

Geotechnical Characterization of Subgrade Soils Using the AASHTO Classification System: A Case Study

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ABSTRACT

This study presents the geotechnical characterization of soils in the vicinity of Shaheed Benazir Bhutto University (SBBU), Nawabshah, employing the American Association of State Highway and Transportation Officials (AASHTO) classification system. Soil samples were obtained from two distinct locations using a hand auger, and subsequent laboratory testing included sieve analysis, liquid limit determination via the Casagrande cup method, and plastic limit testing. The experimental outcomes demonstrated that Soil Sample A contained 31.54% fines passing the No. 200 sieve, with a liquid limit of 31.5%, a plastic limit of 13.73%, and a plasticity index of 17.77%, which classifies it as A-2-6, indicating silty or clayey gravel sand. In contrast, Soil Sample B exhibited 38.34% fines passing the No. 200 sieve, with a liquid limit of 41%, a plastic limit of 25.51%, and a plasticity index of 15.49%, thereby classifying it as A-7-6, indicative of a clayey soil. These findings reveal that the soils in the SBBU vicinity range from silty-clayey gravel sands to clayey soils, thereby providing essential baseline data to inform future construction planning, foundation design, and the development of soil improvement strategies for the area.

Keywords: Geotechnical characterization; Soil classification; AASHTO method; Atterberg limits; Sieve analysis

1. INTRODUCTION

Soil forms the outer, unconsolidated cover of the earth, made up of mineral and organic particles of varying sizes. In geotechnical engineering, it is considered a three-phase material comprising solids, water, and air [1]. The proper identification and grouping of soils are vital to civil engineering because all structures (from buildings and roads to tunnels and dams) require ground support [2]. Assessing subsurface properties at project sites is necessary for producing reliable foundation design data. Poor characterization may lead to environmental harm, structural collapse, or long-term performance problems. Where heavy loads are present and stresses reach great depths, subsurface exploration becomes essential to avoid overdesign and high costs [3].

Various classification systems have been developed to arrange soils by their expected performance under different conditions. Each system reflects the specific aims of its creators [4]. For geotechnical engineers, these tools allow practical use of experience. The fitness of a soil for a given use must be judged by its measured engineering traits, not by visual appearance alone [5]. Bearing capacity depends largely on soil type; fine-grained soils usually have lower capacity than coarse ones. The plasticity index and the liquid limit help describe clay behavior, while permeability affects how well structures perform [6].

The AASHTO system began in 1920 with the U.S. Bureau of Public Roads and was adopted by AASHTO in 1945 [7]. It uses three soil properties: particle-size distribution (AASHTO T-11 and T-27), liquid limit (AASHTO T-89), and plasticity index (AASHTO T-90) [8]. Soils fall into seven main groups, some of which have subdivisions. Classification proceeds left to right on a chart until a matching group is found. For fine-grained soils, a group index is computed as:

$$\text{Group Index} = (F - 35)[0.2 + 0.005(LL - 40)] + 0.01(F - 15)(PI - 10)$$

where F is the percent passing the 0.075 mm sieve, LL is the liquid limit, and PI is the plasticity index

(AASHTO, 1945). Higher index values indicate poorer material.

The scholarly literature reveals extensive investigations into various soil properties relevant to classification. Schelling examined the interconnections among soil genesis, classification, and survey methodologies, proposing that classification frameworks should be validated against their intended objectives through practical application in soil surveys [9]. De Bakker underscored that the nature of any classification system is inherently shaped by the overarching purposes envisioned by its originators, whether these be theoretical/scientific or practical/agricultural/technological [10]. Isbell chronicled the evolution of national soil classification in Australia, highlighting Prescott's foundational contributions in the 1920s, Stephens's subsequent formulation of the Great Soil Group concept, and Northcote's Factual Key [11]. Datta et al. scrutinized the engineering behavior of carbonate soils in India, concluding that existing classification paradigms are not entirely satisfactory from an engineering perspective when applied to such problematic materials [12]. Arman investigated organic soils, establishing correlations among water content, water absorption, and pH, while also critiquing the inaccuracies inherent in conventional combustion techniques for determining organic matter content [13]. Tuncer and Lohnes proposed an engineering classification for basaltic lateritic soils, demonstrating that specific gravity and void ratio could serve as viable classification criteria [14]. Brevik emphasized the critical role of soil mapping and classification in advancing pedological understanding and advocated for a more universally applicable system to enhance international scientific communication [15]. Maharaj presented a case study from Jamaica that illustrated the practical utility of soil classification in road construction planning [16]. Hartemink conducted a bibliometric analysis of the use of soil classification in journal articles from 1975 to 2014, observing a marked exponential increase in the use of Soil Taxonomy and the World Reference Base (WRB) for soil resources [17].

