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2024 Iowa Transportation Conference

GEOTECHNICAL CONSIDERATIONS IN TRANSPORTATION RECONSTRUCTION AND UPGRADES

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Special thanks to Mark Dell, PE, Iowa DOT Soils Design Section

Geotechnical Challenges of Improvements

- Very few true greenfield locations left
- Existing infrastructure constrains how projects can be approached
- Geotechnical considerations need to be incorporated at all project stages
  - New loads, vibrations, differential settlement, drainage paths, etc.
  - Can't wish new works into place

Presentation Overview

- Using typical project timelines:
  - Review geotechnical considerations for stages
  - Discuss potential impacts and solutions
  - Review brief case histories to illustrate
- Expected outcome is greater awareness of the need to collaborate with geotechnical team early and throughout the project life cycle

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Typical Project Timeline

FEASIBILITY STUDIES → ALTERNATIVE EVALUATION → CONCEPTUAL DESIGN → PRELIMINARY DESIGN → FINAL DESIGN → BIDDING → CONSTRUCT

Iowa DOT Soils Project Timeline

S1 → S2 → S3 → CONSTRUCT

S2 → S4 → CONSTRUCT

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Iowa DOT Soils Event Purposes

- S1 – Review proposed alignments for potential soil related (geotechnical) problems impacting design and constructability (Feasibility Studies, Alternative Evaluation, Conceptual Design)
- S2 – Review the geotechnical conditions along preferred alignment and grade to identify soils-related items affecting ROW (Preliminary Design)
- S3 – Final design of soils items for grading and paving
- S4 – Final design of soils items for Bridges and other Structures

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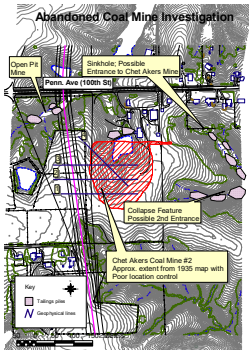
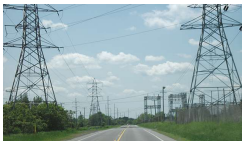
S1 Event

- Geotechnical engineering encompasses the interface between built environment and the earth
- Early investment in geotechnical review can save significant cost later in design and construction
- Identify the major constraints before large investment in time and money
- Avoid or plan to mitigate

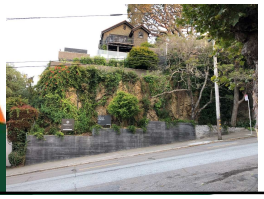


Review Potential Major Constraints

- Partner with other disciplines to review:
  - Wetlands, protected lands – DITCHES?
  - Hazardous waste/LUST sites
  - Abandoned mines
  - Historic/sensitive structures
  - Existing infrastructure/major utilities
- Hazardous slopes, problematic geology (e.g. karst, deep soft soils) – Ground improvement vs Structure length
- Stream impacts/erosion

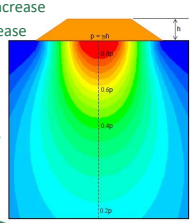
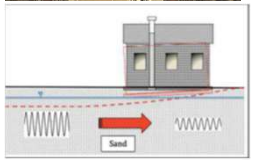







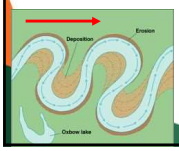

Geotechnical Impacts to Existing Infrastructure

- Screen impacts early during design process
- Results of changes in loading
  - Horizontal stress increase
  - Vertical stress increase
  - Stability concerns
  - Settlement
- Vibrations
- Screen ROW issues
  - Tiebacks/nails

Fluvial Processes

- Impacts to existing and proposed structures
- Scour
- Stream migration
- Erosion



Hazardous Slopes

- Rockfall

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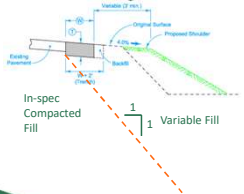
Beware Previous, Outdated Standards

- Past wasting of unsuitable soils on slopes
- Current widening issues



S2 Event – Soils Impacts to ROW

- Geotechnical impacts to ROW needs
  - Stability mitigation
  - Rockfall catchment
  - Ground improvement
  - Easements (permanent and temporary)

