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STUDIES ON ALTERNATIVE MATERIALS FOR THE IMPROVEMENT OF SUBGRADE AND SUBBASE

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Abstract : *This study looks into the viability of using alternative materials, such as Quarry Dust (QD), Saw Dust, Copper Slag (CS), and Fly Ash (FA), to improve the subgrade and subbase in road construction. The deterioration of conventional subgrade and subbase materials, which frequently result in road failures and costly maintenance, necessitates the investigation of sustainable and cost-effective alternatives.*

The study evaluates the engineering attributes and performance characteristics of various alternative materials using laboratory experiments, field evaluations, and numerical modelling. The results show that QD can greatly improve subgrade and subbase strength, whereas Saw Dust is a feasible eco-friendly solution for lightweight fill applications. Furthermore, the integration of CS shows promise in improving mechanical qualities and durability while lowering environmental effects.FA from thermal power plants has the ability to efficiently maintain subgrades and reduce excessive settlement.

Keywords:*Subgrade improvement, Sub base materials, Quarry Dust (QD), Saw Dust, Copper Slag (CS), Fly Ash (FA), Engineering properties, Sustainable construction, Alternative materials, Road infrastructure, Eco-friendly fill materials, Mechanical properties, Durability, Environmental impact, Settlement reduction****.***

I. INTRODUCTION

Expansive soil, often known as soil having a high potential for volumetric expansion or contraction in response to changing subsurface moisture levels, is a severe challenge in geotechnical engineering. The significant swell and shrinkage properties of such soils can cause structural challenges, especially when foundations and pavements are built on them. Pavements are frequently placed atop expansive soils, subjecting them to damage from repeated vehicle loads. Such pavements are prone to elevate as a consequence of moisture penetration and subsequent swelling during periods of soil expansion. Several strategies have been developed to address these concerns and improve the qualities of expansive soils. Surcharging, soil stability, soil replacement, moisture control, and prewetting are examples of these procedures.Soil stabilization has evolved as a popular method in recent years, including a variety of elements such as Quarry Dust (QD), Saw Dust, Copper Slag (CS), and Fly Ash (FA). This technique improves the soil's geotechnical qualities, making it more stable and capable of holding loads with less settling. As a result, the performance of pavements built on such treated soils is significantly improved, even when faced with challenging circumstances such as moisture level changes and applied stress.
Flexible pavements are precisely developed to handle traffic loads while providing motorists with a smooth and comfortable riding surface. Various criteria must be met during the development, building, and upkeep stages to ensure longevity and function. Traffic Load Design, Subgrade Preparation, Pavement Layering, Material Selection, Layer Thickness, Drainage, Quality Control, Surface Smoothness, Ride Quality, Environmental Sustainability, Safety Measures, Traffic Management, and Maintenance and Rehabilitation are examples of such issues. Routine inspections and a dedication to

environmental sustainability highlight the entire approach to resolving the issues of improving soils in the wider context of flexible pavement design and construction.

Objective:

When addressing the impact of quarry dust, copper slag, or significant incorporation of fly ash into expansive soils, the goals should be to improve soil characteristics, mitigate negative effects, and meet specific targets for structural integrity and environmental sustainability. Each of the following primary elements has been included in the objectives for the influence of quarry dust, copper slag, and high volumes of fly ash in expansive soils:

1. Soil Stabilization: The primary purpose is to stabilize the expanding soil, making it more resilient and capable of carrying load.
2. Swelling and Shrinkage Reduction: One of the goals is to reduce the soil's proclivity to experience considerable volumetric expansion and contraction in response to changing moisture levels.
3. Strengthening: The goal is to strengthen the mechanical strength of the soil so that it can withstand applied loads with greater stability.
4. Improved Permeability: The goal is to improve soil permeability, allowing for more efficient water drainage and moisture control.
5. Environmental Impact Reduction: The goals are to minimize the environmental repercussions of using these

materials in soil stabilization.
6. Resource Efficiency: The goal is to maximize resource consumption while minimizing waste output.
7. Cost-cutting measures: The goals are to reduce construction and maintenance costs while keeping performance
criteria.
8. Long-Term Durability: Goals emphasise achieving long-term structural integrity and functionality.
9. Environmental Compliance: The goal is to ensure that environmental legislation and standards are followed.