The construction of bridges, buildings, recreational zones, and waste disposal facilities without rigorous soil characterization exposes these structures to elevated risk. Numerous large-scale infrastructure projects have failed, collapsed, or experienced diminished service life due to insufficient testing, analysis, and classification of the supporting soil strata. Soil classification is therefore essential for selecting appropriate construction techniques, implementing ground improvement measures, determining the necessity for soil replacement, and managing overall project budgets [18].

The present investigation was undertaken with the following aims: to identify the soil types prevalent in the vicinity of SBBU, to establish a baseline for soil mapping to inform future development planning, and to raise awareness of the critical importance of systematic soil classification in construction projects. The specific objectives were to procure soil samples from the study area using auger-boring techniques; to conduct requisite laboratory analyses, including sieve analysis, liquid limit determination, and plastic limit testing; and to classify the soils in accordance with the AASHTO system, thereby assessing their suitability as construction materials.

2. METHODOLOGY

2.1 Study Area and Soil Sampling

Soil specimens were collected from two sites in the vicinity of Shaheed Benazir Bhutto University (SBBU) in Nawabshah. A hand auger was used to extract the samples, as this technique is rapid, cost-effective, and well-suited for soft-to-stiff cohesive deposits. The hand auger comprises a central stem fitted with a transverse handle for rotation and metal-cutting blades and is commercially available in 75 mm or 152 mm diameters.

The sampling process consisted of boring holes at chosen positions with the auger, advancing each hole by manually rotating the cross-handle while exerting downward pressure. Once the auger had filled with earth material, it was withdrawn, and disturbed specimens were collected and kept at the specified depths for subsequent laboratory examination.

2.2 Laboratory Testing Program

2.2.1 Sieve Analysis

A sieve analysis was performed to evaluate the particle size distribution of the soil, following the procedures outlined in ASTM standards [19, 20]. The equipment used for this test consisted of BS410 standard sieves, a mechanical sieve shaker, a balance readable to 0.1 g, a drying oven, porcelain dishes, and spatulas. The test procedure began with stacking the sieves in decreasing order of aperture size. The dried soil sample was then placed on the uppermost sieve, and the stack was mechanically agitated for 10 to 15 minutes. After shaking, the material retained on each sieve was carefully removed and weighed to determine the mass fraction within each

size interval. The sieve analysis test followed a systematic sequence of preparation, sieving, and data reduction, as illustrated in Fig. 1.

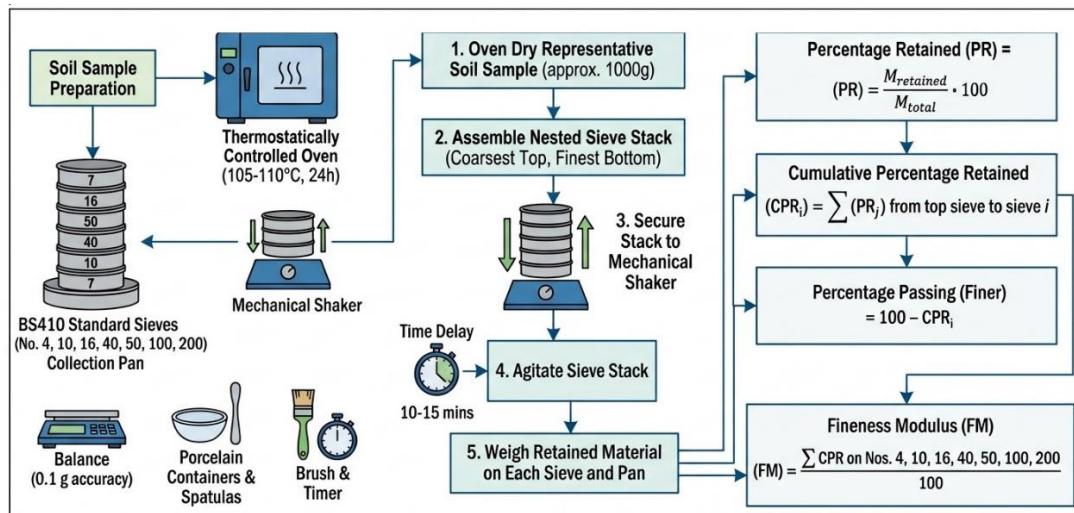


Fig. 1. Schematic workflow of the sieve analysis test procedure and data computations.

