overall, the literature indicates that industrial-waste-based soil stabilization can improve weak subgrade performance while providing a beneficial use for industrial by-products. The improved CBR obtained after stabilization can be used as an input for flexible pavement design and may help achieve an appropriate pavement layer configuration. However, the suitability of a particular waste material must be established through laboratory testing, environmental assessment, and consideration of long-term performance. The present project therefore focuses on evaluating selected industrial waste for subgrade stabilization and using the improved soil properties in flexible pavement design, with the objective of developing a technically suitable, economical, and sustainable pavement system.

III. System Analysis

System analysis is an important stage in evaluating the use of industrial waste for stabilizing weak subgrade soil in flexible pavement construction. The project focuses on improving the strength and bearing capacity of soil using suitable industrial waste materials. Important parameters such as soil type, initial CBR, moisture content, plasticity characteristics, and stabilizer percentage are considered. Suitable industrial waste such as fly ash, steel slag, or other approved by-products is selected based on its engineering properties. The waste material is processed and mixed with the subgrade soil in different proportions. Laboratory tests are conducted to determine changes in compaction and strength characteristics. Parameters such as optimum moisture content, maximum dry density, Atterberg limits, and CBR are evaluated. The properties of untreated soil are compared with those of stabilized soil to determine the improvement achieved. The improved CBR value is used as an input for flexible pavement design. Suitable pavement layer thicknesses are then determined based on the improved subgrade condition. Different stabilization percentages can be compared

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to identify an appropriate and economical mixture. The analysis also considers the practical suitability of the stabilized soil for pavement construction. Overall, the system analysis provides a systematic approach for improving weak subgrade soil through industrial waste utilization.

Existing System

The conventional flexible pavement system generally depends on naturally available soil and traditional stabilization techniques for preparing a suitable subgrade. When the existing soil has low bearing capacity, it may be removed and replaced with better-quality soil or treated using conventional stabilizing materials. Cement, lime, and other commercially available materials can increase subgrade strength, but their use may increase construction cost and material consumption. Excavation and replacement of weak soil also require additional transportation, labor, and construction effort. At the same time, industries generate large quantities of waste materials that require proper storage and disposal. Many industrial by-products are not effectively utilized in pavement construction and may create environmental concerns when poorly managed. Conventional approaches may therefore miss opportunities to convert suitable waste materials into useful construction resources. Determining the correct stabilizer content through repeated laboratory testing can also require considerable time. Changes in subgrade properties may require modifications to the pavement design and repeated calculations. Traditional methods may provide limited evaluation of the long-term performance of stabilized soil. Therefore, a systematic approach is required to evaluate industrial waste as a soil-stabilizing material. Using laboratory testing and pavement design together can provide a more effective method for developing an improved subgrade.

Disadvantages of Existing System

- Relies heavily on conventional stabilization materials.
- Weak soil may require costly excavation and replacement.
- Higher transportation and construction effort for soil replacement.
- Limited utilization of industrial waste materials.
- Industrial waste can create disposal and storage problems.
- Conventional stabilizers may increase material costs.
- Repeated laboratory testing can be time-consuming.
- Difficult to compare several stabilization alternatives efficiently.
- Changes in soil properties may require redesign.
- Limited integration between soil stabilization and pavement design.
- Greater consumption of naturally available construction materials.
- Limited focus on sustainable waste utilization.

Proposed System

The proposed system focuses on improving weak subgrade soil using suitable industrial waste materials for flexible pavement construction. The process begins with identifying the type and engineering properties of the existing subgrade soil. A suitable industrial waste material is selected based on its physical, chemical, and engineering characteristics. The selected waste is collected, processed, and prepared

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for mixing with the soil. Different percentages of the industrial waste are added to the soil to evaluate their influence on subgrade properties. Laboratory tests are conducted on untreated and stabilized soil samples under controlled conditions. Important parameters such as Atterberg limits, compaction characteristics, and California Bearing Ratio are determined. The test results are compared to identify the percentage that provides satisfactory improvement in subgrade strength. The improved CBR value is then used for designing the flexible pavement structure. Suitable pavement layer thicknesses are determined based on the stabilized subgrade condition and applicable design requirements. Different stabilization alternatives can be evaluated to identify a technically suitable and economical solution. The proposed approach also provides a useful application for industrial waste that would otherwise require disposal. Overall, the system combines soil stabilization and pavement design to develop a stronger and more sustainable subgrade.

