1

Soils

Introduction

2

2

Soil

Definition

- Naturally occurring mineral particles which are fairly readily separated into relatively small pieces and in which the mass may contain air, water, or organic materials

3

Main Soil Groups for Road Construction

4

4

Main soil groups

1. Gravelly Soils (Granular Soils)
2. Sandy Soils (Granular Soils)
3. Silty Soils (Fine-Grained Soils)
4. Clayey Soils (Fine-Grained Soils)
5. Loamy Soils (Mixed Soils)
6. Organic Soils (Peat, Muck)
7. Rock Fill

5

5

Main Soil Groups for Road Construction

Visual Description

6

6

Gravelly Soils (Granular Soils)

- Visual Description:
  - *Coarse, angular, or rounded particles visible to the naked eye.*
  - *Can vary in color depending on the parent rock but usually consists of loose rock fragments.*
- Particle Size:
  - *75.0 mm to 2.0 mm in diameter.*
  - *Classified into*
    - Coarse gravel (19 -75 mm)
    - Fine gravel (4.75 - 19 mm).




7

7

Sandy Soils (Granular Soils)

- Visual Description:
  - *It consists of small particles of weathered rock*
  - *Fine to coarse particles, gritty to the touch.*
  - *Can appear light yellow, brown, or white depending on mineral content.*
- Particle Size:
  - *0.075 mm to 4.75 mm.*
  - *Classified into*
    - Fine sand (0.075 mm to 0.425mm).
    - Medium sand (0.425 mm to 2 mm)
    - Coarse sand (2 mm to 4.75 mm)

8

8

Silty Soils (Fine-Grained Soils)

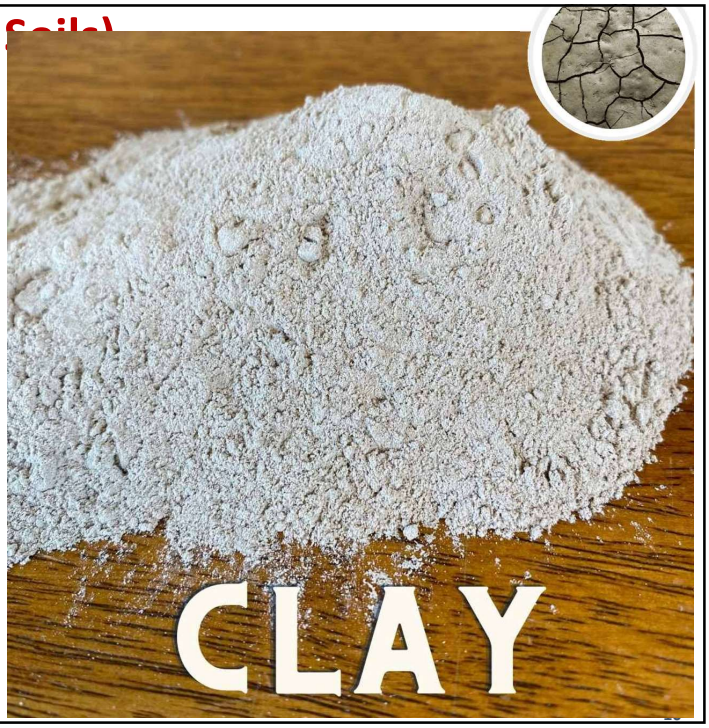
- Visual Description:
  - *Fine particles, smooth when dry, and feels silky to the touch.*
  - *Dusty appearance when dry and sticky or slippery when wet.*
  - *Usually, light gray or brown.*
  - *is made up of rock and other mineral particles,*
    - which are smaller than sand and larger than clay
  - *It is mainly found near the river, lakes and other water bodies*
- Particle Size:
  - *0.005 mm to 0.075 mm.*
  - *Fine enough to be carried by wind or water.*
  - *known to have much smaller particles compared to sandy soil*

9

Clayey Soils (Fine-Grained Soils)

Clay Soil

- Visual Description:
  - *Very fine particles, sticky and plastic when wet, hard and dense when dry.*
  - *Feels smooth or greasy to the touch when wet.*
  - *Typically dark brown, red, or gray depending on mineral content.*
- Particle Size:
  - *Clay has the smallest particle.*
  - *Maximum size of 0.005 mm*
  - *The particles in this soil are tightly packed together with each other with very little or no airspace.*



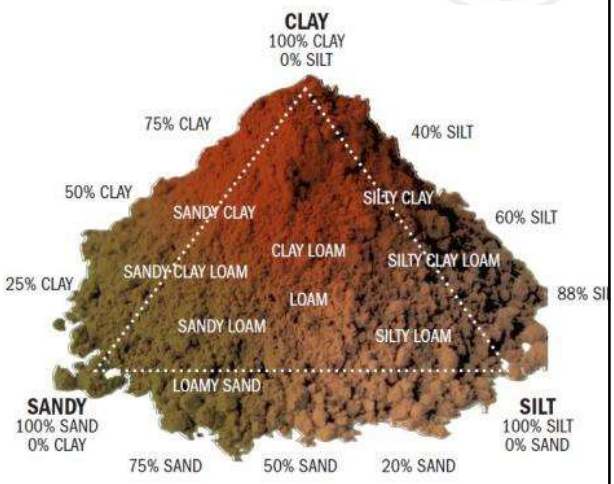
10

11

11

Loamy Soils (Mixed Soils)

- Visual Description:
  - *A balanced mixture of sand, silt, and clay.*
  - *Soft and crumbly, feels smooth but not sticky.*
  - *Typically, brown or black due to organic material content.*
- Particle Size:
  - *A combination of*
    - Sand (0.075 mm to 4.75 mm),
    - Silt (0.005 mm to 0.075 mm),
    - clay (less than 0.005 mm).



12

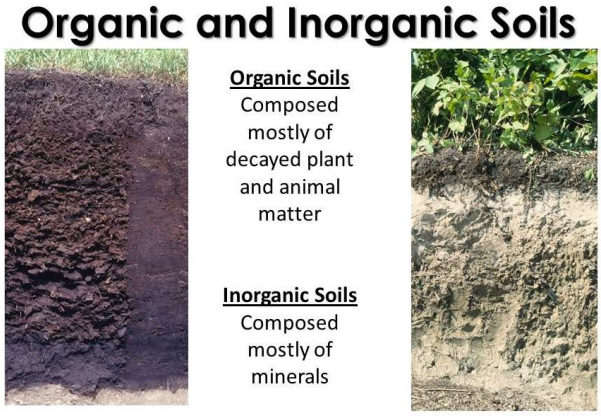
12

13

13

Organic Soils (Peat, Muck)

- Visual Description:
  - *Dark brown or black in color with visible organic material like roots, leaves, and other plant debris.*
  - *Spongy and soft in texture.*
  - *Easily compressible and retains a lot of water.*
- Particle Size:
  - *Varies; consists of organic material mixed with fine soil particles*

