Wood Environment & Infrastructure Solutions, Inc.

Geotechnical Investigations for Airfield Pavements

Presented to :
Association of Georgia General Aviation Airports
2022 Annual Conference

AGGAA
ASSOCIATION OF GEORGIA GENERAL AVIATION AIRPORTS

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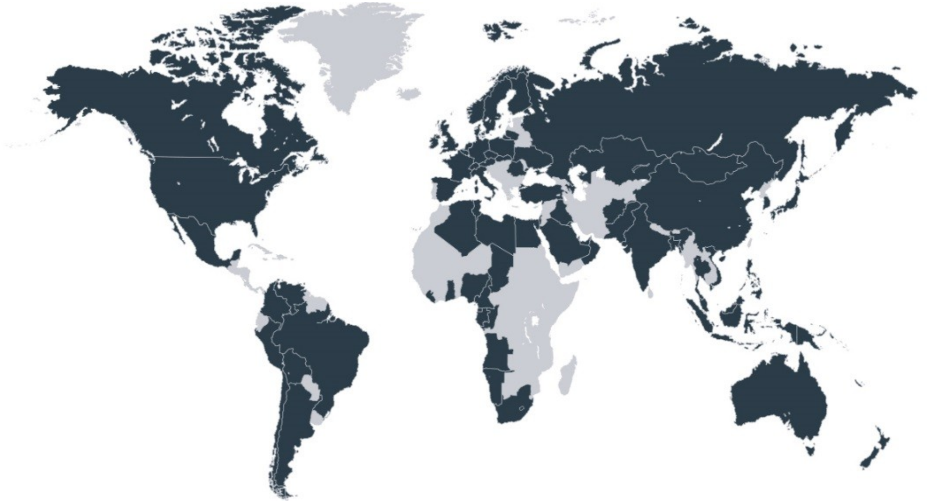

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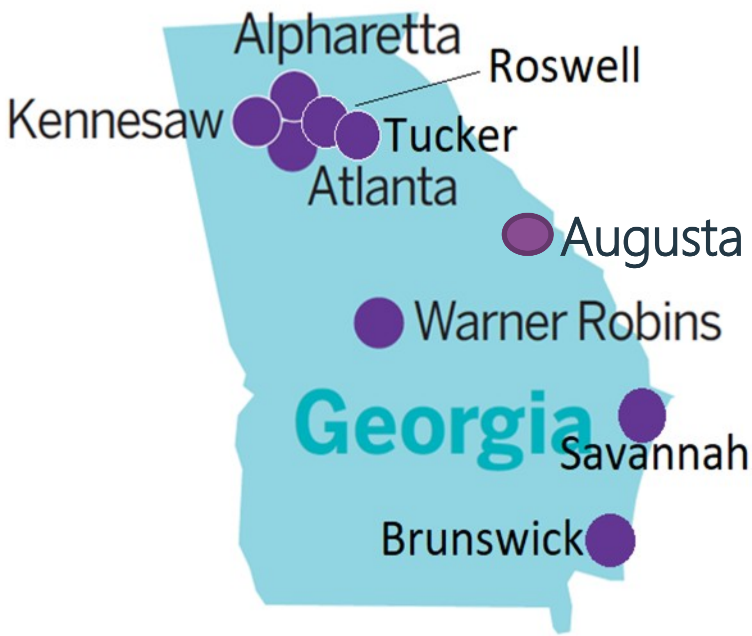
Georgia Area



- Locally serving our customers for over 75 years
- Ranked #1 among Atlanta's Top 25 Engineering Firms by the *Atlanta Business Chronicle*
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- Office focus:
  - Atlanta – Environmental, Geotechnical, CMT, Facility Services, Lab
  - Kennesaw – Environmental, Facility Services, Information Management

Presenter

- Richard L. Curtis, PE, D.GE, F.ASCE
- Senior Associate Geotechnical Engineer with Wood E & I S
- BCE and MSCE from Georgia Tech
- PE in AL, CA, GA, KY, LA, MD, MS, NC, OH, SC and TN
- Over 40 years of geotechnical experience in the SE
- First airport project was the Midfield Terminal of the Hartsfield Atlanta International Airport working as a Georgia Tech co-op student. Involved in concrete and asphalt testing in late 1970's.

Geotechnical – What is it?

