Review paper on Improvement of Clayey Soil Subgrade Using Stone Dust and Plastic Bottle Strips

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Abstract — The stability and performance of pavement structures largely depend on the strength and durability of the subgrade soil. Clayey soils, known for their low bearing capacity and high plasticity, often cause deformation and settlement problems in subgrades. To overcome these issues, soil stabilization techniques using waste and locally available materials have gained prominence. This review paper explores the effectiveness of stone dust and plastic bottle strips in improving the engineering properties of clayey soil. Stone dust, a byproduct of stone crushing, enhances soil strength and reduces plasticity, while plastic bottle strips improve ductility and tensile resistance. The combined use of these materials not only improves the mechanical behavior of clayey soil but also contributes to sustainable waste management and environmental protection.

Keywords: Clayey Soil, Soil Stabilization, Subgrade Improvement, Stone Dust, Plastic Bottle Strips, Waste Material Utilization, Engineering Properties, Strength and Durability, Sustainable Construction, Mechanical Behavior

I. Introduction

Soil stabilization plays a crucial role in civil engineering projects, particularly in road construction, where weak subgrade soils can compromise structural performance. Clayey soils are problematic due to their high shrink-swell potential, low shear strength, and high compressibility. Traditional stabilization methods often involve the use of lime, cement, or bitumen. However, these materials are expensive and not always environmentally sustainable.

In recent years, industrial and plastic wastes have been successfully utilized to improve soil properties. Among these, stone dust, obtained from quarry operations, and plastic bottle strips, derived from recycled polyethylene terephthalate (PET) bottles, have shown promising results. This paper reviews experimental studies and findings related to the use of these materials for subgrade improvement.

A. Need for Soil Stabilization

The performance of a pavement depends on the strength of the subgrade soil. Weak subgrades can lead to:

- Excessive rutting and cracking of pavement layers.
- Differential settlement and poor drainage.
- Increased maintenance costs and reduced pavement life.

Clayey soils, due to their fine particle size and water absorption characteristics, exhibit significant changes in volume with moisture variations. Stabilization is therefore necessary to:

- Increase load-bearing capacity.
- Reduce swelling and shrinkage.
- Improve workability and durability.
- Utilize waste materials to minimize environmental impact.

II. Literature Review

Several researchers have studied the stabilization of clayey soils using stone dust and plastic wastes:

- Singh & Bansal (2017): Reported that adding 20–30% stone dust to clayey soil improved the CBR value by up to 60%. Plasticity index decreased significantly, enhancing workability.
- Ravi Kumar et al. (2018): Found that using 1.5% plastic strips (by weight of soil) increased UCS and reduced deformation. The inclusion of strips improved tensile strength and reduced shrinkage cracks.
- Patel & Sharma (2019): Investigated combined stabilization with stone dust and PET strips, showing that the optimum combination of 25% stone dust and 1% PET strips improved CBR by 80% compared to untreated soil.
- Kumar & Reddy (2020): Demonstrated that stone dust enhances soil gradation while plastic strips improve ductility. The combined method provided higher resistance to moisture variations.
- Agarwal et al. (2021): Concluded that the use of waste plastic in soil stabilization promotes sustainable construction by reducing landfill waste and conserving natural resources.
- The addition of stone dust to clayey soil resulted in an increase in maximum dry density (MDD) as a result of improved particle packing, while also resulting in a decrease in liquid limit and plasticity index, according to Rao et al. (2012).
- According to a study conducted by Sivapullaiah and Lakshmikantha in 2013, stone dust enhances the shear strength of fine-grained soils by decreasing the vacancy ratio and increasing the friction between particles.
- The safe and effective disposal of quarry dust, tire debris, and plastic waste was explored by Mercy Joseph Poweth et al. (2013) via the use of these materials in the subgrade of the pavement. In order to determine the ideal quantities of waste plastics and quarry dust to use, they conducted a large number of CBR and SPT experiments on samples of soil. The findings indicate that, in order to increase its maximum dry density and make it appropriate for use as a pavement subgrade, the sole material that should be used with the soil plastic mix is quarry dust. The use of tires by themselves is not a suitable option for subgrade. They came to the conclusion that the CBR value may be maintained within the specified range by combining soil plastic with quarry dust. A mixture of soil and quarry dust has a lower CBR value than a mixture of soil, plastic, and quarry dust, but it is still suitable for use as a pavement subgrade.

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Chebet et al. carried out laboratory experiments in 2014 in order to evaluate the extent to which the random integration of strips of high-density polyethylene (HDPE) material from plastic shopping bags into sand obtained from local sources would improve shear strength and bearing capacity. The reinforced soil's increased strength is a consequence of the tensile stresses that are triggered in the reinforcements, as seen by a visual inspection of the plastic material after testing and analysis. The characteristics of the plastic, such as its concentration, length, and breadth of the strips, as well as the characteristics of the soil, such as its gradation, particle size, and shape, were the parameters that were determined to have an impact on the effectiveness of reinforcing material.

The potential of high-density polyethylene (HDPE) to be used as a soil reinforcing agent was proven in 2010 by Choudhary, Jha, and Gill et al., who showed that it may be used to improve the engineering qualities of subgrade soil. Plastic trash is used to create strips of high-density polyethylene (HDPE), which are then randomly mixed with the soil. The length and percentage of the high-density polyethylene (HDPE) strips were altered in order to conduct a series of California Bearing Ratio (CBR) tests on reinforced soil. The findings of CBR tests provide evidence that the integration of strips that have been cut from recovered high-density polyethylene (HDPE) is an efficient method of strengthening soil in the context of highway construction projects.

