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Geotechnical and Structural Material Analysis for a Four-Storey Residential Development in Annex, Eldoret

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***Abstract:** This study evaluates the geotechnical properties of reddish gravel material intended for a foundation base and the compressive strength of concrete used for ground floor slabs at the Annex Site. A comprehensive series of laboratory tests were conducted, including Particle Size Distribution (Dry Sieve), Atterberg Limits (BS 1377 Part 2), Moisture-Density Relations (AASHTO T99), California Bearing Ratio (AASHTO T193), and Concrete Compressive Strength (BS 1881). The subgrade soils exhibited Liquid Limits ranging from 43% to 57% and Plasticity Indices between 8% and 13%, indicating low to medium plasticity. Compaction tests revealed Maximum Dry Densities (MDD) ranging from 1493 kg/m³ to 1654 kg/m³, with Optimum Moisture Contents (OMC) between 17.6% and 24.2%. Soaked CBR values at 95% MDD varied across the site from 16% to 28%, demonstrating adequate to good bearing capacity, though noticeable spatial variability exists. Furthermore, Class 20/20 concrete specimens yielded an average 28-day compressive strength of 21.2 N/mm², successfully meeting structural design requirements. Overall, the materials are suitable for their intended construction applications, provided site-specific moisture variations are properly managed.*

I. INTRODUCTION

A. *Context & Background*

The integrity of any civil engineering structure relies heavily on the quality and mechanical properties of its foundational materials. Geotechnical site characterization involves assessing the physical properties of soils to determine their suitability as a foundation base or subgrade. Key parameters include particle size distribution, plasticity, compaction characteristics, and bearing capacity (CBR). Additionally, evaluating the compressive strength of structural concrete is vital to ensure it can safely support anticipated loads over its design lifespan.

B. *Rationale*

The construction project at the Annex Site utilizes a reddish gravel material as the primary foundation base and involves the casting of concrete ground floor slabs. Because soil properties can vary significantly within a single site—especially in areas identified as "water-logged"—it is crucial to perform rigorous laboratory testing. This ensures that the materials conform to standard engineering specifications and that the structural design assumptions are sound.

II. OBJECTIVES & HYPOTHESIS

The primary objective of this study is to characterize the engineering properties of the reddish gravel foundation base material sampled from four distinct site locations (Center Water Logged, Lower Left Water Logged, Upper Left, and Upper Right) and to verify the compressive strength of the concrete used for the ground floor slab.

It is hypothesized that the reddish gravel will exhibit adequate bearing capacity (CBR > 15%) for a foundation base and that the concrete will achieve its targeted 28-day compressive strength of 20 N/mm².

III. MATERIALS AND METHODS (EXPERIMENTAL PROCEDURE)

A. *Detailed Protocol:*

Testing was conducted in November 2025 at the University of Eldoret laboratories.

1) Particle Size Distribution: Conducted using the dry sieve method to determine the grading curve of the soil and aggregate samples.
2) Atterberg Limits & Linear Shrinkage: Executed per BS 1377 Part 2 (Sections 4, 5 & 6) to determine Liquid Limit (LL), Plastic Limit (PL), and Plasticity Index (PI) using standard Casagrande apparatus.

3) Moisture-Density Relations (Compaction): Performed according to AASHTO T99 using a 2.5 kg rammer and a 305 mm drop to identify the Maximum Dry Density (MDD) and Optimum Moisture Content (OMC).
4) California Bearing Ratio (CBR): Conducted in accordance with AASHTO T193. Samples were compacted at 65, 30, and 10 blows per layer (5 layers) with a 4.9 kg surcharge and subjected to a 4-day soak before penetration testing to assess swelling and bearing capacity.
5) Concrete Compressive Strength: Concrete cubes (Class 20/20, OPC 32.5N cement, 120 mm average slump) were cast and cured. Crushing was performed on days 7, 14, and 28 per BS 1881 (Parts 102, 108 & 116).

B. *Materials & Equipment*

1) Samples: Reddish gravel material (4 sampling pits) and fine/coarse aggregates for concrete.
2) Equipment: Standard sieves (0.075mm to 25mm), Casagrande liquid limit device, 2.5 kg compaction rammer, CBR loading press and penetration dial gauges, and a concrete compressive testing machine (22500 mm² crushing face area).