- Foundations
- Earthwork (fill)
- Excavation
- Slabs/pavements
- Retaining walls
- Slopes
- Drainage
- Seismic issues
- Dams
- Other Geohazards

Selecting a Qualified Geotechnical Firm

- Local experience: soil/rock conditions, geology, designers, contractors
- Experience with similar projects
- Qualifications, experience and communication skills of the geotechnical project manager/senior reviewer
- Past working relationship with the design team
- Quality of services: based on references
- Quality of drilling services
- Quality of laboratory and experience of laboratory personnel

Objectives of Geotechnical Exploration

From FAA Advisory Circular for Airport Pavement Design and Evaluation

- To assess soil type and properties for all soils encountered on the project. Collect and identify representative samples to determine:
  - Distribution, profile, physical properties, location and arrangement of various soils;
  - Site topography;
  - Location of water table;
  - Climate data, including frequency of water inundation;
  - Availability/suitability of local aggregate materials for use in construction of pavement structure; and
  - Locations/soil properties of possible additional borrow areas, if needed.

Determining Scope of Work

Information Required:

- Existing site conditions (topography, features, structures, etc.)
- Proposed facility layout
- Type and size of structure(s)
- Structural loads (including any slab/area loads)
- Proposed grading plan (cut and fill depths)
- Traffic loading conditions (pavement design)
- Project construction schedule (some solutions may be less costly but take substantially more time)

Determining Scope of Work

FAA Recommendations for new construction

Table 2-1. Typical Subsurface Boring Spacing and Depth for New Construction[1,2]

Area	Spacing	Depth
Runways, Taxiways and Taxilanes	Random Across Pavement at 200-foot (60 m) Intervals	Cut Areas – 10 ft (3 m) Below Finished Grade Fill Areas – 10 ft (3 m) Below Existing Ground
Other Areas of Pavement	1 Boring per 10,000 Square Feet (930 sq m) of Area	Cut Areas - 10 ft (3 m) Below Finished Grade Fill Areas – 10 ft (3 m) Below Existing Ground
Borrow Areas	Sufficient Tests to Clearly Define the Borrow Material	To Depth of Borrow Excavation

Note 1: Boring depths should be sufficient to determine if consolidation and/or location of slippage planes will impact the pavement structure.

Note 2: Follow geotechnical engineer recommendations for depth of borings when fill greater than 10 feet.

Determining Scope of Work

FAA Recommendations for rehabilitation projects

- Review as-built plans
- Review previous geotechnical reports
- Supplement with nondestructive testing (NDT) or minimally destructive testing sufficient to characterize and verify type and quality of subgrade material
- NDT/minimally destructive testing can consist of falling weight deflectometer (FWD), heavy weight deflectometer (HWD) ground penetrating radar (GPR) or dynamic cone penetrometer (DCP) tests
- If pavement rehabilitation/reconstruction is due to subgrade failure, sufficient borings to characterize subgrade that needs to be improved or replaced.

Geotechnical Exploration Planning/Scoping

Develop a preliminary concept of subsurface conditions from:

- Geologic maps
- Soil survey data
- USGS topographic maps (with historical maps)
- Previous geotechnical reports
- Geotechnical reports/experience in the general area

Integrate the planned construction concept with anticipated subsurface conditions to develop an appropriate exploration program

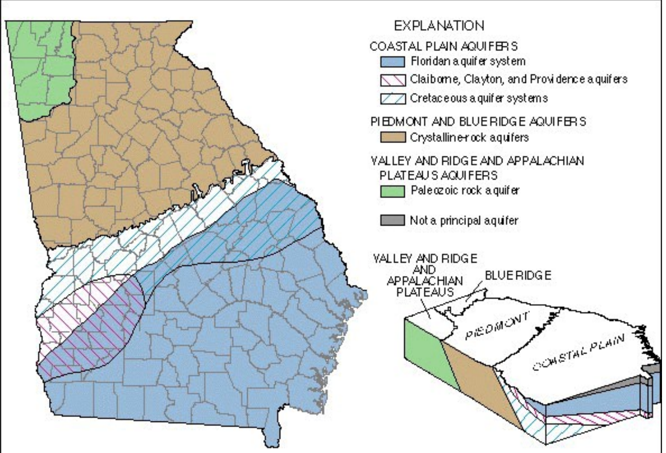
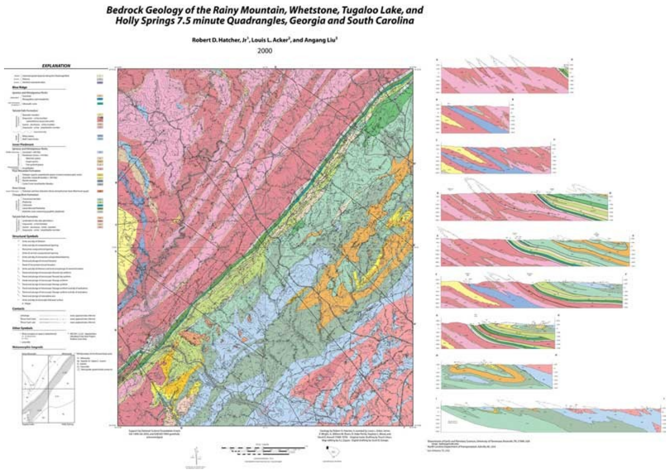