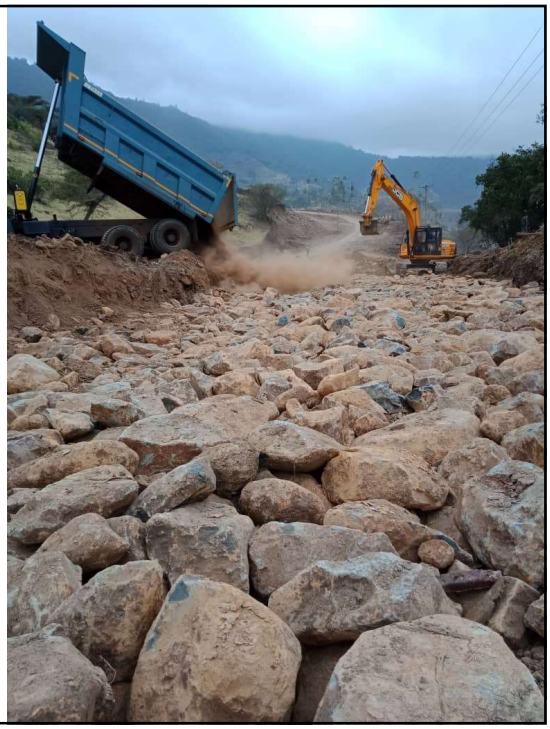


14

14

Rock Fill

- Visual Description:
  - *Large, angular, or rounded fragments of rock.*
  - *Often gray, brown, or white depending on the rock type.*
- Particle Size:
  - *Larger than 75 mm, often up to several hundred millimeters*



15

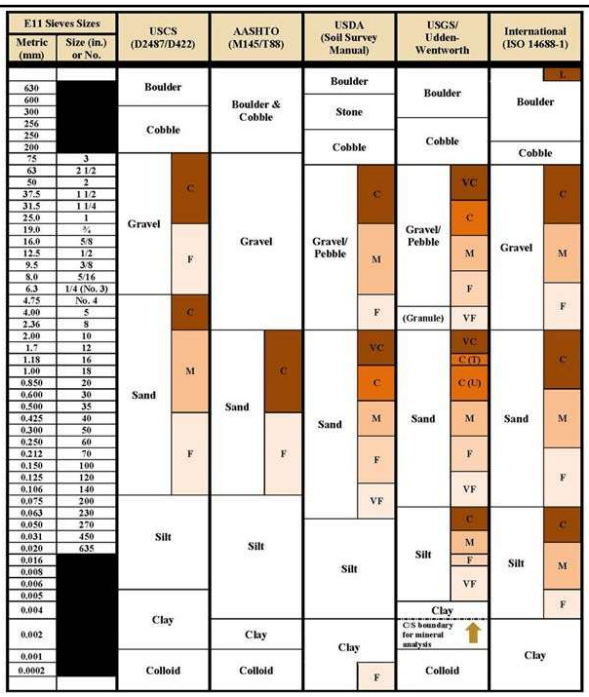
Main Soil Groups for Road Construction

Particle Size

16

16

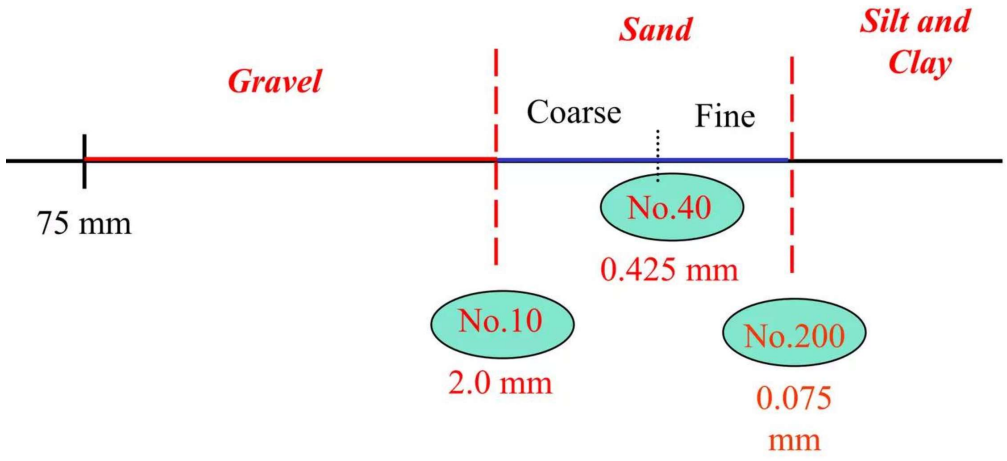
Comparison of Soil groups by Grain Size Diameter (mm)