2.2.2 Liquid Limit Test

The liquid limit (LL) marks the moisture content at which soil transitions from plastic to a liquid state. In this study, the Casagrande cup method was employed to determine this value, as shown in Fig. 2. The soil fraction used in the test passed through a No. 40 (425 µm) sieve. The test began by thoroughly mixing the sieved soil with distilled water until a uniform paste formed. A portion of this paste was then placed into the Casagrande cup, and a standard groove was cut down the center using a grooving tool. The cup was rotated at 2 revolutions per second, and the number of blows required for the groove to close over a 12.7 mm length was recorded. Only tests producing between 15 and 35 blows were considered valid. Following the test, a representative portion of the soil was taken to determine its water content through oven drying.

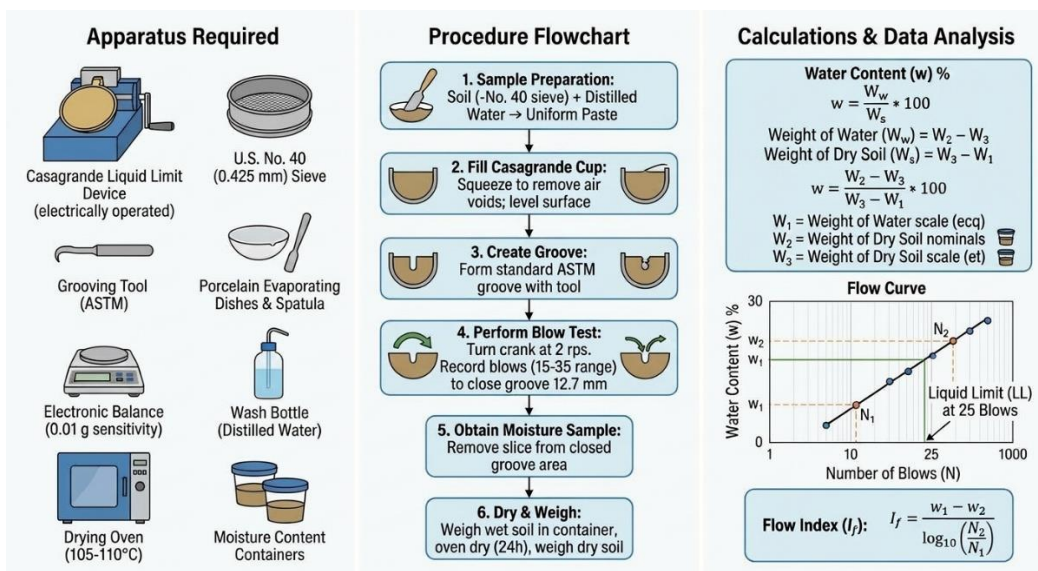


Fig. 2. Experimental setup and procedural steps for determining the liquid limit using the Casagrande cup method.

2.2.3 Plastic Limit Test

The plastic limit (PL) is the moisture content at which soil ceases to be plastic and begins to exhibit semi-solid behavior. To obtain this value, a small amount of the prepared soil was first mixed with water until it could be molded into a ball, as shown in Fig. 3. This ball was then rolled by hand on a smooth glass surface at a rhythm of roughly 90 strokes per minute until it formed a thread approximately 3 millimeters in diameter. The rolling

action was repeated on the same material until the thread started to show signs of crumbling and could no longer be maintained as a coherent cylinder. At this stage, a portion of the crumbled soil was collected to determine its water content through oven drying.

Once both the liquid and plastic limits were known, the plasticity index was calculated by subtracting the plastic limit from the liquid limit. This relationship is expressed as $PI = LL - PL$, and the resulting value indicates the range of moisture over which the soil remains in a plastic condition.