Figure 1. Area of use of principal aquifers and generalized diagram showing aquifers and physiographic provinces in Georgia.

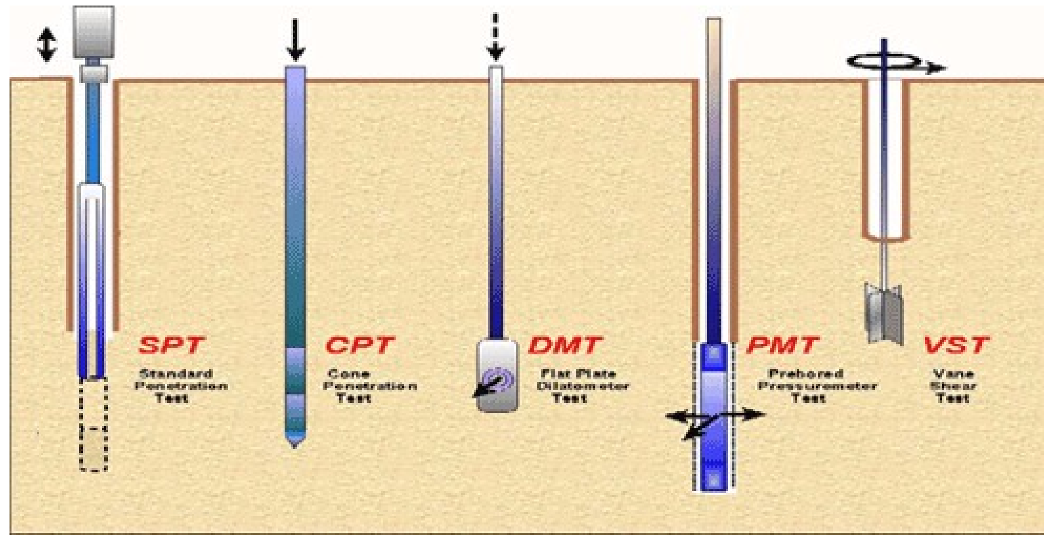


Geology

- Piedmont/Blue Ridge
  - Used to be big (Andes-like) mountains
  - Weathered/eroded down
  - Silt/sand/mica – not much clay
  - Hard Bedrock (gneiss/schist/granite)
- Ridge and Valley
  - Old limestone/sandstone/shale
  - Clay/sand/silt
  - Karst (sinkholes) in some areas
- Coastal Plain
  - Eroded from Piedmont
  - Young rocks
  - Crystalline rocks very deep
  - Clay/sand
  - Karst in some areas

Field Exploration Techniques

- Drilling test borings: hollow-stem augers, rotary wash
- Test pits: limited depth but large visual area
- Sampling: SPT with split-spoon, undisturbed samples, bulk samples
- Rock coring
- In-situ testing (other than SPT): cone – CPT; dilatometer – DMT; pressuremeter – PMT
- Geophysical: seismic refraction, resistivity, GPR, etc.



Rig Selection

- Truck Mounted for cleared/level sites or previously developed.
- All-Terrain Vehicles: Track mounted or Mud-bug for difficult access or where clearing is required.
- Skid/trailer mounted or tripod for steeply sloping sites or indoor drilling.





Soil Samples

Typical split-spoon sample. Note: this is not an undisturbed sample.

Samples are less than 1½-inch in diameter and less than 18 inches long (usually don't get 100% recovery).

Bulk samples (large bag or bucket samples) are used for compaction and CBR tests

Undisturbed samples (thin-walled Shelby tubes) (3-in. diameter sample for strength or consolidation testing).

Pavement Coring

For existing pavement, coring is performed to determine the existing pavement and base conditions (type and thickness)

Existing subgrade conditions can be evaluated immediately under the pavement/base by conducting a boring through the cored hole.

wood.

