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Mechanical Stabilization of Weak Highway Subgrade Using a 70:30 Sand–Gravel Blend: A Case Study of NH-716 Package-I

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Abstract

The subgrade supports the pavement structure and distributes traffic-induced stresses into the underlying ground. Weak, highly plastic soils may exhibit low shear strength, high compressibility, moisture sensitivity, rutting, differential settlement, and premature pavement deterioration. Mechanical stabilization improves such soils by modifying gradation and particle interaction without chemical reactions. NH-716 connects Chennai and Tirupati. Package-I extends approximately 43.95 km from Tiruvallur to the Tamil Nadu–Andhra Pradesh border and includes a four-lane access-controlled highway with paved shoulders. The investigated soil had a four-day soaked California Bearing Ratio of 1.8% and unconfined compressive strength of 75 kPa, indicating inadequate support for direct use as a pavement foundation. This study investigates a fixed 70:30 sand–gravel blend at different dosages to characterize the soil, evaluate compaction, determine unsoaked and soaked California Bearing Ratio, assess unconfined compressive strength with curing period, and identify a practical dosage for field evaluation.

Keywords—Subgrade stabilization, sand-gravel blend, California Bearing Ratio, unconfined compressive strength, highway engineering.

Introduction

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Materials and Methodology

Natural Subgrade Soil

Representative soil was collected from NH-716 Package-I in Tiruvallur District, air-dried, pulverized, and prepared for testing. It was classified as high-plasticity clay. Its properties are given in Table I.

TABLE I
PROPERTIES OF NATURAL SUBGRADE SOIL

Parameter	Value
Liquid limit (%)	54
Plastic limit (%)	24
Plasticity index (%)	30

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Unsoaked California Bearing Ratio (%)	4.5
Four-day soaked California Bearing Ratio (%)	1.8
Unconfined compressive strength (kPa)	75

Granular Materials and Mix Proportions

The stabilization material contained 70% sand and 30% gravel by weight. Sand specific gravity and fineness modulus were 2.65 and 2.8, respectively. Gravel specific gravity, aggregate crushing value, and aggregate impact value were 2.72, 22%, and 18%, respectively. The blend was added at 10%, 20%, 30%, 40%, and 50% by dry weight of soil.

Experimental Program

The program included natural-soil characterization, Standard Proctor compaction, unsoaked and four-day soaked California Bearing Ratio testing, and unconfined compressive strength testing at 7, 14, and 28 days. Tests followed IS 2720 Part 7, Part 16, and Part 10, respectively. Materials were dry-mixed homogeneously, water was added, and specimens were compacted before testing.

Results and Discussion

Compaction Characteristics

Maximum dry density increased progressively with granular content, whereas optimum moisture content decreased. Maximum dry density rose from 15.8 to 19.5 kN/m³ and optimum moisture content fell from 22.0% to 15.0%. Improved packing and replacement of part of the plastic fraction explain this trend.

TABLE II
COMPACTION CHARACTERISTICS

Granular content (%)	OMC (%)	MDD (kN/m³)
0	22.0	15.8
10	20.5	16.5
20	19.0	17.2
30	17.5	18.0
40	16.0	18.8
50	15.0	19.5

California Bearing Ratio

Soaked California Bearing Ratio increased from 1.8% for untreated soil to 24.0% at 50% granular content. The 20% mixture reached 8.0%, the minimum tested dosage satisfying the adopted criterion, while the 30% mixture reached 12.5% and provided a greater strength margin.

TABLE III
CALIFORNIA BEARING RATIO RESULTS

Granular content (%)	Unsoaked CBR (%)	Four-day soaked CBR (%)
0	4.5	1.8
10	8.2	4.5
20	13.5	8.0
30	19.0	12.5
40	25.0	18.0
50	32.0	24.0

Unconfined Compressive Strength

Unconfined compressive strength increased with granular content and curing period. At 28 days, strength rose from 75 kPa for untreated soil to 180 kPa at 20%, 270 kPa at 30%, and 350 kPa at 40%. The improvement is attributed to denser granular contact, frictional resistance, and mechanical interlocking.

TABLE IV
UNCONFINED COMPRESSIVE STRENGTH

Granular content (%)	7-day UCS (kPa)	14-day UCS (kPa)	28-day UCS (kPa)
0	75	75	75
20	150	165	180
30	220	245	270
40	290	320	350

Practical Dosage

The 20% dosage is the minimum tested content meeting the adopted soaked California Bearing Ratio criterion. The 30% dosage is recommended for field evaluation because it achieves 12.5% soaked California Bearing Ratio and 270 kPa 28-day unconfined compressive strength while limiting granular-material consumption compared with higher dosages.

Mechanism of Improvement

The observed improvement is primarily mechanical. Angular gravel particles increase interlocking and improve resistance to deformation. Sand and gravel provide frictional contacts that are stronger than those available in the predominantly cohesive natural soil. Sand also occupies intermediate voids between larger gravel particles and the surrounding soil matrix, producing improved packing and higher maximum dry density.

The addition of non-plastic granular material reduces the relative proportion of the highly plastic soil fraction. This dilution lowers water demand, reduces the influence of plastic fines, and supports compaction at lower optimum moisture content. Because no cementitious or pozzolanic stabilizer was added, the measured strength increase should not be interpreted as chemical curing; it is associated with particle rearrangement, contact improvement, friction, and mechanical interlock.

Practical Implications and Limitations

The results indicate that locally available sand and gravel may provide a technically feasible alternative to complete excavation and replacement for selected weak subgrade zones. The 20% blend meets the adopted soaked California Bearing Ratio criterion in the laboratory, while the 30% blend provides a useful strength margin and remains lower in granular consumption than the 40% and 50% blends. Final selection should consider pavement design requirements, borrow-material availability, haul distance, drainage, construction quality control, and project economics.

The study is laboratory-based and does not fully reproduce field-scale variability, traffic loading, or long-term environmental exposure. Resilient modulus, repeated-load behavior, permeability, pore-water-pressure response, wetting–drying durability, and life-cycle cost were not directly evaluated. Only one sand-to-gravel ratio was investigated. Field trials and project-specific performance monitoring are therefore required before full-scale implementation.

Conclusions

The natural subgrade was high-plasticity clay with liquid limit 54%, plasticity index 30%, soaked California Bearing Ratio 1.8%, and unconfined compressive strength 75 kPa. The 70:30 sand–gravel blend improved compaction and strength. Maximum dry density increased to 19.5 kN/m^3 and optimum moisture content decreased to 15.0% at 50% addition. Soaked California Bearing Ratio increased to 24.0% at 50% addition. The 20% dosage was the minimum tested content satisfying the adopted 8% criterion, while 30% provided a greater margin with 12.5% soaked California Bearing Ratio and 270 kPa 28-day unconfined compressive strength. Field trials, repeated-load testing, resilient-modulus measurement, durability assessment, and economic evaluation are required before full-scale implementation.

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