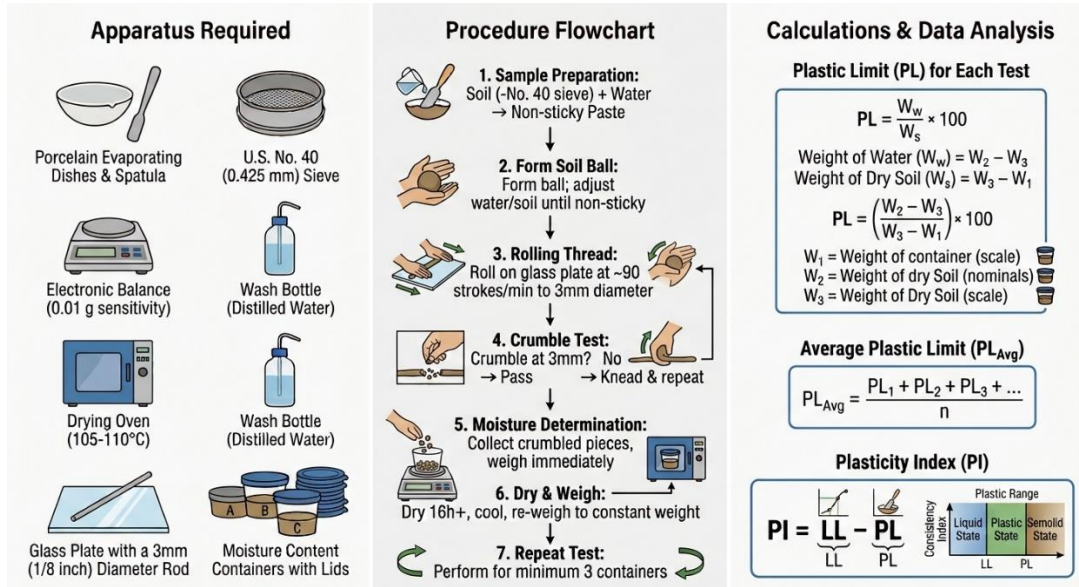


Fig. 3. Equipment arrangement and procedural workflow for the plastic limit test and plasticity index determination.

2.3 Soil Classification

The soil classification system follows a systematic, step-by-step approach in accordance with AASHTO [21]. The process begins by compiling the relevant soil test data, including the percentages passing the No. 10, No. 40, and No. 200 sieves, as well as the liquid limit and plasticity index. Using the standard AASHTO classification chart, the next step is to scan the table from the leftmost column toward the right until the first group designation that encompasses all the soil's measured parameters is identified.

For soils containing a substantial fine fraction (generally those with more than 35 percent of particles passing the No. 200 sieve), an additional step is required. In such cases, the group index is computed using the expression:

$$GI = (F - 35)[0.2 + 0.005(LL - 40)] + 0.01(F - 15)(PI - 10)$$

Within this equation, GI represents the group index, which is ultimately reported as a whole number rounded to the nearest integer. The term F denotes the percentage of soil passing the 0.075 mm sieve, while LL and PI correspond to the liquid limit and plasticity index, respectively. Once calculated, the group index is placed in parentheses immediately following the group symbol, thereby providing a more complete classification of the soil's engineering characteristics.

3. RESULTS AND DISCUSSION

3.1 Particle Size Distribution

3.1.1 Soil Sample A

According to the sieve analysis data for soil Sample A (Table 1), the percentages of material passing the key sieve sizes are as follows: 98.18% through the No. 10 (2 mm) sieve, 94.20% through the No. 40 (0.425 mm) sieve, and 31.54% through the No. 200 (0.075 mm) sieve. These results show that the sample consists largely of fine-grained particles, with nearly one-third of the total mass smaller than 0.075 mm. Such high fines content

(exceeding 30%) indicates soil that is likely to exhibit cohesive behavior. In practical engineering terms, this means the material will tend to have low hydraulic conductivity and greater susceptibility to compression under load. Consequently, structures built on this soil may face challenges related to poor drainage and time-dependent settlement, both of which should be carefully evaluated during project planning and foundation design.