The goal of optimal mix design is to create well-balanced soil-material mixes that maximize performance and sustainability.

10.Testing and Evaluation: Comprehensive assessment and analysis are crucial to validate the effectiveness of the chosen materials and techniques.
11. Sustainability Objectives: The overall goal is to integrate the project with sustainability principles, which include economic, environmental, and social elements.
12. Risk Mitigation: Goals include identifying and mitigating potential risks connected with material use.
13. Local Material Sourcing: Promoting the use of locally available materials to lessen the environmental impacts of transportation.
14. Public and Stakeholder Engagement: Encouraging active participation and awareness of the project's goals and results among members of the community and stakeholders.
15. Monitoring and Management: The objectives include continuous monitoring and adaptive management of the stabilizing process and its consequences.
16. Knowledge Sharing: The goal is to publish discoveries and best practices to benefit the engineering and environmental communities as a whole.

Venkateshwarlu and colleagues (2015) conducted a thorough study to analyze the impact of introducing quarry dust in various proportions (0%, 5%, 10%, and 15%) within expansive soil. Their findings revealed a significant increase in bulk soil strength, particularly when 10% quarry dust was added.
Mohan Chand and his colleagues (2017) focused their efforts in a separate study on improving the performance of black cotton soil by incorporating copper slag and steel slag in varied concentrations.
Samidurai et al. (2017) conducted a study to systematically examine the impact of fly ash on a varied range of soils at ratios ranging from 5% to 30%.

II. MATERIALS USED

Copper Slag:

Copper slag is a byproduct generated during the smelting of copper ore. The copper slag used in this investigation was obtained from Waltair in Visakhapatnam. Table 2.1 contains detailed information on the physical properties of copper slag.

Properties	**Test Values**
Particle Size	Angular
Surface Texture	Granular
Colour	Blackish grey
Unit weight	2800 – 3800 kg/m^3
Water Absorption	0.13%
Crushing Value	10.0 – 26.4%
Specific Gravity	3.395

Table 2.1 Physical Properties of Copper Slag

Quarry Dust:

Quarry dust is produced as a byproduct of the stone crushing process. Table 2.2 provides complete information on the physical properties of quarry dust in this context.

Properties	**Test Values**
Bulk Specific Gravity	2.68
Apparent Specific Gravity	2.72

Table2.2 Physical Properties of Quarry Dust

Fly Ash:

Fly ash, which is often viewed as a byproduct or waste material, has intrinsic cementitious properties and is widely used in soil stabilization. Despite its potential environmental disadvantages, fly ash is used in cement products to reduce its environmental impact. Table 2.3 contains detailed information on the physical properties of fly ash.

Properties	**Test Values**
Specific Gravity	2.21
Fineness of Flyash	4500 cm^2/kg

Table 2.3 Physical Properties of Flyash

Crushed Stone Aggregates:

Crushed stone aggregates from Maddilapalem and Tagarapuvalasa in Visakhapatnam are an essential component in the building of bituminous pavements and are used in a variety of construction projects. Table 2.4 provides complete information on the physical parameters of these crushed stone aggregates.

Properties	**Test Values**
Bulk Specific Gravity	2.70
Apparent Specific Gravity	2.72
Impact Value	18%
Flakiness and Elongation (Combined) Index	28%
Water Absorption	0.5%

Table 2.4 Physical Properties of Stone Crushed Aggregates

Cement:

The cement used in this study was obtained from a large supplier in Yandada, Visakhapatnam. Cement is a key construction material that plays a significant role in civil engineering applications. Table 2.5 contains detailed information about the physical properties of cement.