Table of Pavement Thickness Measurements

Wood Project No.: 6162-22-XXXX

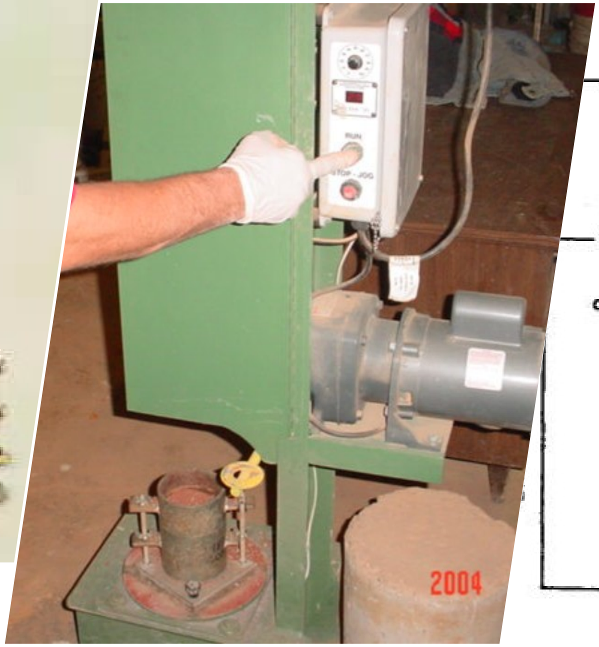
Core Location	Pavement Thickness (inches)	
	Asphalt	Stone/GAB*
C-1	5	4
C-2	4 ¼	4
C-3	4 ½	4
C-4	5	5
C-5	3 ¼	4
C-6	4 ¾	4

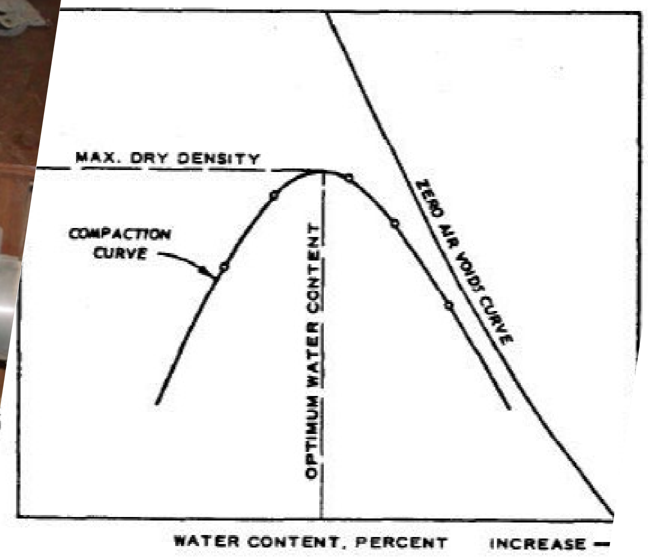
Laboratory Testing Program

- Typical minimum: Moisture content, grain size and Atterberg Limits for classification (shrink/swell potential)
- Moisture-density (Proctor) tests for fill compaction
- California bearing ratio (CBR) tests for pavement design
- Consolidation tests for settlement analysis
- Triaxial compression/direct shear tests for strength properties, typically used for slopes, retaining walls, deep foundations, shoring, etc.
- Permeability tests for dewatering/drainage design