Table 1. Sieve analysis results for Sample A

ASTM Sieve No.	Sieve Opening (mm)	Weight Retained (g)	% Retained	Cumulative % Retained	% Finer
#4	4.76	8.2	0.82	0.82	99.18
#10	2.00	10.0	1.00	1.82	98.18
#16	1.19	16.8	1.68	3.50	96.50
#40	0.425	23.0	2.30	5.80	94.20
#50	0.300	67.6	6.76	12.56	87.44
#100	0.150	180.0	18.00	30.56	69.44
#200	0.075	379.0	37.90	68.46	31.54
Pan	-	315.4	31.54	100.00	0

3.1.2 Soil Sample B

The sieve analysis results for soil Sample B, as shown in Table 2, indicate that 91.68% of the material passed the No. 10 (2 mm) sieve, 82.32% passed the No. 40 (0.425 mm) sieve, and 38.34% passed the No. 200 (0.075 mm) sieve. Compared to Sample A, this sample contains a notably larger proportion of fine particles, as reflected in the higher percentage passing the finest sieve. With over 38% of the soil finer than 0.075 mm, it is likely to exhibit stronger plasticity and may pose greater engineering challenges. These include an increased risk of volume changes due to swelling and shrinkage, as well as reduced load-bearing capacity. Additionally, the elevated fines fraction implies that the soil can retain more water, making it more susceptible to dimensional changes whenever moisture conditions vary.

Table 2. Sieve Analysis Results for Sample B

ASTM Sieve No.	Sieve Opening (mm)	Weight Retained (g)	% Retained	Cumulative % Retained	% Finer
#4	4.76	76.0	7.60	7.60	92.40
#10	2.00	7.2	0.72	8.32	91.68
#16	1.19	12.04	1.20	9.52	90.48
#40	0.425	80.6	8.06	17.68	82.32
#50	0.300	117.38	11.74	29.32	70.68
#100	0.150	141.6	14.16	43.48	56.52
#200	0.075	181.74	18.17	61.66	38.34
Pan	-	383.44	38.34	100.00	0

3.2 Atterberg Limits

3.2.1 Soil Sample A

Table 3 contains the liquid limit test data for soil Sample A, recorded across a range of blow counts. From the flow curve, as shown in Fig. 4, the liquid limit was interpolated at 25 blows, yielding 31.5%. This places the soil within the moderate plasticity range, which typically covers liquid limits between 30% and 50%. In practical terms, such soil remains workable with standard earthmoving and compaction equipment, though it does demand attentive moisture management during placement and densification. The measured liquid limit also implies that the soil will respond noticeably to changes in water content; therefore, adequate surface and subsurface drainage measures should be incorporated into the design to minimize the risk of strength loss or volume instability.

The plastic limit tests for soil Sample A, summarized in Table 4, yielded an average PL value of 13.73%. This relatively low plastic limit indicates that the soil loses its plastic behavior and enters a semi-solid state at a low water content, suggesting a composition that includes both sand-sized and clay-sized particles. From this, the plasticity index was determined as $PI = LL - PL$, giving $31.5 - 13.73 = 17.77\%$. A PI of roughly 18% falls within the medium plasticity category, suggesting a moderate proportion of clay in the soil matrix. In field applications, such soil is likely to experience modest volume changes with wetting and drying and will therefore require close oversight of compaction moisture levels during grading and filling operations to avoid performance issues.

Table 3. Liquid limit determination for Sample A

Parameter	Test 1	Test 2	Test 3
Number of Blows	15	20	38
Container No.	T-07	59-5	19-5
Weight of container (W_1) g	70	60	60
Weight of container + wet soil (W_2) g	83	80	70
Weight of container + dry soil (W_3) g	79	75	68
Weight of water ($W_2 - W_3$) g	4	5	2
Weight of dry soil ($W_3 - W_1$) g	9	15	8
Water content (%)	44.44	33.33	25.00