Properties	**Test Values**
Colour	Dark Gray
Specific Gravity	3.1
Specific area cm^2/gm	3250

Table 2.5 Physical Properties of Cement

III. ResultsAndDiscussions

Within the research area, which consists of six separate places, it is noticed that two of these areas are classified as CL, two as CI, and the remaining two as CH.

Figure 3.1 demonstrates the effect of different mix proportions on low-compressible inorganic clay with low plasticity. Surprisingly, these patterns persist in intermediate compressible inorganic soil (CI) and highly compressible inorganic soil (HCI) with moderate plasticity, as seen in Figures 3.2 and 3.3, respectively.

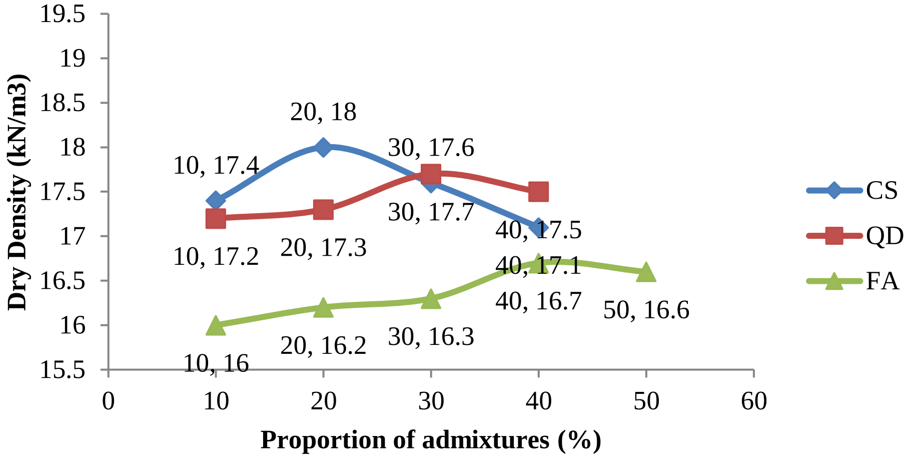


Figure 3.1 MDD Vs various proportions of CS, QD and FA for CL group of clayey soil

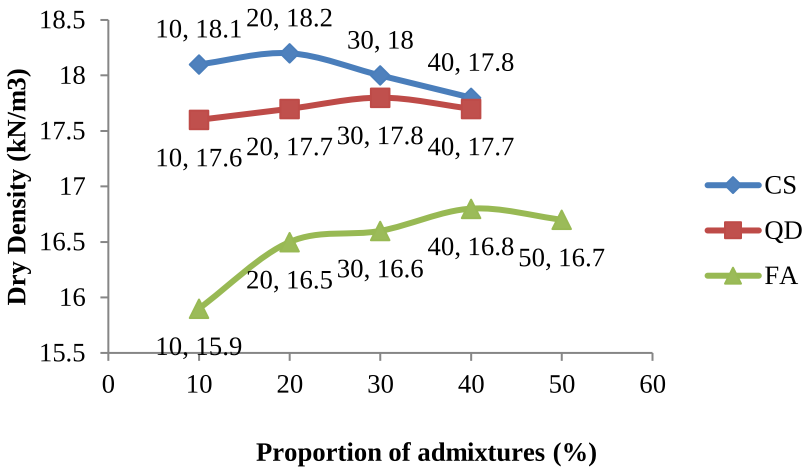


Figure 3.2 MDD Vs various proportions of CS, QD and FA for CI group of clayey soil