17

17

Comparison of Soil groups by Grain Size Diameter (mm) and sieve size

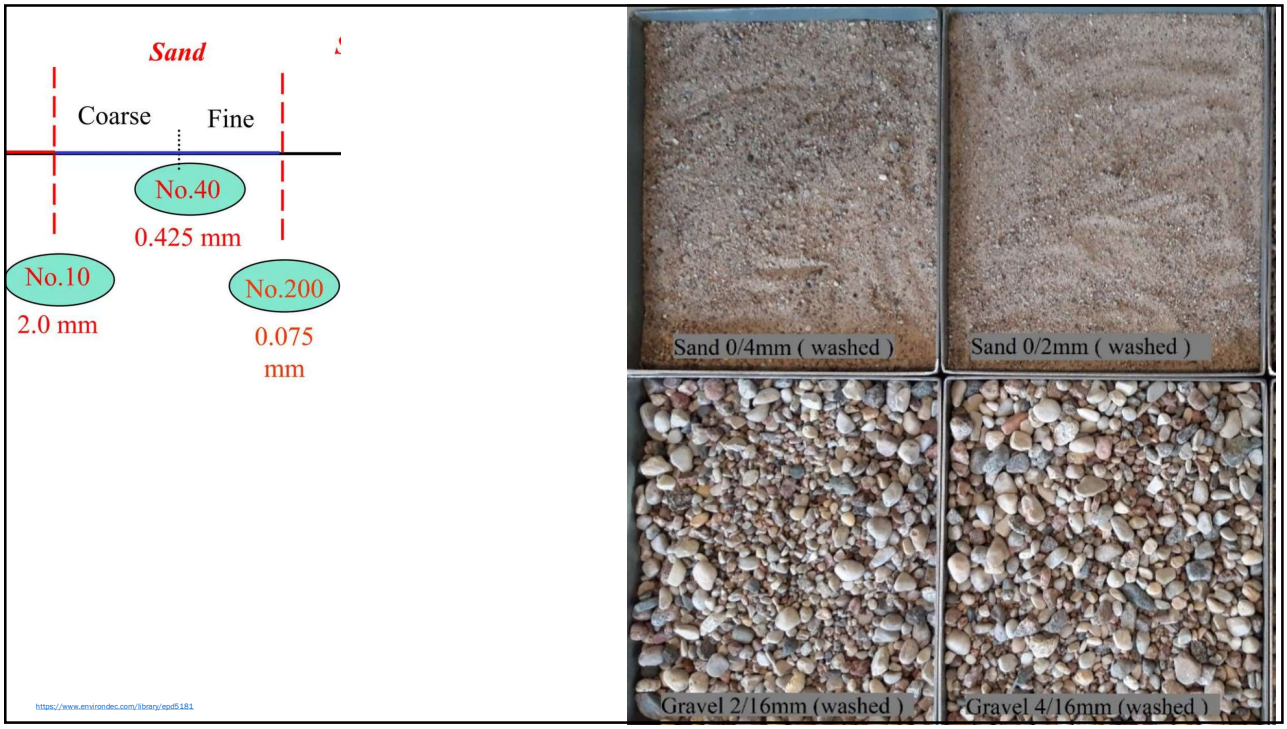


18

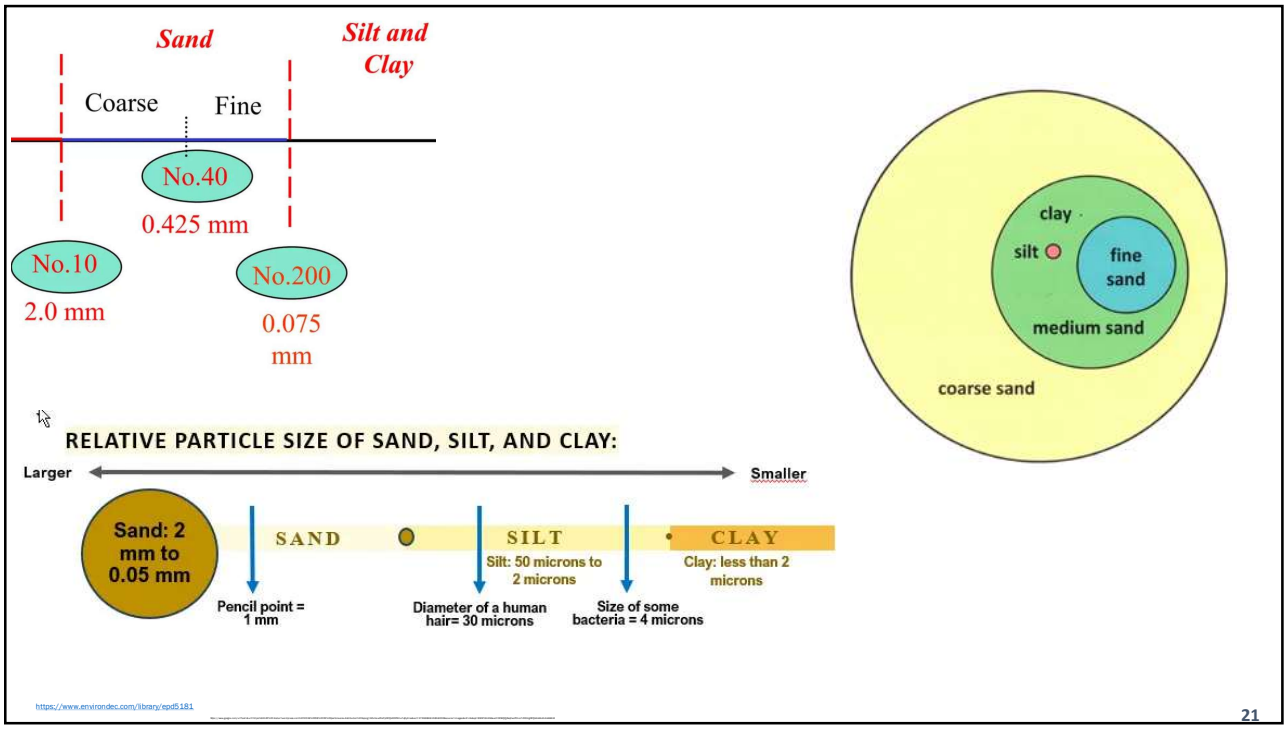
18


Gravel
Coar
75 mm
No.10
2.0 mm
Washed crushed gravel 11/16 mm
Washed crushed gravel 8/11 mm
Washed crushed gravel 0/2 mm
Washed crushed gravel 0/5 mm
Washed crushed gravel 4/16 mm
Washed crushed gravel 5/8mm
Washed crushed gravel 11/22 mm
Washed crushed gravel 5/11
Washed crushed gravel 11/16 mm
Washed crushed gravel 8/11 mm
https://www.environdec.com/library/epd5181

19


Sand
Coarse
Fine
No.40
0.425 mm
No.10
2.0 mm
No.200
0.075
mm
Sand 0/4mm (washed)
Sand 0/2mm (washed)
Gravel 2/16mm (washed)
Gravel 4/16mm (washed)
https://www.environdec.com/library/epd5181

20



21

Main Soil Groups for Road Construction

Properties

22

22

Load-Bearing Capacity

The ability of soil to support loads without excessive deformation or failure

Soil Group	Rank
Rock Fill	Very high
Gravelly Soils	High
Sandy Soils	Moderate
Silty Soils	Low when wet
Clayey Soils	Low
Loamy Soils	Moderate

23

23

Plasticity

- Definition
  - *The ability of soil to be deformed without cracking or breaking.*
- The Atterberg limits
  - *are a series of tests that measure the plasticity characteristics of fine-grained soils,*
  - *specifically focusing on the moisture content at which the soil transitions between different states: solid, plastic, and liquid.*
  - *It includes:*
    - Liquid Limit (LL):
    - Plastic Limit (PL):
    - Plasticity Index (PI):

24

24

Atterberg Limits

- Liquid Limit (LL):
  - *The moisture content at which the soil changes from a plastic state to a liquid state.*
  - *This is the threshold beyond which the soil cannot maintain its shape.*
  - *Can range be from zero to 1000; but most soils have LL's less than 100*
  - A high liquid limit normally indicates
    - High compressibility
    - High shrinkage/swelling potential
- Plastic Limit (PL):
  - *The moisture content at which the soil changes from a plastic state to a semi-solid state.*
  - *Below this moisture content, the soil becomes too stiff to be deformed easily.*
  - *The plastic limit can range from zero to 100 or more, with most being less than 40*
- Plasticity Index (PI):
  - *The difference between the Liquid Limit and Plastic Limit (PI = LL - PL).*
  - *This index indicates the range of moisture content over which the soil exhibits plastic behavior.*

25

25

Plasticity

- Non-Plastic Soils :
  - *Soils that do not exhibit any plastic behavior.*
  - *They do not change shape or deform when moisture content changes,*
  - *meaning they remain rigid and do not flow or mold*
- Plastic Soils:
  - *Soils that exhibit plastic behavior, meaning they can deform without breaking when moisture content changes.*
  - *They can transition between solid, plastic, and liquid states depending on the amount of water present.*

28

28

Plastic Soils:

- Types:
  - *Low Plasticity:*
    - Soils that can be molded slightly but will return to their original shape when pressure is removed (e.g., some silty soils).
    - These soils will have low values for both LL and PL, indicating limited plastic behavior.
    - The Plasticity Index will be low, suggesting minimal deformation when moist.
  - *High Plasticity:*
    - Soils that can be easily molded and retain the new shape (e.g., clayey soils).
    - Exhibit significant differences between LL and PL, leading to a high Plasticity Index

29

29

Plasticity

The ability of soil to be deformed without cracking or breaking.

Soil Group	Atterberg Limits	Plasticity Index (PI)	Plasticity	Behavior with Moisture Changes
Rock Fill	Not applicable	Not applicable	Non-plastic	Rigid, stable under varying moisture conditions
Gravelly Soils	Not applicable	Not applicable	Non-plastic	Rigid, does not deform; good drainage properties
Sandy Soils	Low LL and PL	Low PI (=0)	Low plasticity	Limited deformation, stable, but may erode
Silty Soils	Liquid Limit: 20%-35%,	Low PI (4%-10%)	Low to moderate plasticity	Some volume change with moisture; can become unstable when wet
Clayey Soils	Liquid Limit: 30%-70%, Plasticity Index: 10%-40%	High PI (10%-40%)	High plasticity	Significant volume changes; high shrink-swell potential
Loamy Soils	Varies depending on clay content	Moderate PI (varies)	Moderate plasticity	Moderate volume changes; retains some moisture

30

30

Ease of Volume Change

The extent to which a soil's volume changes with variations in moisture content

Soil Group	Rank
Rock Fill	Very low (negligible)
Gravelly Soils	Very low
Sandy Soils	Low
Silty Soils	Moderate to high
Clayey Soils	Very high (shrink-swell potential)
Loamy Soils	Moderate

31

31

Drainage

The ability of soil to remove or allow water to flow away, preventing water accumulation.