Laboratory Testing Program

Moisture-density (Proctor) or compaction tests

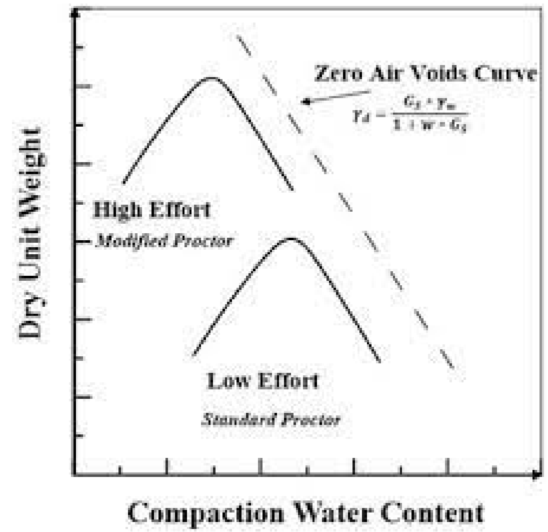


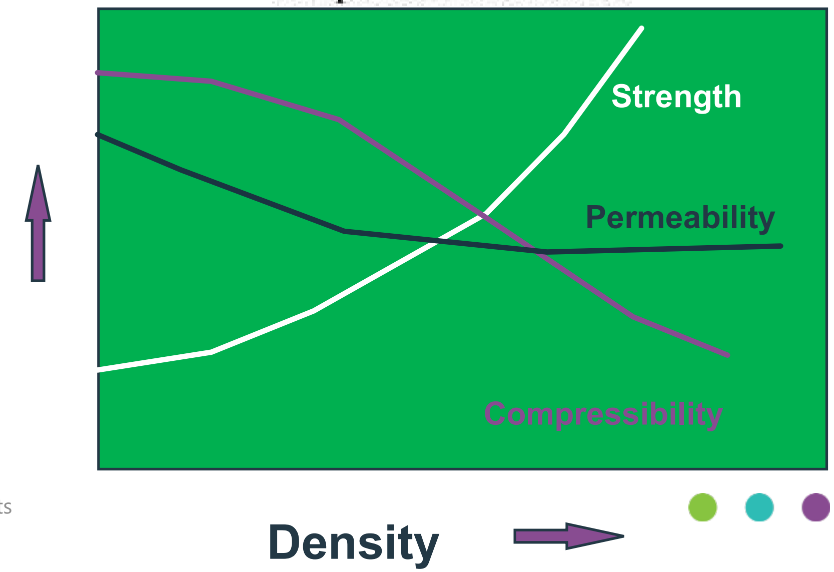


Laboratory Testing Program

Moisture-density (Proctor) or compaction tests

- Two types of tests based on compaction effort, Standard or Modified
- Standard uses a 5.5-lb hammer dropping 12 inches: to simulate light rollers or tamping
- Modified uses a 10-lb hammer dropping 18 inches: to simulate heavy rollers.
- Soil Density is related to soil strength, compressibility and permeability



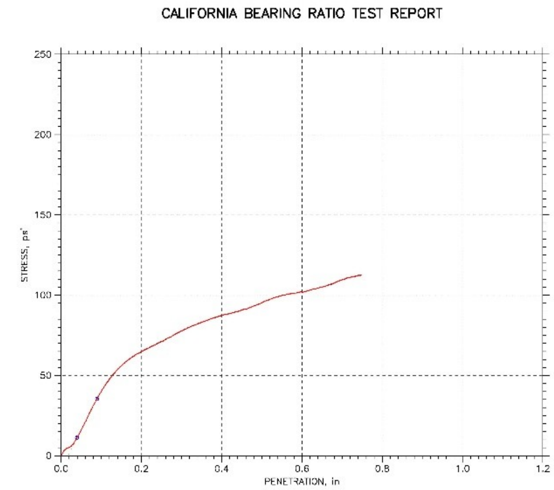


Laboratory Testing Program

California Bearing Ratio (CBR) tests

CBR tests are used to determine the strength of subgrade for pavements.

The CBR test is a penetration test where a piston is pushed into a soil sample at a uniform strain rate. The force required to produce a given penetration is compared to the force required to produce the same penetration in standard crushed stone.



Sample Height: 4.581 in	California Bearing Ratio			
Sample Area: 28.274 in^2	at 0.1 in: 5	at 0.3 in: 4	at 0.5 in: 4	
Sample Volume: 129.52 in^3	at 0.2 in: 4	at 0.4 in: 4		
Sample Mass: 4032.5 gm				
Sample Condition: Soaked	Water Content	Before	Top	Average
Swell: 1.18 %	Tare ID	F-219	1710	F-219
Surcharge: 259 gm	Tare Mass, gm	4.2	4153.8	4.2
Void Ratio: 0.60	Mass Tare + Wet Soil, gm	208.1	8816.3	208.1
Wet Unit Weight: 118.6 pcf	Mass Tare + Dry Soil, gm	185.4	97	160.8
Dry Unit Weight: 105.4 pcf	Water Content, %	12.53	0.00	30.20

wood.	Project: [redacted]	Location: N/A	Project No.: 6162211965
	Boring No.: C-7	Tested By: D. Camper	Checked By: T.Zhao
	Sample No.: 21026-10	Test Date: 2-21-2022	Depth: 1'
	Test No.: 21026-10	Sample Type: Soil	Elevation: N/A
	Description: Dark Grey Silty SAND		
	Remarks:		