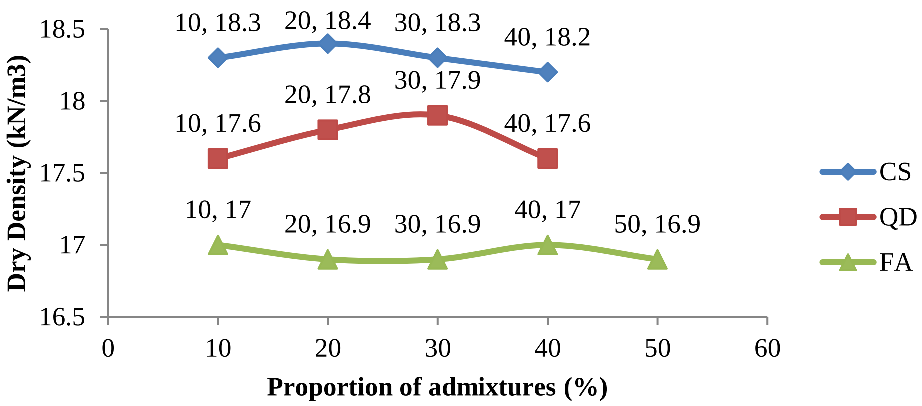


Figure 3.3 MDD Vs various proportions of CS, QD and FA for CH group of clayey soil

Figures 3.4–3.6 show the variations in optimal moisture content (OMC) caused by changing ratios of CS (Copper Slag), QD (Quarry Dust), and FA (Fly Ash) put into clay soils classified as CL, CI, and CH.