Soil Group	Rank
Rock Fill	Excellent
Gravelly Soils	Excellent
Sandy Soils	Good (coarse sand)
Silty Soils	Poor
Clayey Soils	Very poor
Loamy Soils	Moderate

32

32

Summary

Soil Group	Load-Bearing Capacity	Plasticity	Ease of Volume Change	Drainage	Frost Susceptibility
Rock Fill	Very high	Non-plastic	Very low (negligible)	Excellent	None
Gravelly Soils	High	Non-plastic	Very low	Excellent	Minimal
Sandy Soils	Moderate	Low to non-plastic	Low	Good (coarse sand)	Low to moderate
Silty Soils	Low when wet	Low plasticity	Moderate to high	Poor	High
Clayey Soils	Low	High plasticity	Very high (shrink-swell potential)	Very poor	Very high
Loamy Soils	Moderate	Moderate plasticity	Moderate	Moderate	Moderate

33

33

What do you think ?

34

34

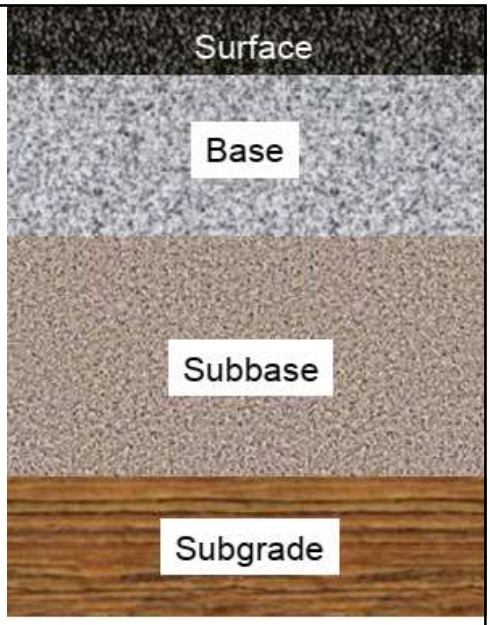
What soil groups is best to be used in pavement layers ? Why ?

35

35

Which soil group would provide the good drainage ?

Examples of subbase drainage at pavement core holes. Good, medium and poor drainage, from left to right, respectively.



36

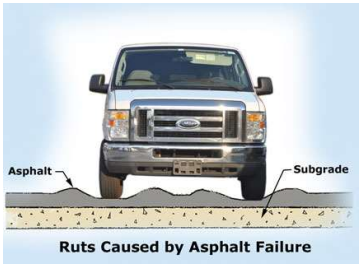
36

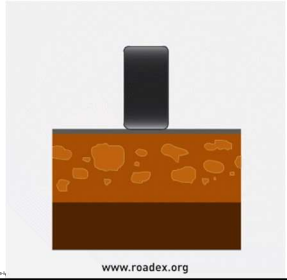
Which soil group would provide the loading support ?

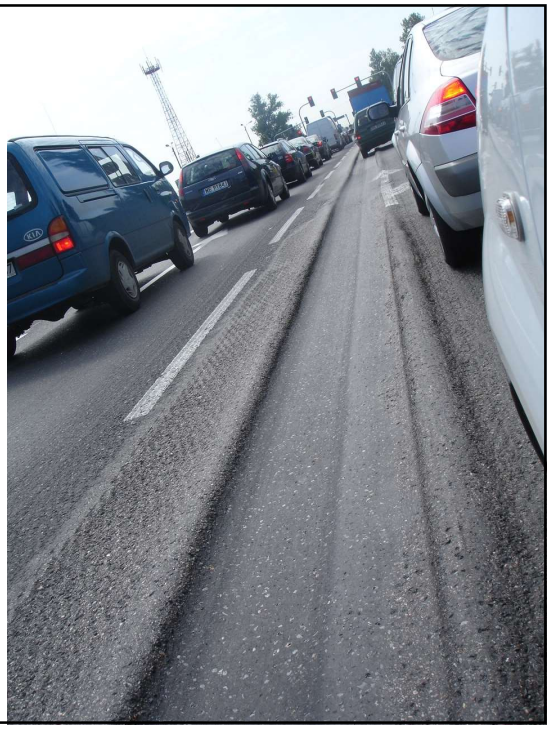
37

37

Which soil group would cause this failure ?







38

Frost Susceptibility

The likelihood of soil to expand when frozen, potentially causing frost heaving

Soil Group	Rank
Rock Fill	None
Gravelly Soils	Minimal
Sandy Soils	Low to moderate
Silty Soils	High
Clayey Soils	Very high
Loamy Soils	Moderate

39

Which soil group would cause this failure ?

Road damage caused by landslides

40

Main Soil Groups for Road Construction

Soil Classification

41

41

Soil Classification for Highway Purposes

- Soil classification 'system represents, in effect,
  - *A language of communication between engineers.*
  - *It provides a systematic method of categorizing soils according to their probable engineering behavior, allowing engineers access to the accumulated experience of other engineers.*
- Engineering properties have been found to correlate quite well with the index and classification properties of a given soil deposit.
  - *Thus, by knowing the soil classification, the engineer already has a fairly good general idea of the suitability of the soil for a particular application and its behavior during construction, under structural loads, and so on*
- Highway classification system is aims to
  - *Predict the soil performance on the basis of a few simple tests performed on the soil in a disturbed condition.*

42

42

Soil Classification for Highway Purpos

Importance of Soil Classification in Design

- Design Decisions:
  - *Thickness of layers,*
  - *material selection*
  - *Drainage design.*
- Impact:
  - *Affects road durability, maintenance frequency, and overall safety.*

43

43

Soil Classification for Highway Purposes

Available systems

1. Unified Soil Classification System (USCS)
   - *Classify soil by type rather than by engineering suitability for specific uses*
   - *Primarily focuses on physical properties (grain size, plasticity) without considering the engineering behavior in specific contexts.*
   - *It Less emphasis on suitability for road applications, potentially overlooking factors critical for highway stability and performance*
2. American Association of State Highways and Transportation officials (AASHTO)
   - *Divides the soil into seven major groups*
   - *Essentially classifying soils according to their suitability as subgrades.*
     - Some groups may be further divided into subgroups

44

44

Soils

Unified Soil Classification System (USCS)

45

45

Unified Soil Classification System (USCS)

- Purpose:
  - *The USCS categorizes soils based on their particle size and plasticity to predict their behavior under load and moisture conditions.*
- Importance:
  - *Widely used in civil engineering and geotechnical practices for effective soil analysis and construction planning*
- Grain Size Distribution:
  - *USCS uses sieve analysis to determine the particle size distribution of soil samples.*
- Atterberg Limits:
  - *Tests to evaluate the liquid and plastic limits help classify fine-grained soils.*

46

46

Unified Soil Classificat

Soil Categories

Coarse-Grained Soils

- *more than 50% of soil by weight is larger than 0.075 mm*

- Gravel (G):
  - *GW: Well-graded gravel.*
  - *GP: Poorly graded gravel.*
- Sand (S):
  - *SW: Well-graded sand.*
  - *SP: Poorly graded sand*