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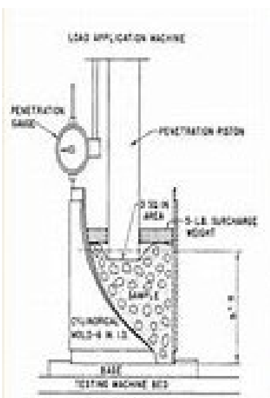


Laboratory Testing Program

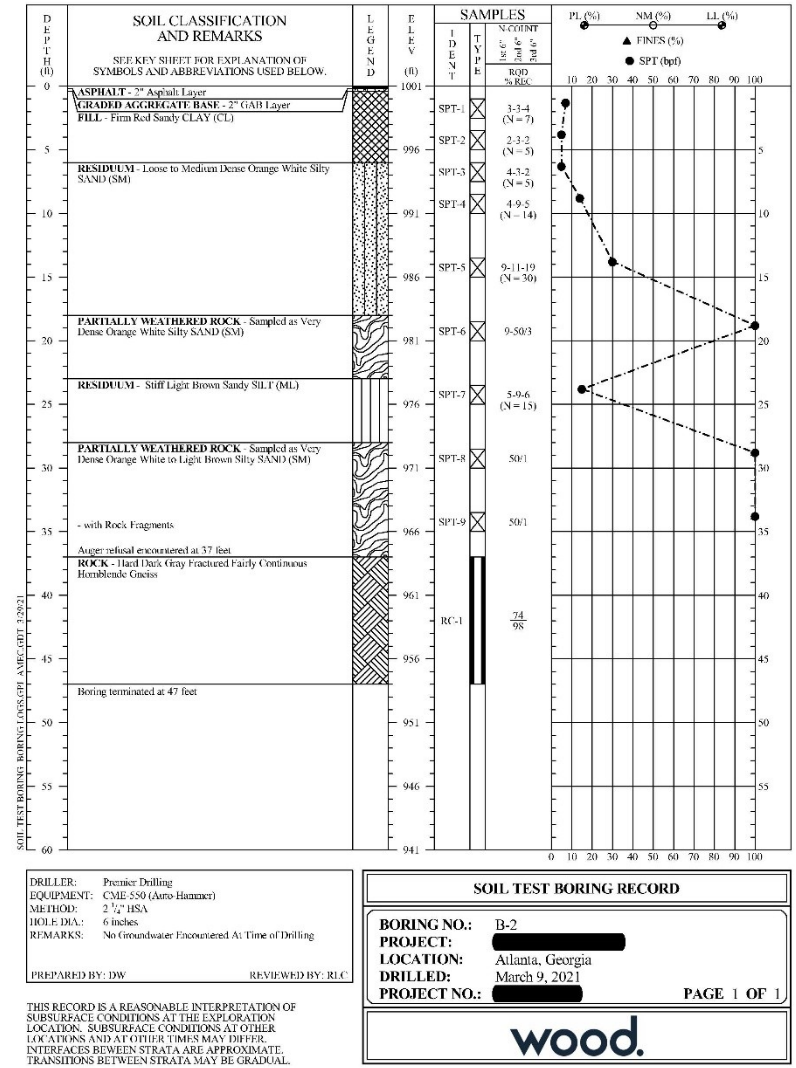
California Bearing Ratio (CBR) tests

- Tests performed on remolded
- Samples are soaked for 4 days to simulate condition of a pavement that has been in service
- If pavement program uses Elastic Modulus,
  E (psi) = 1500 x CBR
- For rigid/concrete pavement design, a modulus of subgrade reaction (k-value) is used, correlated with CBR:
  $k \text{ (pci)} = 28.6926 \times CBR^{0.7788}$