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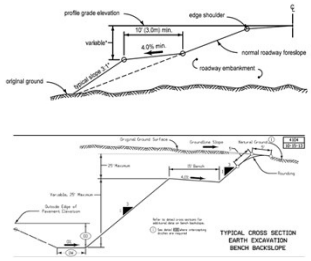
Stability Mitigation

- Require additional footprint
  - Flatten slopes
  - Stability berms
  - Backslope Benching



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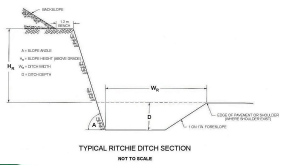
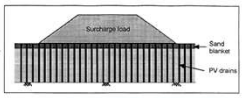
Rockfall Catchment

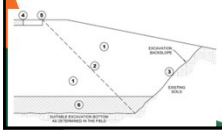
- Provide area for falling rocks to land away from traffic



Ground Improvement

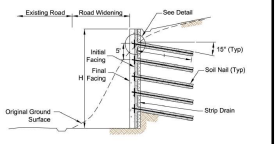
- Construction areas larger than embankment footprint
- Access needs
- Excavation and replacement/core outs
- Ground improvement vs Structure length





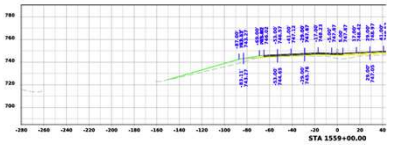
Easements

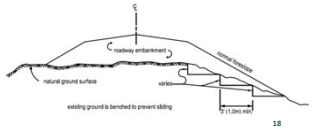
- Permanent
  - Tiebacks
  - Anchors
  - Soil nails
  - Reinforcement
- Temporary
  - Construction



Sliver Fills

- Thin fills on existing slopes
- Have to be benched
- Can be fixed early by small changes in alignment or profile grade





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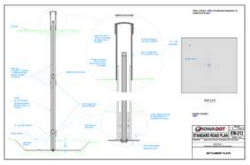
S3 Event – Grading and Paving

- Final design for grading and paving portions of projects
- Includes all soils design plans, details, and requirements relating to earthwork including:
  - Settlement mitigation, e.g. surcharge, delays, PVDs, core-outs, etc.
  - Ground improvement details
  - Staged construction
  - Benching
  - Sliver fills
  - Instrumentation
  - Subdrains



Schedule Considerations

- Multiple mitigation solutions
- Mitigation requires various amount of time
- Understanding schedule, cost, and traffic impacts are key to efficient design
- Collaboration with geotechnical partner is key

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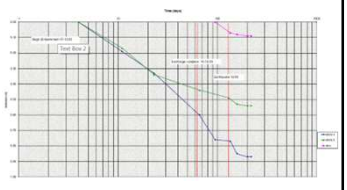
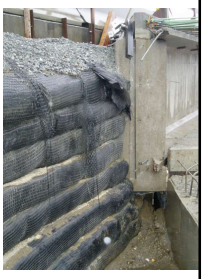
Settlement

- Caused by change in loads
- Takes time to occur
- Can be accelerated
  - PVDs/Wick Drains
  - Surcharge - extra load



Staged Construction

- Shoring/Temporary support
- Impacts on existing infrastructure
  - Loads
  - Loss of support
  - Vibrations
- Maintenance of Traffic



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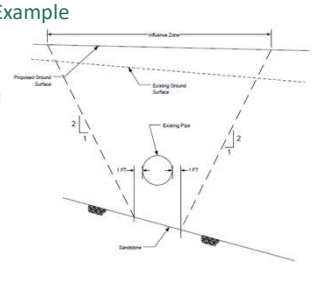
Utility Impacts

- Existing corridors have significant utilities
- Utilities may not accommodate planned improvements – load limits
- Ground disturbance from existing utilities

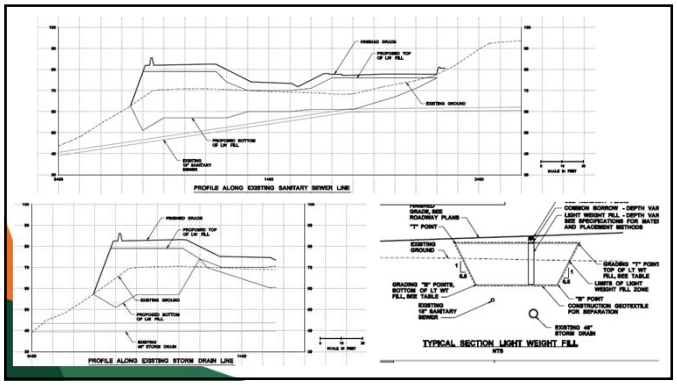
Existing Utility Example

- Raising grade by ~15 ft
- Existing 18” sanitary sewer and 48” storm drain >20’ below existing grade
- Unable to relocate line
- No net increase in load to protect
- Lightweight fill