C. *Controls & Deviations*

All tests strictly adhered to standard AASHTO and BS guidelines. Samples were thoroughly air-dried where required by protocol prior to moisture conditioning. No significant deviations from standard testing protocols were noted.

IV. RESULTS

A. *Atterberg Limits and Shrinkage*

Table 1 summarizes the plasticity characteristics of the reddish gravel across the four sampling locations.

Table 1: Atterberg Limits and Linear Shrinkage Results

Sample ID	Liquid Limit (LL) %	Plastic Limit (PL) %	Plasticity Index (PI) %	Linear Shrinkage %
Center Water Logged	53	45	8	4.1
Lower Left Water Logged	43	30	13	7.1
Upper Left	57	49	8	4.3
Upper Right	49	37	12	5.7

B. *Moisture-Density Relations and CBR*

Table 2 details the compaction metrics and the soaked California Bearing Ratio results.

Table 2: Compaction and CBR Test Results (4-Day Soak)

Sample ID	MDD (kg/m³)	OMC (%)	CBR at 95% MDD (%)	Swell (%)
Center Water Logged	1608	17.7	26.0	0.75
Lower Left Water Logged	1654	17.6	28.0	0.84
Upper Left	1493	24.2	16.0	0.97
Upper Right	1532	22.3	23.0	0.76

C. *Concrete Compressive Strength*

Concrete mix Class 20/20 was tested over a 28-day curing period.

Table 3: Compressive Strength of Cubical Concrete Specimens

Age in Days	Specimen IDs	Density (kg/m³)	Applied Load at Failure (KN)	Compressive Strength (N/mm²)	Average Strength (N/mm²)
7	AS3, AS3V	2207, 2326	288.3, 296.3	12.8, 13.2	13.0
14	ASC, ASC2	2240, 2284	410.0, 405.0	18.2, 18.0	18.1
28	AS1, AS2	2210, 2228	480.3, 472.3	21.3, 21.0	21.2

V. DISCUSSION

A. *Interpretation*

The reddish gravel material exhibits low to medium plasticity (PI between 8% and 13%). According to general geotechnical standards, a PI under 15% is typically favorable for foundation layers as it suggests lower susceptibility to massive volume changes due to moisture fluctuations.

The compaction characteristics show an inverse relationship between MDD and OMC; the Upper Left sample required the highest moisture (24.2%) to achieve the lowest density (1493 kg/m³), which directly correlated with the lowest CBR value recorded (16%). Conversely, the "Lower Left Water Logged" zone exhibited the best packing characteristics (MDD = 1654 kg/m³) and the highest bearing strength (CBR = 28%).

The concrete strength steadily increased from 13.0 N/mm² at 7 days to 21.2 N/mm² at 28 days, successfully achieving the structural target of 20 N/mm² for Class 20/20 concrete.

B. *Contextualization*

The CBR values for all tested samples are greater than 15%, which generally classifies the soil as a "good" subgrade material suitable for foundation bases. The findings align with theoretical expectations where well-graded gravels with moderate fines yield acceptable bearing capacities.

The concrete strength development followed the standard asymptotic curing curve, reaching ~65% of its 28-day strength at day 7.

C. *Limitations & Errors*

Variability in the soil properties was observed across the site, particularly between the "Upper" and "Water Logged" sample zones. Spatial heterogeneity is a natural limitation in soil testing. Potential sources of minor errors include variations in manual compaction effort or slight moisture loss during sample transfer prior to oven drying.

D. *Improvements*

Future studies could benefit from Modified Proctor compaction tests (AASHTO T180) to evaluate if heavier compaction equipment on-site could yield significantly higher bearing capacities. Furthermore, due to the high OMC in the Upper Left sector, site drainage strategies should be optimized before compaction to ensure the soil does not exceed optimal moisture during actual construction.