Major Divisions		Letter	Name	Value as Foundation When Not Subject to Frost Action	Value as Base Directly under Wearing Surface	Potential Frost Action	Shrink and Swell	Drainage Characteristic	Unit Dry Weight (pcf)	CBR	Subgrade Modulus k (pci)
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Coarse-gravelly soils	Gravel and gravelly soils	GW	Gravel or sandy gravel, well graded	Excellent	Good	None to very slight	Almost none	Excellent	125-140	60-80	300 or more
		GP	Gravel or sandy gravel, poorly graded	Good	Poor to fair	None to very slight	Almost none	Excellent	120-130	35-60	300 or more
		GU	Gravel or sandy gravel, uniformly graded	Good to excellent	Poor	None to very slight	Almost none	Excellent	115-125	25-50	300 or more
		GM	Silty gravel or silty sandy gravel	Good	Fair to good	Slight to medium	Very slight	Fair to poor	130-145	40-80	300 or more
		GC	Clayey gravel or clayey sandy gravel	Good to excellent	Poor	Slight to medium	Slight	Poor to practically impervious	120-140	20-40	200-300
	Sand and sandy soils	SW	Sand or gravelly sand, well graded	Good	Poor to not suitable	None to very slight	Almost none	Excellent	110-130	20-40	200-300
		SP	Sand or gravelly sand, poorly graded	Fair to good	Not suitable	None to very slight	Almost none	Excellent	105-120	15-25	200-300
		SU	Sand or gravelly sand, Poor uniformly Not suitablegraded	Fair to good	Poor	None to very slight	Almost none	Excellent	100-115	10-20	200-300
		SM	Silty sand or silty gravelly sand	Good	Not suitable	Slight to high	Very slight	Fair to poor	120-135	20-40	200-300
		SC	Clayey sand or clayey gravelly sand	Fair to good	Not suitable	Slight to high	Slight to medium	Poor to practically impervious	105-130	10-20	200-300
Fine grained soils	Low compress ibility LL<50	ML	Silts, sandy silts, gravelly silts, or diatomaceous soils	Fair to good	Not suitable	Medium to very high	Slight to medium	Fair to poor	100-125	5-15	100-200
		CL	Lean clays, sandy clays, or gravelly clays	Fair to good	Not suitable	Medium to very high	Medium	Practically impervious	100-125	5-15	100-200
		OL	Organic silts or lean organic clays	Poor	Not suitable	Medium to very high	Medium to high	Poor	90-105	4-8	100-200
	High compress ibility LL<50	MH	Micaceous clays or diatomaceous soils	Poor	Not suitable	Medium to very high	High	Fair to poor	80-100	4-8	100-200
		CH	Fat clays	Poor to very poor	Not suitable	Medium	High	Practically impervious	90-110	3-5	50-100
		OH	Fat organic clays	Poor to very poor	Not suitable	Medium	High	Practically impervious	80-105	3-5	50-100
Peat and other fibrous organic soils		Pt	Peat, humus and other	Not suitable	Not suitable	Slight	Very high	Fair to poor	-	-	-

Typical Boring Log

- Log provides all data retrieved from the field (along with some lab results)
- N-values (SPT blow counts) are typically graphed
- Soil description shows:
  - Strata – fill, alluvium, residuum, PWR, etc.
  - Consistency or relative density (based on N-values)
  - Color, moisture, soil components, USCS classification, other notes



Develop Subsurface "Model"

- Soil types based on visual descriptions/classification tests
- On most small projects, use N-values (blow counts from SPT tests) are used to determine strength characteristics
- Laboratory test data
- Type of subgrade bearing material
- Groundwater levels
- Experience with similar conditions and structures

Engineering Evaluations

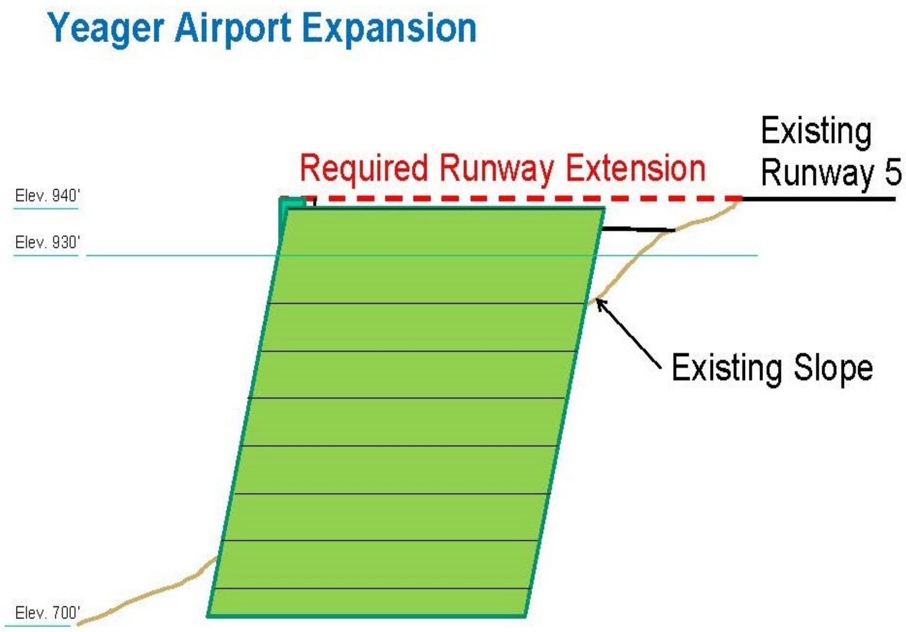
- Determination of design value of CBR
- For low strength or expansive soils, subgrade stabilization may be required. Stabilization may include:
  - Chemical stabilization such as lime or cement
  - Mechanical stabilization such as a layer of rock
  - Use of geosynthetics for separation and/or strength
- Other items that may need evaluation include:
  - Poor drainage
  - High water table
  - Frost susceptibility (usually not a problem in the South!)
- Slope stability analysis for any high slope configurations
- Settlement analysis for any deep fills/compressible soils