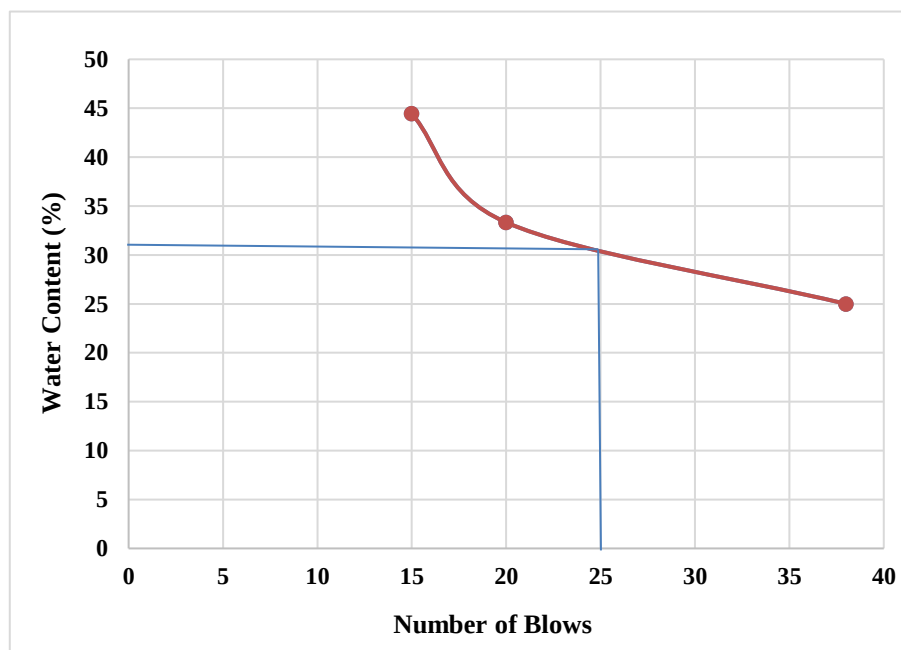


Fig. 4. Liquid limit of soil Sample A =31.5

Table 4. Plastic limit determination for Sample A

Parameter	Test 1	Test 2	Test 3
Container No.	8-5	10-5	19-5
Weight of container (W_1) g	60	65	60
Weight of container + wet soil (W_2) g	70	74	71
Weight of container + dry soil (W_3) g	68.5	73	69.9
Weight of dry soil ($W_3 - W_1$) g	8.5	8	9.9
Weight of water ($W_2 - W_3$) g	1.5	1	1.1
Water content (%)	17.6	12.5	11.11

3.2.2 Soil Sample B

Table 5 presents the liquid limit test results for soil Sample B, obtained over a series of blow counts. The flow curve was used to estimate the liquid limit at 25 blows, as shown in Fig. 5, yielding LL = 41%. This figure is notably higher than that recorded for Sample A, suggesting that Sample B contains a larger fraction of clay minerals and is therefore more responsive to shifts in water content. A liquid limit of 41% falls into the high-plasticity range, indicating that the soil is likely to pose handling and performance challenges unless appropriately treated before construction. In practice, such soils demand rigorous moisture monitoring during compaction and are prone to considerable swelling or shrinkage as environmental moisture conditions change over time.

The plastic limit tests for soil Sample B yielded an average plastic limit of PL = 25.51%, as shown in Table 6. The higher plastic limit compared to Sample A indicates that this soil remains plastic over a wider range of moisture contents, a characteristic typical of clay-rich soils. The plasticity index was calculated as $PI = LL - PL = 41 - 25.51 = 15.49\%$. Although the plasticity index is slightly lower than that of Soil Sample A, the higher liquid limit suggests that Soil Sample B contains more active clay minerals. This combination of properties indicates a soil that may be prone to significant shrink-swell behavior, potentially causing distress to lightly loaded structures, roads, and pavements if not properly addressed.

Table 5. Liquid limit determination for Sample B

Parameter	Test 1	Test 2	Test 3
Number of Blows	45	30	15
Container No.	25-H	7#	16-5
Weight of container (W ₁) g	60	60	56
Weight of container + wet soil (W ₂) g	75	75	70
Weight of container + dry soil (W ₃) g	72	71	65
Weight of water (W ₂ -W ₃) g	3	4	5
Weight of dry soil (W ₃ -W ₁) g	12	10	9
Water content (%)	25.00	36.66	55.55