TABLE 2.7 Unified Soil Classification System

Criteria for Assigning Group Symbols and Group Names Using Laboratory Tests[a]				Soil Classification: Group Symbol	Soil Classification: Group Name[b]
(1)	(2)	(3)	(4)	(5)	(6)
COARSE-GRAINED SOILS	GRAVELS	CLEAN GRAVELS	$C_u \geq 4$ and $1 > C_c < 3^e$	GW	Well-graded gravel[f]
More than 50% retained on No. 200 sieve	More than 50% of coarse fraction retained on No. 4 sieve	Less than 5% fines[c]	$C_u < 4$ and/or $1 > C_c < 3^e$	GP	Poorly graded gravel[f]
		GRAVELS WITH FINES	Fines classify as ML or MH	GM	Silty gravel[f,g,h]
		More than 12% fines[c]	Fines classify as CL or CH	GC	Clayey gravel[f,g,h]
	SANDS	CLEAN SANDS	$C_u > 6$ and $1 < C_c < 3^e$	SW	Well-graded sand[i]
	50% or more of coarse fraction passes No. 4 sieve	Less than 5% fines[d]	$C_u < 6$ and/or $1 > C_c > 3^e$	SP	Poorly graded sand[i]
		SANDS WITH FINES	Fines classify as ML or MH	SM	Silty sand[g,h,i]
		More than 12% fines[d]	Fines classify as CL or CH	SC	Clayey sand[g,h,i]
FINE-GRAINED SOILS	SILTS AND CLAYS	Inorganic	PI > 7 and plots on or above "A"-line[j]	CL	Lean clay[k,l,m]
50% or more passes No. 200 sieve	Liquid limit less than 50		PI < 4 and plots below "A"-line[j]	ML	Silt[k,l,m]
		Organic	$\frac{LL_{oven\text{-}dried}}{LL_{natural}} < 0.75$	OL	Organic clay[k,l,m,n] Organic silt[k,l,m,o]
	SILTS AND CLAYS	Inorganic	PI plots on or above "A"-line	CH	Fat clay[k,l,m]
	Liquid limit 50 or more		PI plots below "A"-line	MH	Elastic silt[k,l,m]
		Organic	$\frac{LL_{oven\text{-}dried}}{LL_{natural}} < 0.75$	OH	Organic clay[k,l,m,p] Organic silt[k,l,m,q]
Highly organic soils		Primarily organic matter, dark in color, having organic odor		Pt	Peat

47

Unified Soil Classificat

Soil Categories

Fine-Grained Soils

- *more than 50% of soil by weight is smaller than 0.075 mm):*

- Silt (M):
  - *ML: Low plasticity silt.*
  - *MH: High plasticity silt.*
- Clay (C):
  - *CL: Low plasticity clay.*
  - *CH: High plasticity clay*

TABLE 2.7 Unified Soil Classification System

Criteria for Assigning Group Symbols and Group Names Using Laboratory Tests[a]				Soil Classification: Group Symbol	Soil Classification: Group Name[b]
(1)	(2)	(3)	(4)	(5)	(6)
COARSE-GRAINED SOILS	GRAVELS	CLEAN GRAVELS	$C_u \geq 4$ and $1 > C_c < 3^e$	GW	Well-graded gravel[f]
More than 50% retained on No. 200 sieve	More than 50% of coarse fraction retained on No. 4 sieve	Less than 5% fines[c]	$C_u < 4$ and/or $1 > C_c < 3^e$	GP	Poorly graded gravel[f]
		GRAVELS WITH FINES	Fines classify as ML or MH	GM	Silty gravel[f,g,h]
		More than 12% fines[c]	Fines classify as CL or CH	GC	Clayey gravel[f,g,h]
	SANDS	CLEAN SANDS	$C_u > 6$ and $1 < C_c < 3^e$	SW	Well-graded sand[i]
	50% or more of coarse fraction passes No. 4 sieve	Less than 5% fines[d]	$C_u < 6$ and/or $1 > C_c > 3^e$	SP	Poorly graded sand[i]
		SANDS WITH FINES	Fines classify as ML or MH	SM	Silty sand[g,h,i]
		More than 12% fines[d]	Fines classify as CL or CH	SC	Clayey sand[g,h,i]
FINE-GRAINED SOILS	SILTS AND CLAYS	Inorganic	PI > 7 and plots on or above "A"-line[j]	CL	Lean clay[k,l,m]
50% or more passes No. 200 sieve	Liquid limit less than 50		PI < 4 and plots below "A"-line[j]	ML	Silt[k,l,m]
		Organic	$\frac{LL_{oven\text{-}dried}}{LL_{natural}} < 0.75$	OL	Organic clay[k,l,m,n] Organic silt[k,l,m,o]
	SILTS AND CLAYS	Inorganic	PI plots on or above "A"-line	CH	Fat clay[k,l,m]
	Liquid limit 50 or more		PI plots below "A"-line	MH	Elastic silt[k,l,m]
		Organic	$\frac{LL_{oven\text{-}dried}}{LL_{natural}} < 0.75$	OH	Organic clay[k,l,m,p] Organic silt[k,l,m,q]
Highly organic soils		Primarily organic matter, dark in color, having organic odor		Pt	Peat

48

Unified Soil Classification System (USCS)

Limitations of USCS for road construction

- USCS limitation :
  - *Primarily focuses on physical properties (grain size, plasticity) without considering the engineering behavior in specific contexts.*
- Therefore, AASHTO system was
  - *Designed specifically for highway materials, focusing on performance-related characteristics.*
  - *AASHTO provides classifications that directly correlate with material performance for road construction.*

49

49

Soils

AASHTO Soil Classification System

50

50

Introduction to AASHTO Classification

- What is AASHTO?
  - *Developed by the American Association of State Highway and Transportation Officials.*
  - *A system to classify soils based on their suitability for road construction.*
- Purpose
  - *To determine how different soil types will perform as a highway subgrade.*
- Classify to two main groups:
  - *Granular Materials (A-1, A-3)*
  - *Silt-Clay Materials (A-4 to A-7)*

51

51

Basic Soil Groups

Feature	Granular Materials (A-1, A-3)	Silt-Clay Materials (A-4 to A-7)
Composition	Coarse materials (gravel, sand)	Fine materials (silt, clay)
Grain Size	Larger particle sizes	Smaller particle sizes
Plasticity	Low plasticity	High plasticity
Strength	High load-bearing capacity	Lower load-bearing capacity
Drainage	Excellent drainage	Poor drainage
Compaction	Easy to compact	Difficult to compact
Typical Uses	Ideal for highway subgrades	Often requires stabilization for use

52

52

Basic Soil Groups

Classifies soils into 7 main groups

- A-1 (Best for subgrade)
  - *A-1-a*
  - *A-1-b*
- A-2
  - *A-2-4 and A-2-5*
  - *A-2-6 and A-2-7*
- A-3
- A-4
- A-5
- A-6
- A-7 (Worst for subgrade)

53

53

A-1 Class (Granular Materials - Best Subgrade Soils)

A-1-a (Stone Fragments, Gravel, and Sand):

- Predominantly stone fragments or gravel, with or without binder.
- Contains 50% or more of gravel and coarse fragments.
- Less than 15% fines (passing the #200 sieve)
- **Uses**:
  - *Excellent for highway subgrades due to high strength, good drainage, and minimal plasticity.*

Soil Properties and their Correlations, Second Edition. Michael Carter and Stephen P. Bentley

54

54

A-1 Class (Granular Materials - Best Subgrade Soils)

A-1-b (Coarse Sand):

- Predominantly coarse sand with or without binder
- Contains 50% or more of coarse sand particles.
- Less than 25% of fine particles.
- Uses:
  - *Excellent for subgrades but slightly inferior to A-1-a due to the presence of more fines.*

Soil Properties and their Correlations, Second Edition.