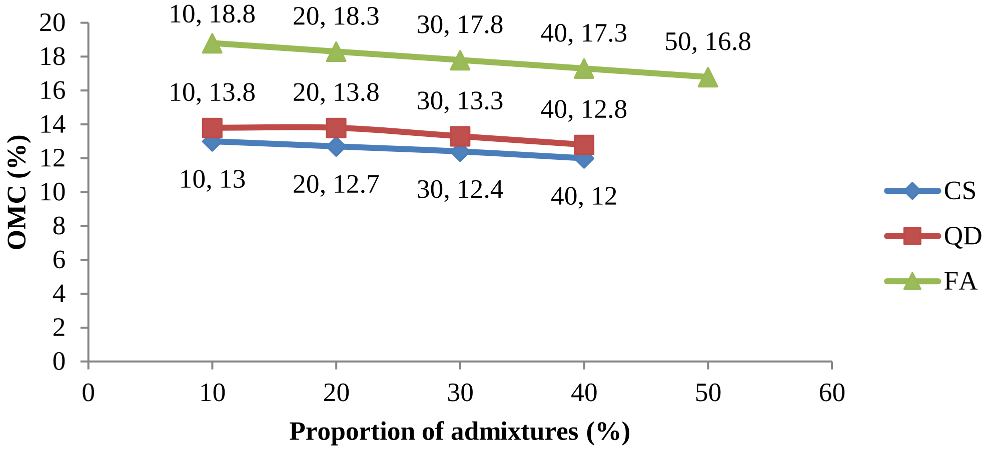


Figure 3.4 OMC Vs various proportions of CS, QD and FA for CL group clayey soil

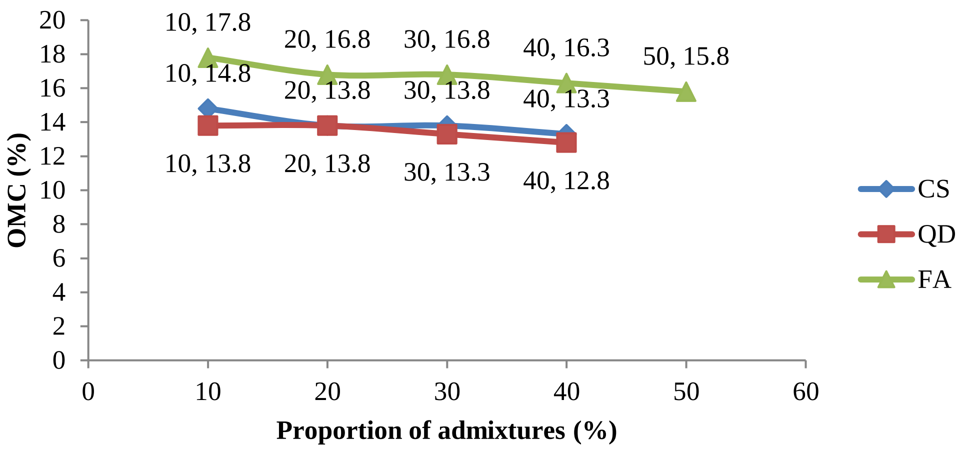


Figure 3.5 OMC Vs various proportions of CS, QD and FA for CI group clayey soil

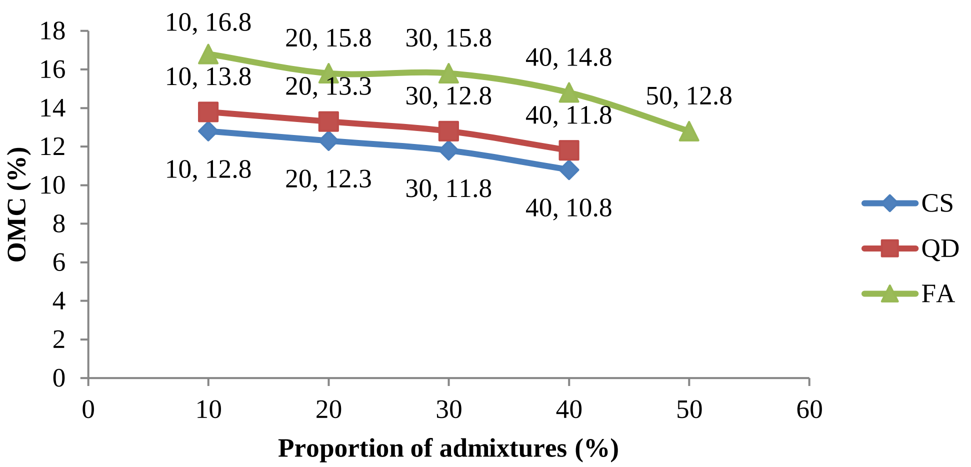


Figure 3.6 OMC Vs various proportions of CS, QD and FA for CH group clayey soil

Tables 3.7, 3.8, and 3.9 demonstrate the strength results of the California Bearing Ratio under damp conditions for the CL, CI, and CH groups, with deep penetrations of 2.5 mm and 5 mm.

% of Clayey Soil (CL - Group)	**% of Admixtures**	**CBR %**	
		2.5 mm Penetration	**5 mm Penetration**
Copper Slag			
90	10	6	5
80	20	7	6
70	30	6	5
60	40	4	4
Quarry Dust			
90	10	4	3
80	20	5	4
70	30	6	6
60	40	4	4
Flyash			
90	10	3	2
80	20	3	3
70	30	4	4
60	40	5	4
50	50	4	3

Table 3.7 Soaked CBR 2.5mm and 5mm penetration value for CL group of clayey soil with various proportion of admixtures

% of Clayey Soil (CI - Group)	**% of Admixtures**	**CBR %**	
		2.5 mm Penetration	**5 mm Penetration**
Copper Slag			
90	10	8	7
80	20	10	9
70	30	9	8
60	40	8	7
Quarry Dust			
90	10	7	5
80	20	8	6
70	30	9	7

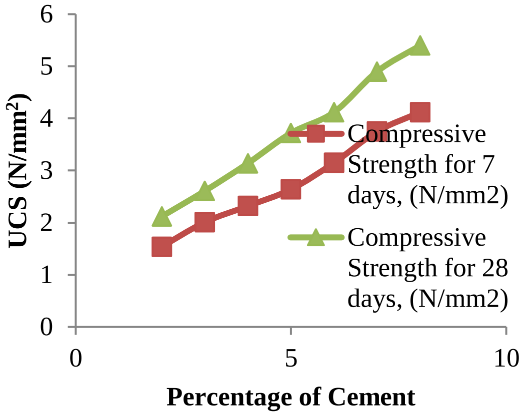
60	40	8	5
Flyash			
90	10	5	3
80	20	5	3
70	30	6	4
60	40	7	5