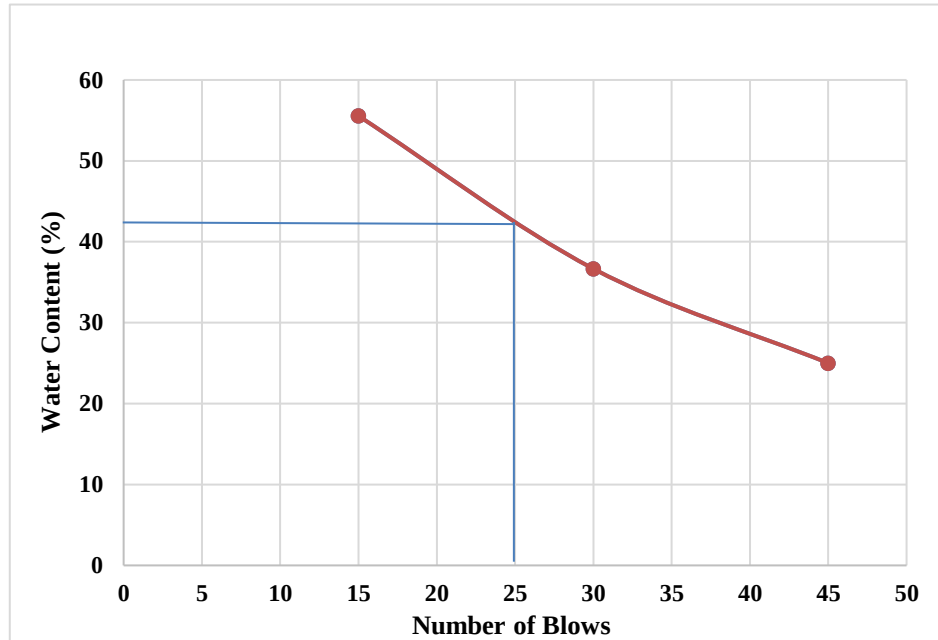


Fig. 5. Liquid limit of soil Sample B =41

Table 6: Plastic Limit Determination for Soil Sample B

Parameter	Test 1	Test 2	Test 3
Container No.	TP-1	S-3	S-5
Weight of container (W ₁) g	60	70	60
Weight of container + wet soil (W ₂) g	70	81.5	71
Weight of container + dry soil (W ₃) g	68	79.3	68.6
Weight of dry soil (W ₃ -W ₁) g	8	9.3	8.6
Weight of water (W ₂ -W ₃) g	2	2.2	2.4
Water content (%)	25.00	23.65	27.90

3.3 Soil Classification (AASHTO Method)

3.3.1 Soil Sample A

Using the AASHTO classification table with the following characteristics: 31.54% passing the No. 200 sieve, liquid limit of 31.5%, and plasticity index of 17.77%, the soil was classified as A-2-6 (Silty or Clayey Gravel Sand), as shown in Fig. 6.

The group index was calculated as:

$$GI = (F - 35)[0.2 + 0.005(LL - 40)] + 0.01(F - 15)(PI - 10)$$

Since $F = 31.54\%$ ($< 35\%$), the group index is 0.

This classification indicates a granular soil with silty-clayey fines that exhibits moderate plasticity. Soils in the A-2 group are generally considered excellent to good subgrade materials for highways and pavements. The A-2-6 subgroup specifically includes silty or clayey gravels and sands that perform well as subgrade materials when properly compacted and drained. The presence of fines enhances cohesion but also increases sensitivity to moisture. For construction purposes, this soil type generally provides adequate bearing capacity for light- to moderate-load structures, provided that proper drainage is maintained and the soil is compacted at the optimal moisture content. The moderate plasticity suggests that the soil can be readily compacted with conventional equipment, making it suitable for use as fill material, embankment construction, and pavement subgrade.

AASHTO Classification System

General Classification	Granular materials (35% or less passing No. 200 Sieve (0.075 mm))							Silt-clay Materials More than 35% passing No. 200 Sieve (0.075 mm)			
Group Classification	A-1		A-3	A-2				A-4	A-5	A-6	A-7
	A-1-a	A-1-b		A-2-4	A-2-5	A-2-6	A-2-7				A-7-5 A-7-6
(a) Sieve Analysis: Percent Passing											
(i) 2.00 mm (No. 10)	50 max										
(ii) 0.425 mm (No. 40)	30 max	50 max	51 min								
(iii) 0.075 mm (No. 200)	15 max	25 max	10 max	35 max	35 max	35 max	35 max	36 min	36 min	36 min	36 min
(b) Characteristics of fraction passing 0.425 mm (No. 40)											
(i) Liquid limit				40 max	41 max	40 max	41 min	40 max	41 min	40 max	41 min
(ii) Plasticity index	6 max		N.P.	10 max	10 max	11 min	11 min	10 max	10 max	11 min	11 min*
(c) Usual types of significant Constituent materials	Stone Fragments Gravel and sand		Fine Sand	Silty or Clayey Gravel Sand				Silty Soils		Clayey Soils	
(d) General rating as subgrade.	Excellent to Good							Fair to Poor			