Images source: https://www.youtube.com/watch?v=vT-xl0rCQuM

55

55

A-3 Class (Fine Sand - Marginal Subgrade Soils)

- Composed primarily of fine sand with very few fines or clay particles.
  - *Typically, fine beach or desert sand*
- Less than 10% fines.
- Uses:
  - *Generally poor for subgrade material, although it has good drainage.*
  - *Suitable for lightly loaded or temporary roads.*

Soil Properties and their Correlations, Second Edition. Michael Carter and Stephen P. Bentley

Images source: https://www.youtube.com/watch?v=vT-xl0rCQuM

56

56

A-4 Class (Silty Soils - Poor Subgrade Soils)

- Silty soil with moderate plasticity.
  - *Liquid Limit (LL) < 40.*
  - *usually with a high percentage passing the 0.075 mm sieve.*
- Uses:
  - *Not ideal for subgrades without stabilization.*
  - *Prone to poor drainage and low strength, especially in wet conditions.*

Silt Soil

Image source: https://www.boughton.co.uk/products/topsoils/soil-types/

57

57

A-5 Class (High Liquid Limit Silty Soils)

- Similar to A-4 but with higher plasticity.
  - *Silty soil with High plasticity.*
  - *Liquid Limit (LL) > 40.*
  - *usually with a high percentage passing the 0.075 mm sieve.*
- Uses:
  - *Performs poorly as a subgrade due to high compressibility and poor load-bearing capacity.*
  - *Requires stabilization for use..*

Silt Soil

Soil Properties and their Correlations, Second Edition.

Image source: https://www.boughton.co.uk/products/topsoils/soil-types/

58

58

A-6 Class (Clayey Soils - Very Poor Subgrade Soils)

- High plastic clay soil,.
  - *Liquid Limit (LL) < 40*
  - *Plasticity Index (PI) > 10.*
  - *having a high percentage passing the 0.075 mm sieve.*
  - *prone to shrink and swell with moisture content changes*
- Materials in this group have a high-volume change between wet and dry states.
- Uses:
  - *Very poor for subgrade material,*
  - *often requiring chemical stabilization (lime or cement) to improve performance.*

A-7 Class (Highly Plastic Clayey Soils - Worst Subgrade Soils)

- Similar to material described under group A-6 except that it has
  - *high liquid limit characteristic of group A-5*
  - *may be elastic as well as* ***subject to high volume change****.*
- Subgroup
  - A-7-5
  - A-7-6

A-7 Class (Highly Plastic Clayey Soils - Worst Subgrade Soils)

A-7-5: Low to moderate plasticity.

- Materials have moderate plasticity indices in relation to the liquid limits
  - *Liquid Limit (LL) > 40,*
  - *but moderate Plasticity Index (PI)*
    - PI =< LL - 30
- Subject to volume change.
- Uses:
  - *Poor subgrade material; must be stabilized for any significant use.*

Image source: https://www.youtube.com/watch?v=vTxIOrCQuM

A-7 Class (Highly Plastic Clayey Soils - Worst Subgrade Soils)

A-7-6: Highly plastic clayey soils.

- Materials have high plasticity indices in relation to the liquid limits
  - *Liquid Limit (LL) > 40,*
  - *high Plasticity Index (PI > 11)*
  - *PI > LL - 30*
- Subject to **extremely high-volume change**
- **Uses**:
  - *Extremely poor subgrade material.*
  - *Susceptible to drastic volume changes with moisture variations, making it unsuitable without stabilization*

Image source: https://www.youtube.com/watch?v=vTxIOrCQuM

A-2 Class (Granular Materials with Fines - Variable Subgrade Soils)

- It Includes
  - *a wide variety of 'granular' materials Which are borderline between the granular A-I and A-3 groups and the silty clay materials of groups A-4 to A-7.*
- They are classified into several subgroups based on the percentage of fines and plasticity characteristics.
  - *A-2-4*
  - *A-2-5*
  - *A-2-6*
  - *A-2-7*

A-2 Class

A-2-4 (Silty Gravel or Silty Sand)

- Composition:
  - *Contains a moderate percentage of fine particles (10 - 35% passing the #200 sieve).*
  - *Typically has a higher gravel or coarse sand content.*
- Moderate plasticity
  - *Typically, less than 10% fines.*
  - *LL < 40,*
  - *PI < 10.*
- Uses:
  - *Suitable for subgrade in lightly trafficked roads.*
  - *Can be used in embankments and backfill applications.*

A-2 Class

A-2-5 (Clayey Gravel or Clayey Sand)

- Composition:
  - *Similar to A-2-4 but with a higher clay content.*
  - *Contains 10-35% fines, with some clay particles contributing to plasticity.*
- Moderate to high plasticity.
  - *LL typically between 25 - 40,*
  - *PI between 7-12.*
- Uses:
  - *Acceptable for subgrade, but caution is needed for heavily trafficked areas.*
  - *Commonly used in structural fills and embankments with proper compaction.*

Soil Properties and their Correlations, Second Edition.

Images source: https://www.youtube.com/watch?v=vT-xl0rCQuM

65

65

A-2 Class

A-2-6 (Clayey Sand)

- Composition:
  - *Contains significant clay content, with 15-30% fines.*
  - *Characterized by its sandy texture with clay inclusions.*
- High plasticity,
  - *potentially problematic in wet conditions.*
  - *LL > 40,*
  - *PI > 10.*
- Uses:
  - *Generally not recommended for subgrade without treatment or stabilization.*
  - *May be used in low-traffic areas with proper moisture control.*

Soil Properties and their Correlations, Second Edition.

Images source: https://www.youtube.com/watch?v=vT-xl0rCQuM

66

66

A-2 Class

A-2-7 (Silty Clay)

- Composition:
  - *Contains a high percentage of fines (30-50% passing the #200 sieve).*
  - *Predominantly clayey with silt.*
- Very high plasticity.
  - *LL > 40,*
  - *PI > 12.*
- Uses:
  - *Unsuitable for subgrade without extensive stabilization (lime, cement).*
  - *Typically used in controlled environments or structures that can accommodate movement.*

Soil Properties and their Correlations, Second Edition.

Images source: https://www.youtube.com/watch?v=vT-xl0rC0uM

67

67

Group A-8

- Composition:
  - *Contains a significant amount of organic matter, highly plastic clays, or mixtures that lead to unpredictable engineering properties.*
- Plasticity Index (PI):
  - *Often high due to the organic content.*
- Behavior:
  - *Generally poor load-bearing capacity, high compressibility, and significant shrink-swell potential.*
- Uses:
  - *Typically avoided for subgrade applications without significant treatment or stabilization.*

68

68

AASHTO Soil Classification System

Classification Procedures

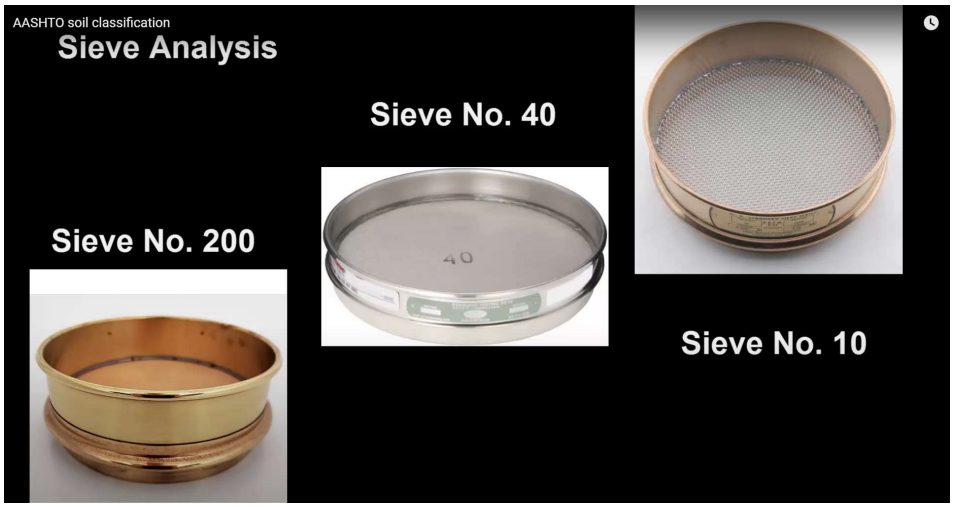
69

69

Soil Properties for Classification

Grain Size Distribution:

- Gravel and sand
  - *Fraction retained on the No. 200 (0.075-mm)*
- Silt and clay :
  - *Fraction passing the No. 200*



70

70

Soil Properties for Classification

Atterberg Limits:

- Liquid Limit (LL):
  - *The moisture content at which the soil changes from plastic to liquid state.*
- Plastic Limit (PL):
  - *The moisture content at which the soil changes from semi-solid to plastic state.*
- Plasticity Index (PI):
  - $PI = LL - PL$

71

71

Classification Procedures

1. Sample Collection:
   - *Collect undisturbed soil samples from the site.*
2. Sieve Analysis:
   - *Conduct a sieve analysis to determine the distribution of particle sizes.*
3. Atterberg Limits Testing:
   - *Perform LL and PL tests to obtain plasticity values.*
4. Assigning AASHTO Group Symbols:
   - *Use results from grain size distribution and Atterberg limits to classify according to AASHTO guidelines.*
   1. *Apply the test data from **left** to **right***
   2. *Apply process of elimination,*
      - The first group from the left into which the test data fit is the correct classification
5. Interpretation of Results:
   - *Assess suitability for engineering applications based on AASHTO group*

72

72

GENERAL CLASSIFICATION	GRANULAR MATERIALS (35% or less passing 0.075mm sieve)							SILT-CLAY MATERIALS (> 35% passing 0.075mm sieve)			
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
Sieve analysis, % passing:											
2mm (No. 10)	50 max	–	–	–	–	–	–	–	–	–	–
0.425mm (No. 40)	30 max	50 max	51 min	–	–	–	–	–	–	–	–
0.075mm (No. 200)	10 max	25 max	10 max	35 max	35 max	35 max	35 max	36 min	36 min	36 min	36 min
Fraction passing 0.425mm:											
Liquid limit	–		Non-plastic	40 max	41 min	40 max	41 min	40 max	41 min	40 max	41 min
Plasticity index	6 max			10 max	10 max	11 min	11 min	10 max	10 max	11 min	11 min*
Usual types of significant constituents	Stone fragments, gravel, sand		Fine sand	Silty or clayey gravel and sand				Silty soils		Clayey soils	
General rating as a subgrade	Excellent to good							Fair to poor			

* Plasticity index of A-7-5 subgroup is equal to or less than liquid limit – 30.
* Plasticity index of A-7-6 subgroup is greater than liquid limit – 30.

73

73

AASHTO Soil Classification System

Group Index

74

74

AASHTO Soil Classification System

Group Index (GI)

- Evaluate the quality of a soil as highway subgrade material
  - *Originally the group index was used directly to obtain pavement thickness designs, using the 'group index method'*
  - *but this approach has long since been superseded and **the group index is used only as a guide.***
- In general, the quality of performance of a soil as a subgrade material is **inversely** proportional to the group index
  - *Higher GI indicate poor performance materials*

GI value	Quality of material
0 to 1	Good subgrade material
2 to 4	Fair subgrade material
5 to 9	Poor subgrade material
10 to 20	Very poor subgrade material

75

75

AASHTO Soil Classification System

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

% passing No. 200

Partial Index for A-2-6 and A-2-7

$$GI = (F_{200} - 35)[0.2 + 0.005(LL - 40)] + 0.01(F_{200} - 15)(PI - 10)$$

Partial GI determined from *LL*

Partial GI determined from *PI*

F_{200} :The percentage passing the 75μm (0.075mm) sieve, expressed as a whole number
LL : Liquid Limit.
PI : Plasticity Index (nearest whole number)

76

76

AASHTO Soil Classification System

Rules for the computed GI

$$GI = (F_{200} - 35)[0.2 + 0.005(LL - 40)] + 0.01(F_{200} - 15)(PI - 10)$$

- This index is written in parentheses after the group or subgroup classification
  - *A-7 (35)*
- IF the computed GI has a negative value,
  - *then it taken as GI=0*
- There is no upper limit for the group index
- The computed GI is rounded to the nearest whole number
  - GI = 3.4 is rounded off to 3
  - GI = 3.5 is rounded off to 4
- The group index of soils belonging to groups A-1-a, A-1-b, A-2-4, A-2-5, and A-3 is always 0
- When calculating the group index for soils that belong to groups A-2-6 and A-2-7 use this formula
  - *GI = 0.01 (F_{200}-15)(PI - 10)*

77

77

Table 3 – DGI Based on Soil Type

Soil Classification	Estimated DGI Range
A-3 Clean Sand	0 to 2
A-1 Gravelly Sand A-2 Non-plastic Sand with Silt	2 to 4
A-2 Plastic Silty or Clayey Sand A-4 Sandy Silt	10 to 12
A-4 Silt A-6 Lighter Clayey Silt	12 to 14
A-6 Heavier Clayey Silt A-7 Silty Clay and Clay	14 to 16

78

78

AASHTO Soil Classification System

Examples

79

79

AASHTO Soil Classification System

Example -1

The results of the particle-size analysis of a soil are as follows:

Percent passing through the No. 10 sieve = 100
Percent passing through the No. 40 sieve = 80
Percent passing through the No. 200 sieve = 58

The liquid limit and plasticity index of the minus No. 40 fraction of the soil are 30 and 10, respectively. Classify the soil by the AASHTO system.

80

80

AASHTO Classification System

Example -1 _ Solution

% pass No. 10 = 100

% pass No. 40 = 80

% pass No. 200 = 58

LL=30

PI =10

Table 17.1 AASHTO Classification of Soils and Soil Aggregate Mixtures

General Classification	*Granular Materials (35% or Less Passing No. 200)*							*Silt-Clay Materials (More than 35% Passing No. 200)*			
	A-1			*A-2*							*A-7*
Group Classification	*A-1-a*	*A-1-b*	*A-3*	*A-2-4*	*A-2-5*	*A-2-6*	*A-2-7*	*A-4*	*A-5*	*A-6*	*A-7-5, A-7-6*
Sieve analysis Percent passing											
No. 10	−50 max.	–	–	–	–	–	–	–	–	–	
No. 40	30 max.	50 max.	51 min.	–	–	–	–	–	–	–	–
No. 200	15 max.	25 max.	10 max.	35 max.	35 max.	35 max.	35 max.	36 min.	36 min.	36 min.	36 min.
Characteristics of fraction passing No. 40:											
Liquid limit	–		–	40 max.	41 min.	40 max.	41 min.	40 max.	41 min.	40 max.	41 min.
Plasticity index	6 max.		N.P.	10 max.	10 max.	11 min.	11 min.	10 max.	10 max.	11 min.	11 min.*
Usual types of significant constituent materials	Stone fragments, gravel and sand		Fine sand	Silty or clayey gravel and sand				Silty soils		Clayey soils	
General rating as subgrade	Excellent to good							Fair to poor			

*Plasticity index of A-7-5 subgroup ≤ LL − 30. Plasticity index of A-7-6 subgroup > LL − 30.