Advantages of Proposed System

- Utilizes suitable industrial waste in pavement construction.
- Improves the strength and bearing capacity of weak soil.
- Can increase the CBR of stabilized subgrade.
- Reduces the need for soil excavation and replacement.
- Promotes beneficial reuse of industrial by-products.
- Helps reduce industrial waste disposal requirements.
- Supports sustainable pavement construction.
- Allows comparison of different stabilizer percentages.
- Helps identify an optimum stabilization content.
- Provides laboratory-based evaluation of soil improvement.
- Supports flexible pavement design using improved subgrade properties.
- Can reduce material and construction requirements where technically appropriate.

IV. Methodology

The methodology begins with collecting representative weak subgrade soil and identifying its basic engineering properties. The initial soil characteristics such as moisture content, grain-size distribution, Atterberg limits, compaction properties, and CBR are determined. A suitable industrial waste material is then selected based on its availability and engineering characteristics. The waste material is processed appropriately before being mixed with the soil. Different percentages of the selected industrial waste are added to separate soil samples. The prepared samples are mixed uniformly and conditioned according to the selected testing procedure. Compaction tests are conducted to determine the maximum dry density and optimum moisture content of the stabilized soil. CBR tests and other relevant strength tests are then performed to evaluate the improvement in subgrade performance. The results are compared with the properties of untreated soil to determine the effect of stabilization. The stabilization percentage providing suitable strength and engineering performance is selected as the optimum content. The improved CBR value is then used as an input for the flexible pavement design. Suitable pavement layer thicknesses are determined using the applicable pavement design procedure. Finally, the stabilized subgrade and

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proposed pavement structure are evaluated for technical suitability, economy, and sustainable use of industrial waste.

System Architecture

The system architecture represents the complete workflow for flexible pavement design using industrial waste for subgrade soil stabilization. The process begins with Project Input Data, including road requirements, soil information, traffic conditions, and design period. The Subgrade Soil Evaluation Module determines the initial properties of the soil, including CBR, plasticity, and compaction characteristics. The Industrial Waste Selection Module identifies a suitable waste material based on its engineering properties and availability. The Waste Processing Module prepares the selected material through cleaning, drying, crushing, grinding, or sieving where required. The Soil Stabilization Module mixes different percentages of industrial waste with the weak subgrade soil. The stabilized samples are evaluated through the Laboratory Testing Module for compaction, CBR, and other relevant engineering properties. The Comparative Analysis Module compares untreated and stabilized soil results to determine the improvement achieved. The Optimum Content Module identifies a suitable stabilizer percentage based on the required performance criteria. The improved subgrade properties are transferred to the Flexible Pavement Design Module for determining suitable pavement layer thicknesses. The Performance Evaluation Module checks the proposed pavement structure under the expected design conditions. Finally, the Results and Reporting Module provides stabilization results, improved CBR, pavement thickness, comparisons, recommendations, and final design documentation. Overall, the architecture follows the workflow **Input Data → Soil Evaluation → Industrial Waste Selection → Waste Processing → Soil Stabilization → Laboratory Testing → Comparative Analysis → Optimum Content Selection → Flexible Pavement Design → Performance Evaluation → Final Results & Report**.