NOT TO SCALE

SCHEMATIC OF PIPE INFLUENCE ZONE



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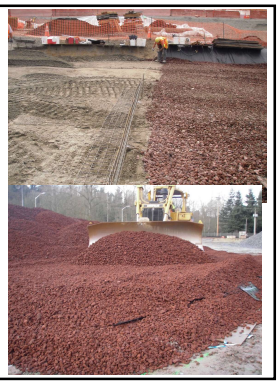
Lightweight Fill

- Scoria in influence zone
  - Volcanic rock
  - Highly vesicular
  - Angular
  - Durable
  - Lightweight (50-60 psf)
  - "Self-compacting"
  - "Lava rock" that is used in barbeque grills
- Eliminated need to move or rehab deep sewer line



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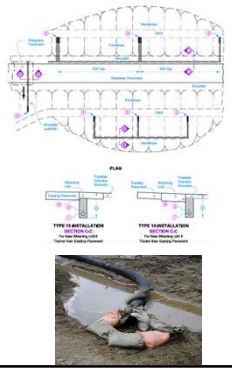
Subdrains

- Water is bane of geotechnical engineering
- Trapped water weakens subgrades and embankments
- Drainage can solve a plethora of ills
- Widening and rehab can cut off drainage causing good subgrade to fail
- Failure to maintain can cause similar failures



S4 Event – Bridges and Structure s

- Final design for bridges and other structures (culverts, walls, etc.) for projects
- Includes all geotechnical plans, details, and requirements relating to structures
- Impacts to existing structures and staging are key inputs needed from geotechnical partner early in process

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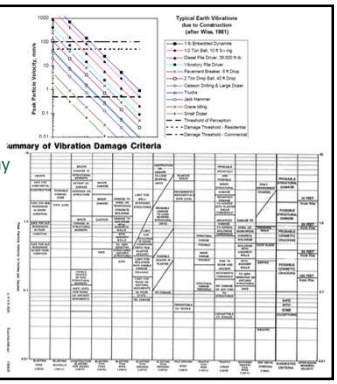
Vibrations

- All construction activities produce vibrations
- Existing structures near projects may be receptors
  - Sensitive historic
  - Loose soil supported
- Vibration impacts:
  - Cracking due to structure response
  - Densification and settlement



Vibrations (Continued)

- Generally, for transportation projects, structural damage due to physical shaking is low
- Highest risk is vibration induced settlement
- Vibration sensitive soils
  - Loose to medium dense sands and non-plastic silts
  - Unconsolidated fill soils
  - Saturation makes problem worse!!
- Problematic foundations
  - Shallow supported (spread footings, culverts, etc.) on vibration sensitive soils
  - Deep foundations terminating in vibration sensitive soils

IV. Structural damage due to dynamic effects

III. Settlement and/or strength loss due to cyclic effects

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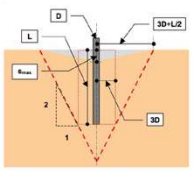


Figure 4 Basic method of estimating settlements adjacent to a single pile in homogeneous sand.

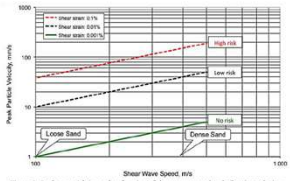
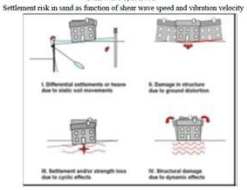


Figure 3 Settlement risk in sand as function of shear wave speed and vibration velocity

TABLE 1 Compression factor, α, for sand based on soil relative density and level of driving energy.

Ground Vibrations:	Low	Medium	High
Soil Density	Compression factor, α		
Very loose	0.02	0.03	0.04
Loose	0.01	0.02	0.03
Medium	0.005	0.01	0.02
Dense	0.00	0.005	0.01
Very dense	0.00	0.00	0.005

$s_{ave} = \alpha(L+6D)$; $s_{avg} = \frac{\alpha(L+3D)}{3}$



Massarsch, K.R and Fellenius, B.H., 2014. Ground vibrations from pile and sheet pile driving. Part 1 Building Damage. Proceedings of the DFI/EFFC International Conference on Piling and Deep Foundations, Stockholm, May 21-23, pp. 131-138.