Table 3.8 Soaked CBR 2.5 mm and 5 mm penetration value for CI group of clayey soil with various proportion of admixtures

% of Clayey Soil (CH - Group)	**% of Admixtures**	**CBR %**	
		2.5 mm Penetration	**5 mm Penetration**
Copper Slag			
90	10	10	8
80	20	12	10
70	30	11	9
60	40	11	8
Quarry Dust			
90	10	7	5
80	20	8	6
70	30	10	8
60	40	8	6
Flyash			
90	10	4	3
80	20	4	3
70	30	5	4
60	40	7	5

Table 3.9 Soaked CBR 2.5 mm and 5 mm penetration value for CH group of clayey soil with various proportion of admixtures

As illustrated in Figure 3.10, an intermediate gradation range was purposefully chosen in the context of granular sub-base materials to optimize the consequences. The addition of cement to cement-treated granular sub-base materials significantly improves their compressive strength, with the optimum levels attained with the addition of 4% cement. The highest compressive strength is 3.1 N/mm2 after 7 days, and this value increases to 4.2 N/mm2 .



Percentage of Cement Vs UCS for CTGSB

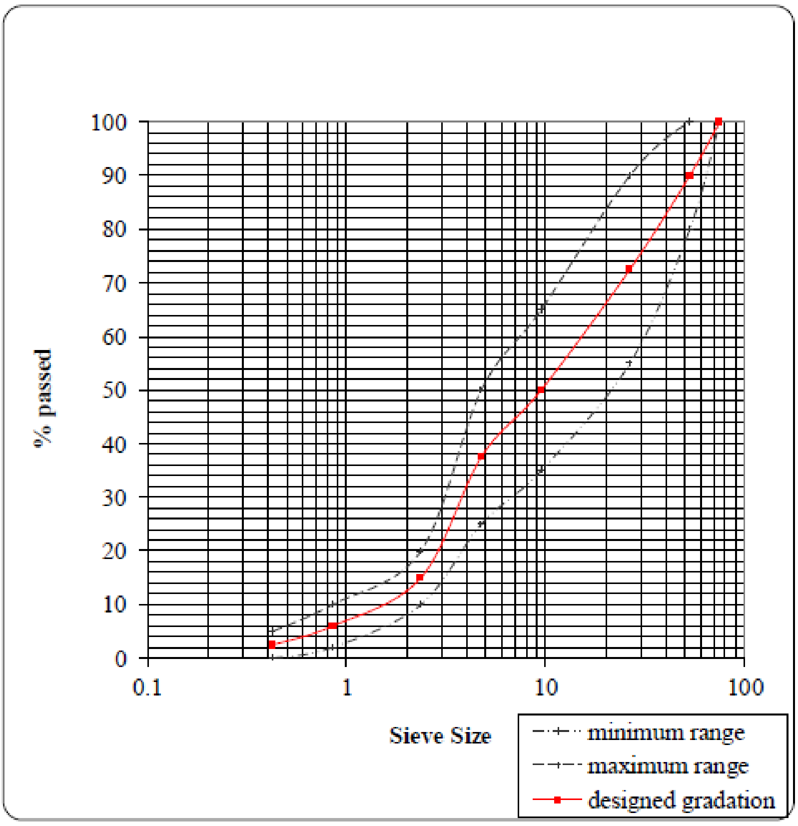


Figure 3.10 Gradation chart for Granular Sub-base

Cement Content in Percentage (%)	Compressive Strength for 7 days, (N/mm^2)	Compressive Strength for 28 days, (N/mm^2)
2	1.54	2.12
2.5	2.01	2.61
3	2.32	3.14
3.5	2.64	3.72
4	3.15	4.12
4.5	3.75	4.90
5.0	4.12	5.40