SOURCE: Adapted from *Standard Specifications for Transportation Materials and Methods of Sampling and Testing*, 27th ed., Washington, D.C., The American Association of State Highway and Transportation Officials, copyright 2007. Used with permission.

81

81

AASHTO Soil Classification System

Example -1 _ Solution

Solution

Using Table 4.1, since 58% of the soil is passing through the No. 200 sieve, it falls under silt-clay classifications – that is, it falls under group A-4, A-5, A-6, or A-7. Proceeding from left to right, it falls under group A-4.

From Eq. (4.1),

$$GI = (F_{200} - 35)[0.2 + 0.005(LL - 40)] + 0.01(F_{200} - 15)(PI - 10)$$

$$= (58 - 35)[0.2 + 0.005(30 - 40)] + (0.01)(58 - 15)(10 - 10)$$

$$= 3.45 \simeq 3$$

So, the soil will be classified as **A-4(3)**. ■

82

82

AASHTO Classification System

Example -1 _ Solution

% pass No. 10 = 100

% pass No. 40 = 80

% pass No. 200 = 58

LL=30

PI =10

Table 17.1 AASHTO Classification of Soils and Soil Aggregate Mixtures

General Classification	*Granular Materials (35% or Less Passing No. 200)*							*Silt-Clay Materials (More than 35% Passing No. 200)*			
	A-1			*A-2*							*A-7*
Group Classification	*A-1-a*	*A-1-b*	*A-3*	*A-2-4*	*A-2-5*	*A-2-6*	*A-2-7*	*A-4*	*A-5*	*A-6*	*A-7-5, A-7-6*
Sieve analysis Percent passing											
No. 10	−50 max.	–	–	–	–	–	–	–	–	–	
No. 40	30 max.	50 max.	51 min.	–	–	–	–	–	–	–	–
No. 200	15 max.	25 max.	10 max.	35 max.	35 max.	35 max.	35 max.	36 min.	36 min.	36 min.	36 min.
Characteristics of fraction passing No. 40:											
Liquid limit	–		–	40 max.	41 min.	40 max.	41 min.	40 max.	41 min.	40 max.	41 min.
Plasticity index	6 max.		N.P.	10 max.	10 max.	11 min.	11 min.	10 max.	10 max.	11 min.	11 min.*
Usual types of significant constituent materials	Stone fragments, gravel and sand		Fine sand	Silty or clayey gravel and sand				Silty soils		Clayey soils	
General rating as subgrade	Excellent to good							Fair to poor			

*Plasticity index of A-7-5 subgroup ≤ LL − 30. Plasticity index of A-7-6 subgroup > LL − 30.

SOURCE: Adapted from *Standard Specifications for Transportation Materials and Methods of Sampling and Testing*, 27th ed., Washington, D.C., The American Association of State Highway and Transportation Officials, copyright 2007. Used with permission.

83

83

AASHTO Soil Classification System

Example -2

For a soil, given

Sieve No.	Percent passing
4	90
10	76
200	34

Liquid limit = 37

Plasticity index = 12

Classify the soil by the AASHTO system.

84

84

AASHTO Classification System

Example -2 _ Solution

For a soil, given

Sieve No.	Percent passing
4	90
10	76
200	34

Liquid limit = 37
Plasticity index = 12
Classify the soil by the AASHTO system.

Table 17.1 AASHTO Classification of Soils and Soil Aggregate Mixtures

General Classification	*Granular Materials (35% or Less Passing No. 200)*							*Silt-Clay Materials (More than 35% Passing No. 200)*			
	A-1			*A-2*							*A-7*
Group Classification	*A-1-a*	*A-1-b*	*A-3*	*A-2-4*	*A-2-5*	*A-2-6*	*A-2-7*	*A-4*	*A-5*	*A-6*	*A-7-5, A-7-6*
Sieve analysis Percent passing											
No. 10	−50 max.	–	–	–	–	–	–	–	–	–	
No. 40	30 max.	50 max.	51 min.	–	–	–	–	–	–	–	–
No. 200	15 max.	25 max.	10 max.	35 max.	35 max.	35 max.	35 max.	36 min.	36 min.	36 min.	36 min.
Characteristics of fraction passing No. 40:											
Liquid limit	–		–	40 max.	41 min.	40 max.	41 min.	40 max.	41 min.	40 max.	41 min.
Plasticity index	6 max.		N.P.	10 max.	10 max.	11 min.	11 min.	10 max.	10 max.	11 min.	11 min.*
Usual types of significant constituent materials	Stone fragments, gravel and sand		Fine sand	Silty or clayey gravel and sand				Silty soils		Clayey soils	
General rating as subgrade	Excellent to good							Fair to poor			

*Plasticity index of A-7-5 subgroup ≤ LL − 30. Plasticity index of A-7-6 subgroup > LL − 30.
SOURCE: Adapted from *Standard Specifications for Transportation Materials and Methods of Sampling and Testing*, 27th ed., Washington, D.C., The American Association of State Highway and Transportation Officials, copyright 2007. Used with permission.

85

85

AASHTO Classification System

Example -3 solution

Solution

The percentage passing through the No. 200 sieve is less than 35, so the soil is a granular material. From Table 4.1, we see that it is type A-2-6. From Eq. (4.2),

$$GI = 0.01(F_{200} - 15)(PI - 10)$$

For this soil, $F_{200} = 34$ and $PI = 12$, so

$$GI = 0.01(34 - 15)(12 - 10) = 0.38 \approx 0$$

Thus, the soil is type **A-2-6(0)**. ■

86

86

Main Soil Groups for Road Construction

Comparison of soil groups in the Unified and AASHTO systems

87

87

Comparison of soil groups in the Unified and AASHTO systems

Comparing Unified ASTM with AASHTO

Unified/ASTM soil group	Most probable AASHTO soil group
GW	A-1-a
GP	A-1-a
GM	A-1-b, A-2-4 A-2-5, A-2-7
GC	A-2-6, A-2-7
SW	A-1-b
SP	A-3, A-1-b
SM	A-1-b, A-2-4 A-2-5, A-2-7
SC	A-2-6, A-2-7
ML	A-4, A-5
CL	A-6, A-7-6
OL	A-4, A-5
MH	A-7-5, A-5
CH	A-7-6
OH	A-7-5, A-5
Pt	–

Comparing AASHTO with Unified ASTM

AASHTO soil group	Most probable Unified/ASTM soil group
A-1-a	GW, GP
A-1-b	SW, SP, GM, SM
A-3	SP
A-2-4	GM, SM
A-2-5	GM, SM
A-2-6	GC, SC
A-2-7	GM, GC, SM, SC
A-4	ML, OL
A-5	OH, MH, ML, OL
A-6	OL
A-7-5	OH, OM
A-7-6	CH, CL

Soil Classification	
Group Symbol	Group Name[b]
(5)	(6)
GW	Well-graded gravel[f]
GP	Poorly graded gravel[f]
GM	Silty gravel[f,g,h]
GC	Clayey gravel[f,g,h]
SW	Well-graded sand[i]
SP	Poorly graded sand[i]
SM	Silty sand[g,h,i]
SC	Clayey sand[g,h,i]
CL	Lean clay[k,l,m]
ML	Silt[k,l,m]
OL	Organic clay[k,l,m,n] Organic silt[k,l,m,o]
CH	Fat clay[k,l,m]
MH	Elastic silt[k,l,m]
OH	Organic clay[k,l,m,p] Organic silt[k,l,m,q]
Pt	Peat

Soil Properties and their Correlations, Second Edition. Michael Carter and Stephen P. Bentley

88