Preliminary Screening for Vibration Concerns

- Check as-builts for foundation and soils information
- Review geologic setting and site history
- Review proposed improvements
- Review construction staging – will receptors remain?
- Review construction methods and distance to receptors
- Evaluate potential vibrations produced and impacts
- Determine if potential impacts are acceptable and adjust design if needed
- Gather project-specific geotechnical information
- Revaluate potential vibration impacts and confirm design

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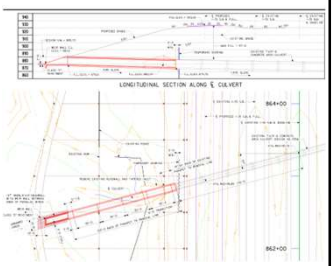
Culvert Extensions

- Differential settlement caused by:
  - Differential loading on consistent soil profile
  - Uniform loading on variable soil profile
  - Variable loading on variable soil profile
- Culvert extensions at widenings are primed for differential settlement
  - Existing culvert settlement is complete
  - Stream bottoms with soft soils
  - Shallow groundwater
  - Soils respond to new embankment loads



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I-35 Widening, RCB Extension

- Widening of SB I-35 required extension of existing 8’ x 10’ RCB
  - ~38’ of fill required
  - ~20’ of soft to very soft alluvial clay
  - Approximately 30” of settlement estimated under max fill
  - 24 months for settlement to complete
- Grade and pave project, so compressed schedule for settlement
- Incorporated PVDs and Geofoam to accelerate and reduce settlement

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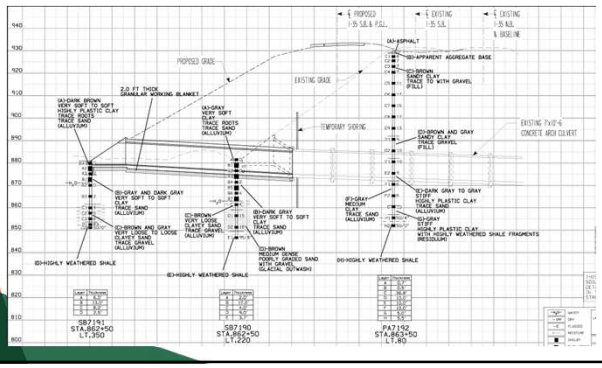

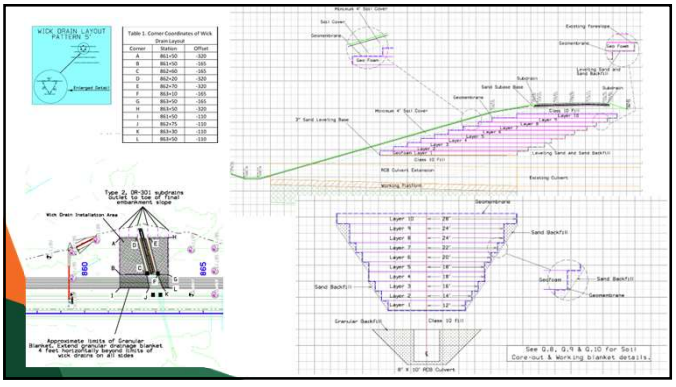

Construction

- Geotechnical engineering judgement based on limited data
  - Access constraints
  - Borings and tests are not continuous, but are representative
- Designs based on specific judgements and conditions
- Areas of previous development work can be highly variable
  - "Night work"
  - Old standards

Construction

- Continuity of professional responsibility
  - Make sure geotechnical engineer involved in writing and reviewing specifications
  - Confirm judgements and decisions made during design
  - Confirm construction according to design
  - Address inherent variability in geologic conditions
  - Reduce uncertainty, reduce associated conservatism
- Codes allow higher resistance factors with inspection and testing (e.g. PDA)

Conclusion

- Reconstruction and rehabilitation pose constraints not found generally in greenfield sites
- Geotechnical engineering touches all other civil disciplines
- Get your geotechnical people involved early and often
- Upfront effort pays dividends later in the project

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Questions?