Table 3.11 Unconfined Compressive Strength

IV. Conclusion

This research project investigated soil parameters, soil improvement techniques, and the applicability of various materials for infrastructure development, namely flexible pavement construction. The major goal of this study was to evaluate inorganic clay soils from the CL, CI, and CH groups at six different locations in Visakhapatnam, Andhra Pradesh, India. The research was conducted in two stages, each of which provided vital insights into the optimization of subgrade and granular sub-base materials for resilient infrastructure.

The first phase of the research included key activities that built the groundwork for succeeding phases. This phase began with a thorough assessment of the virgin soils, which included suggestive qualities, physical properties, and strength properties, notably for soils from the CL, CI, and CH groups. Standard Proctor compaction tests were performed on these soils, both in their natural state and when mixed with varied ratios of copper slag (CS) and quarry dust (QD).

Furthermore, the optimum moisture content (OMC) and matching maximum dry density (MDD) for each soil-mixture combination were determined for all three soil groups using fly ash (FA). Wet California Bearing Ratio (CBR) tests were performed to evaluate the load-bearing capacity of the soil-mix combinations.
The study determined the most effective soil-mix combinations for each soil type, paving the way for Phase II experimentation. This phase aims to improve subgrade performance by incorporating 2% to 4% cement by weight into the amended soils, changing them into a standard graded granular sub-base. The goal was to obtain the specified minimum unconfined compressive strength while maximizing the sub-base material's maximum dry density, ensuring its appropriateness for infrastructure building.

Several major discoveries emerged from the study of the experimental data. Copper slag (CS) added at an 80:20 ratio consistently produced the highest maximum dry density (MDD) for highly compressible clay soil (CH). In the CL, CI, and CH soil groups, a 70:30 ratio of quarry dust (QD) was critical for obtaining MDD. Incorporating 60:40 fly ash (FA) into these soil groups consistently resulted in increased MDD values.

Furthermore, the study found that adding fly ash (FA) in a 60:40 ratio raised the optimal moisture content

(OMC) for CL, CI, and CH soil groups. Unconfined compressive strength (UCS) values were also much greater for all soil categories, with an 80:20 CS ratio, with CH soil consistently demonstrating the highest UCS values. The maximum California Bearing Ratio (CBR) values were obtained under wet conditions with an 80:20 CS ratio for all soil groups, and the CH group consistently demonstrated the highest CBR values.

These findings highlight the importance of material composition and proportion in improving soil qualities for building and pavement design. The study found that copper slag, especially when mixed in an 80:20 ratio, is the best material for compaction in all types of clay soils (CL, CI, and CH). Quarry dust was also effective, especially when mixed with highly compressible clay soil (CH).The research advises incorporating 4% cement into the granular sub-base material over the compacted subgrade to satisfy the specified minimum compressive strength of 4.5 MPa at a maximum dry density of 2.39 g/cm3.

Furthermore, when mixed with conventional aggregates, copper slag (CS), fly ash (FA), and waste shredded plastic (WSP), the dense bituminous macadam layer reaches peak performance at a mix ratio of 20% to 30%. When the CS content is increased to 40%, it falls short of meeting the criterion.

Finally, this study has contributed significantly to understanding and tackling the issues faced by inorganic clay soils in the Visakhapatnam region. The study provides important insights into the selection of optimal soil-mix combinations and the use of appropriate materials, such as copper slag, quarry dust, fly ash, and cement, to improve soil properties and ensure the construction of long-lasting and robust infrastructure, particularly in flexible pavement projects. These findings provide engineering and construction experts operating in similar geological and environmental situations with useful advice.

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