* If plasticity index is equal to or less than (liquid Limit—30), the soil is A—7—5 (i.e. PL > 30%)
If plasticity index is greater than (Liquid Limit—30), the soil is A—7—6 (i.e. PL < 30%)

Fig. 6. AASHTO classification system of sand

3.3.2 Soil Sample B

Using the AASHTO classification table with the following characteristics: 38.34% passing the No. 200 sieve, liquid limit of 41%, and plasticity index of 15.49%, the soil was classified as A-7-6 (Clayey Soil), as shown in Fig. 6. Since the plastic limit (25.51%) is less than 30%, the soil falls into the A-7-6 subgroup.

The group index was calculated as:

$$GI = (3.34)[0.2 + 0.005(1)] + 0.01(23.34)(5.49)$$

$$GI = (3.34)(0.205) + 0.01(23.34)(5.49)$$

$$GI = 0.685 + 1.281 = 1.966 \approx 2$$

This classification indicates a clayey soil with moderate to high plasticity that requires special attention in foundation design and earthwork operations. Soils in the A-7 group are considered fair to poor subgrade materials. The A-7-6 subgroup specifically consists of clayey soils with moderate plasticity and is typically problematic for construction due to susceptibility to volume changes with moisture variations. Such soil can cause significant settlement issues, requiring deep foundations, soil replacement, or ground improvement techniques for heavy structures. The high fines content, combined with significant plasticity, suggests that this soil would exhibit substantial shrink-swell behavior, potentially causing damage to lightly loaded structures, pavements, and utilities. For construction on this soil type, appropriate measures such as lime or cement stabilization, proper moisture control during compaction, and the design of suitable foundation systems are essential.

4. CONCLUSION

This study successfully characterized the soils around Shaheed Benazir Bhutto University using the AASHTO classification framework. Based on the experimental results, the following conclusions are drawn:

- Sample A falls under the A-2-6 group (silty or clayey gravel sand). It contains 31.54% fines passing the No. 200 sieve, with a liquid limit of 31.5%, a plastic limit of 13.73%, and a plasticity index of 17.77%.
- Sample B belongs to the A-7-6 group (clayey soil). It has 38.34% fines passing the No. 200 sieve, a liquid limit of 41%, a plastic limit of 25.51%, and a plasticity index of 15.49%.
- The presence of both A-2-6 and A-7-6 soils within the university vicinity reflects heterogeneous subsurface conditions. This variability underscores the importance of conducting site-specific geotechnical assessments before any construction activity.
- From an engineering standpoint, Sample A is generally acceptable as subgrade material, provided that adequate drainage and compaction are ensured. In contrast, Sample B, due to its clay-rich composition, may necessitate adjustments in foundation design, soil stabilization measures, or other ground

improvement techniques.

- The AASHTO system proved to be a practical and effective tool for classifying the soils studied, offering a useful basis for decisions related to foundations, pavements, and earthworks.
- Overall, this work provides foundational soil data for the SBBU campus, which can guide future building projects, reduce the risk of structural distress, and support cost-efficient planning.

Author Contributions: **Ajay Kumar:** Conceptualization; Methodology; Project administration; Supervision; Visualization; Writing – original draft; Writing – review & editing; Formal analysis; Investigation; Data curation; Resources; Software. **Muhammad Waseem:** Investigation; Data curation; Formal analysis; Writing – original draft (Introduction and Methodology sections); Software; Visualization; Resources. **Muhammad Shafique:** Writing – review & editing; Visualization; Investigation (field and laboratory assistance). **Asad Ali:** Formal analysis; Data curation; Software; Visualization; Investigation.

Funding: No funding to be declared.

Data availability: All data generated or analyzed during this study are included in this published article.

Conflict of interest: The authors declare no conflict of interest.

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