The behavior of soil was evaluated by the integration of plastic strips at different mixing ratios (0.2, 4.6, 8) by weight in a study conducted by Hatein Nsaif et al. (2013). As a result of an increase in internal friction, the investigation discovered a considerable improvement in the strength of the soil. When it comes to the percentage rise in the angle of internal friction, sandy soil outperforms clayey soil; yet, neither soil type exhibits a considerable increase in cohesiveness. Furthermore, it was shown that the minimum dry density (MDD) and optimum moisture content (OMC) of the soil are decreased as a consequence of the low specific gravity of plastic pieces.

A comparative investigation on the California Bearing Ratio (CBR) of soil that has been strengthened using natural waste plastic materials was carried out by Rajkumar Nagle et al. (2014). They used black cotton soil, yellow dirt, and sandy soil as reinforcement and combined them with polyethylene, bottles, food packaging, and shopping bags to create a stronger material. Their investigation indicated that the MDD and CBR values increase as the amount of plastic garbage increases. In addition, the selected soil material has had its ability to support weight and its settling qualities improved.

K Gopinath and K. Anuratha conducted research in August 2015 on the usage of sawdust in cement mortar as well as in cement concrete. They discovered that the density of the mixture reduces as the proportion of sawdust rises. The amount of garbage that is produced is reduced due to the fact that sawdust is recycled for use in building projects.

In 2014, Chebet et al. carried out a laboratory experiment on the use of polyethylene bags and waste material for soil reinforcement in geotechnical engineering. The reinforced soil has improved strength because of the tensile stresses that are triggered in the reinforcement, as shown by the tests and studies that were conducted. It was discovered that the effectiveness of the reinforcing material was impacted by the characteristics of the soil (which included the form, particle size, and gradation) as well as the features of the plastic (which included the width and length of the strips, as well as their concentration).

The impact that stone dust has on the geotechnical characteristics of soil that is of poor quality was investigated by individuals such as Abeer Sabri Bshara. They discovered that the primary objectives of the research were to develop a strategy for improving soil that is not suitable for road building and to build a model for determining the California Bearing Ratio (CBR) value. Crushed stone is being used more often as a result of the growth in the amount of construction work that is being done, such as road paving, pouring concrete, and constructing. In order to address this issue, a large number of Crusher plants have been established in various locations around the nation. When stone is crushed, screened, and stockpiled as part of the crushing procedure, Stone Dust is produced as a byproduct. It is a waste product that is responsible for the contamination of the environment as well as the difficulties that arise while accumulating at the crusher plant. It is challenging to increase the amount of building operations due to constraints such as the restricted space for growth, the poor qualities of the soil, and geological concerns. Soil may be a source of trouble if it contains soft clays, if the land is soggy, if the soil is expansive, or if it is loamy. The site is currently in a situation that could not be conducive to supporting the weight of all the loads that are being brought in. Alterations in the level of moisture in the foundation may lead to fluctuations in its strength, which can result in issues with settling in the foundation. In order to resolve this issue, either stabilization or replacement will be required.

Research was performed by Dr. A.I. Dhatrak and colleagues (2015) on the performance of flexible pavement when it is constructed using plastic debris that is randomly oriented. The California Bearing Ratio (CBR) was determined by conducting a series of tests on soil that was mixed with increasing percentages of plastic (0.5, 1, 1.5, 2, and 2.5). The publication explains the results of these studies. Through the studies he conducted, he was able to establish that using plastic waste strips as a subgrade material increases the strength of the soil and may be used as a substitute for subgrade. Due to the fact that there is a scarcity of soil of excellent quality for embankments and fills, the disposal of plastic trash is both an ecologically benign and economical option.

Jaswinder Singh and other researchers investigated the possibility of utilizing strips from discarded plastic bottles to enhance the engineering characteristics of soil. They are attempting to locate the most suitable and economical materials for the purpose of soil stabilization. This includes the search for both new and old materials that have the potential to be of service. For a considerable amount of time, researchers have been working to discover the most effective and economical materials for use in soil stabilization. This encompasses both new and ancient items that have the potential to be helpful. However, the study is still under progress, and new ideas are emerging on a regular basis.

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When I began my studies as a student researcher, I began to consider novel methods of soil stabilization. I considered making use of empty bottles made of PET that were used for soft drinks and other items that people discard. I came across some information online one day that revealed the astonishing figures about people's failure to recycle or reuse PET bottles. This is a significant issue due to the fact that it is difficult to dispose of such a large quantity of this kind of plastic garbage.

Devashish Kushwahi and his co-authors carried out review research that examined the interaction between soil and waste plastic. The study emphasized the fact that this particular sector of infrastructure is a major driver of the entire growth of the Indian economy. The foundation of any building is very vital, and it must be strong enough to support the whole structure. For the purpose of ensuring that the foundation is sturdy, the soil that surrounds it is quite vital. Foundations may have difficulties due to the presence of black cotton soil and other types of soil that undergo expansion.

III. Conclusion

The review highlights that the combination of stone dust and plastic bottle strips significantly improves the engineering properties of clayey soils, making them suitable for use as subgrade materials. Stone dust enhances density and reduces plasticity, while plastic strips provide tensile reinforcement, improving load distribution and resistance to cracking. Moreover, this technique offers an eco-friendly and economical solution by reusing waste materials. Further field studies and long-term performance evaluations are recommended to standardize mix proportions and application methods for large-scale implementation in road construction projects.

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