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V. Result and Output

VI. Conclusion

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The project successfully demonstrated the design of flexible pavement using industrial waste for subgrade soil stabilization. The study evaluated the use of suitable industrial waste materials to improve the engineering properties of weak subgrade soil. Laboratory investigations showed that stabilization can improve important properties such as compaction characteristics, California Bearing Ratio (CBR), and overall soil strength. Different percentages of industrial waste were considered to identify a suitable stabilizer content for achieving improved subgrade performance. The improved CBR value can be used in flexible pavement design to determine an appropriate pavement layer configuration. Stabilizing the subgrade can reduce excessive deformation and improve the load-bearing capacity of the pavement foundation. The approach also provides a beneficial use for industrial by-products that may otherwise require disposal. This can help reduce the consumption of conventional construction materials and support sustainable pavement development. The study demonstrates the importance of laboratory testing before selecting the optimum stabilizer content for field application. Overall, industrial-waste-based soil stabilization provides a promising and economical approach for improving weak subgrades and developing durable flexible pavements. Further studies can focus on long-term durability, environmental assessment, field trials, and the performance of different industrial waste materials under varying traffic and climatic conditions.

References

[1] Kumar, R. D., Prudhviraj, G., Vijay, K., Kumar, P. S., & Plugmann, P. (2024). Exploring COVID-19 through intensive investigation with supervised machine learning algorithm. In Handbook of Artificial Intelligence and Wearables (pp. 145-158). CRC Press.

[2] Swathi, B., Vijay, K., Sushanth Babu, M., & Dinesh Kumar, R. (2024, November). Machine Learning Techniques in Cloud Based Intrusion Detection. In The International Conference on Artificial Intelligence and Smart Environment (pp. 557-564). Cham: Springer Nature Switzerland.

[3] Sv satyakrishna, shirisha rangu ,bhargavi nalacheruve.(2024) Prospective investigation on colorectal cancer with SMOTE on machine learning Algorithm

[4] Dr.G.Vishnu Murthy, BhargaviNalacheruve 1Professor, Department of computer Science & engineering, Anurag University, TS, India. 2Student, Department of computer Science & engineering, Anurag University, TS, India.

[5] V. N. S. Manaswini, K. K, C. Nigam, S. S. Ali, R. Niranjana, and Suman, “Real-Time Object Detection in Drone Surveillance Using YOLOv5,” in Proc. 2025 3rd Int. Conf. IoT, Communication and Automation Technology (ICICAT), Gorakhpur, India, 2025, pp. 1–6, doi: 10.1109/ICICAT68430.2025.11414670.

[6] B. Soundarya, V. N. S. Manaswini, M. Ayyakrishnan, R. D. Kumar, “Contextual Analysis of Big Data Analytics in Intelligent Transportation Frameworks,” in Intersection of Artificial Intelligence, Data Science, and Cutting-Edge Technologies: From Concepts to Applications in Smart Environment, Lecture Notes in Networks and Systems, vol. 1353, Cham: Springer, 2025, doi: 10.1007/978-3-031-88304-0_79.

[7] R. D. Kumar, V. N. S.Manaswini, “Applications of blockchain in smart cities: detecting fake documents from land records using blockchain technology,” in Blockchain for Smart Cities, Elsevier, 2021, pp. 105–117, doi: 10.1016/B978-0-12-824446-3.00017-X.

[8] Tejavath Veeramma, Badarla Anil, Guguloth Ravinder, "An advanced movie recommender using collaborative filtering and sentiment analysis," International Research Journal of Modernization in Engineering Technology and Science, vol. 7, no. 7, July 2025, doi: 10.56726/IRJMETS81618.
[9] Ravi Kumar Banoth, Ramana Murthy B V, "Automatic crop recommendation system using LightGBM and decision tree machine learning models," Journal of Machine and Computing, vol. 5, no. 1, pp. 343, Jan. 2025, doi: 10.53759/7669/jmc202505026.
[10] Ravi Kumar Banoth, Dr. B.V. Ramana Murthy, "Smart agriculture through IoT and machine learning for analyzing carbon footprints," in Proc. Int. Conf. Computer Science and Communication Engineering (ICCSCE), Apr. 2025.
[11] Ravi Kumar Banoth, B. V. Ramana Murthy, "Soil image classification using transfer learning approach: MobileNetV2 with CNN," SN Computer Science, vol. 5, art. no. 199, 2024, doi: 10.1007/s42979-023-02500-x.