VI. CONCLUSION

This laboratory investigation confirmed that the reddish gravel at the Annex Site is a suitable material for use as a foundation base. The soils exhibit manageable plasticity and deliver acceptable soaked CBR values (16% to 28%), supporting the initial hypothesis. Additionally, the concrete testing verified that the mix design is structurally sound, exceeding the required Class 20/20 benchmark with a 28-day compressive strength of 21.2 N/mm². To ensure long-term stability, it is recommended that strict moisture control and proper compaction protocols are enforced on-site, particularly in regions exhibiting higher optimum moisture contents.

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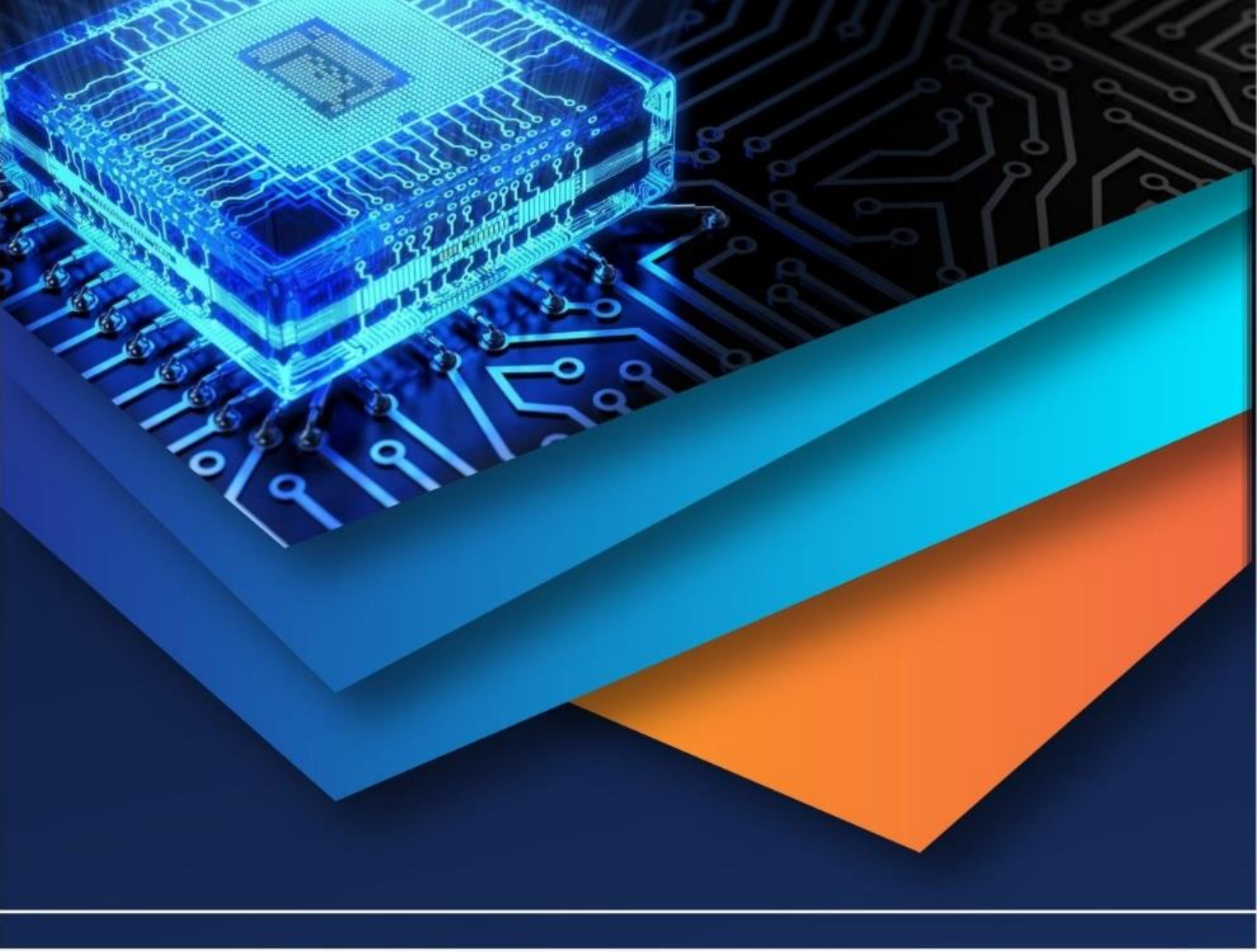

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