Geotechnical Report Contents

- Project description with structural details: important to verify design team is all on same page
- Description of subsurface conditions
- Site and subgrade preparation/earthwork recommendations
- Design and construction recommendations for pavements, retaining walls, slopes, etc.
- Drainage and stabilization recommendations, if needed
- Slope and settlement recommendations, if needed

Before Closing - A Cautionary Tale

- Yeager Airport in Charleston, WV
- Originally constructed in 1947 as Kanawha Airport
- Airport was constructed across 7 semi-connected hilltops
- Due to FAA safety requirements, a runway extension of about 500 ft was necessary
- Bridge, wall and slope structures were all considered.
- A geosynthetic reinforced slope was selected



Yeager Airport Runway Extension Slope

- Slope Height: up to 240 feet!
- Completed in 2007

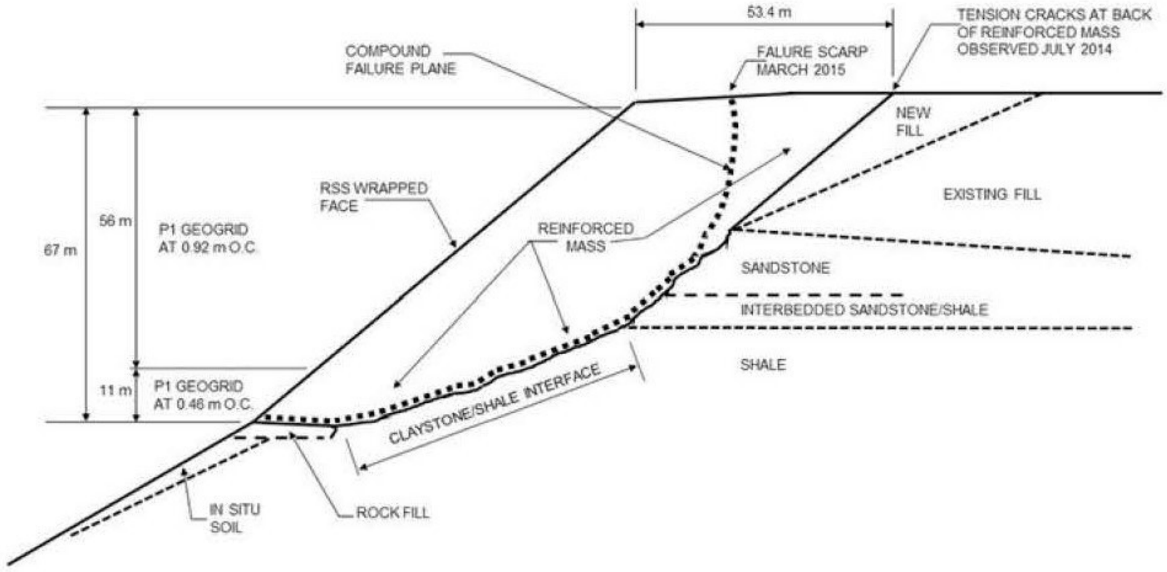
Yeager Airport Runway Extension Slope

- Touted as "Tallest known geosynthetic reinforced 1H: 1V slope in North America" **until it failed in 2015.**

Yeager Airport Runway Extension Slope

Contributing Factors to Failure

- Insufficient subsurface exploration and interpretation of data
- Insufficient foundation preparation and rock backcut benching
- Insufficient safety factor used for design
- Adaptations of design made during construction by the contractor and/or design engineer



Closing

- Thank You!
- Any questions?

- I can be reached at:
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  - 404-873-4761

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