Evaluation of Ground Improvement Methods for the Remediation of Roadway Settlements

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69th ANNUAL OHIO TRANSPORTATION ENGINEERING CONFERENCE
Roadway Settlement

[Images of potholes and cracks in the roadway]
Roadway Settlement
Remediation

- Lime Stabilization
- Remove & Replace
- Wick Drains (w/ Pre-Loading)
- Deep Foundations
- Ground Improvement
Research

- Evaluation of Ground Improvement Methods
- Development of “Decision Tree”
- Subsurface investigation of two sites having settlement issues
- Analysis and implementation of decision tree
- Long term cost-benefit analysis
Ground Improvement Methods

Methods Evaluated:

- Vibro-flotation
- Vibro-Replacement Stone Columns
- Vibro-Replacement Concrete Columns
- Rammed Aggregate Piers
- Deep Soil Mixing
- Controlled Modulus Columns
- Compaction Grouting
- Jet Grouting
- Sand Columns
Decision Matrix
Decision Matrix Considerations:

- Soil type
- Groundwater and drainage
- Cost and construction duration
- Hard/dense layer overlaying problems soils
- SPT-N (soil strength estimate)
- Depth
- Nearby structures
Decision Matrix

Spreadsheet version:

Input:

- Site Conditions
- Installation Parameters
- Area to be improved
- Grid spacing
- Average depth of installation
- LTP requirement
- Allowable settlement
Decision Matrix

Flowchart version

PROBLEM SOIL TYPE(S)

- Silt
- Clay & Silt
- Clay

Organics & Silt
Organics
Organics & Clay

Top Depth of Problem Soil Less Than 3 m (10 ft)

Hard/Dense Soil Overlying Problem Soils

- Yes
  - Problem Soils with SPT-N < 4
    - Yes
      - Depth to Bottom of Problem Soil Layer
    - No
      - Depth to Bottom of Problem Soil Layer

- No
  - Problem Soils with SPT-N < 4
    - Yes
      - Depth to Bottom of Problem Soil Layer
    - No
      - Depth to Bottom of Problem Soil Layer

POTENTIAL METHOD(S):

- VCC, JG, CMC, RAP
- JG, CMC, RAP
- JG, CMC
- JG

- VCC, DSM, JG, CMC, RAP
- DSM, JG, CMC, RAP
- DSM, JG, CMC
- DSM, JG

- VSC, VCC, JG, CMC, RAP
- DSM, JG, CMC, RAP
- DSM, JG, CMC
- DSM, JG

- VSC, DSM, JG, CMC, RAP
- DSM, JG, CMC, RAP
- DSM, JG, CMC
- DSM, JG

- VSC, JG, CG, CMC, RAP
- JG, CG, CMC, RAP
- JG, CG, CMC
- JG, CG

- VSC, VCC, JG, CG, CMC, RAP
- DSM, JG, CG, CMC
- DSM, JG, CG
- DSM, JG

- VSC, DSM, JG, CG, CMC, RAP
- DSM, JG, CG, CMC
- DSM, JG, CG
- DSM, JG

- VSC, VCC, DSM, JG, CG, CMC, RAP
- DSM, JG, CG, CMC
- DSM, JG, CG
- DSM, JG
Evaluation of ODOT Recommended Sites With Settlement Issues
Case Studies

- Presented with two sites in northeastern Ohio just southeast of Akron
  - SUM-224-13.14
  - STA-44-18.23

- Site info for determination of ground improvement feasibility
Case Study 1

SUM224-13.14

Background:

- Adjacent to wetland & lake
- Continual settlement followed by repaving
- Lightweight fill Elastizell Engineered Fill used but failed in controlling settlements
- Roadway lights not installed on north side due to inadequate bearing capacity
- Curb on north side has sunk below grade
- Loss of super-elevation on north side of roadway
Case Study 1
Case Study 1

Field Testing

- Drilling
  - Split spoon
  - Shelby tubes
- Pressuremeter testing
- CPT
  - U2 Dissipation testing
- Installation of monitoring wells and inclinometers

Lab Testing

- ODOT Classification
- Moisture Content
- Loss on Ignition
- Specific Gravity
- Unconfined Compression
- Triaxial
- Consolidation
Case Study 1

SUM224-13.14

Results Summary:

- Problem soils consisting of:
  - Very soft organic clays and silts
  - Peat

- Soft material down to 60 ft with WOH blow counts down to 50 ft

- Loss on Ignition values up to 89.0%

- Moisture Contents up to 403%

- Groundwater at about 2.5'
Case Study 1

Implementation of Decision Matrix

- Results for SUM224:
  - Jet grouting
  - Deep soil mixing
  - Controlled modulus columns
Case Study 2

STA44-18.23

Background:

- Adjacent to wetland
- Continual settlement followed by repaving
  - Up 22” of asphalt in some areas
- Significant pavement distress
- Underwent embankment stabilization in 2005 but shoulder distress in that location persists
- Severe rutting where water ponds in roadway
Case Study 2

Field Testing
- Drilling
  - Split spoon
  - Shelby tubes
- Pressuremeter testing
- CPT
  - U2 Dissipation testing
- Installation inclinometers

Lab Testing
- ODOT Classification
- Moisture Content
- Loss on Ignition
- Specific Gravity
- Unconfined Compression
- Triaxial
- Consolidation
Case Study 2

SUM224-13.14

Results Summary:

- Problem soils consisting of:
  - Very soft to soft organic clays and silts down to 25 ft
- Loss on Ignition values up to 53.0%
- Moisture Contents up to 265%
Implementation of Decision Matrix

- Results for STA44:
  - Jet grouting
  - Deep soil mixing
  - Controlled modulus columns
  - Rammed Aggregate Piers

Case Study 2
Ground Improvement Implementation

vs.

Current Approach
(Repaving and Continual Maintenance)
Ground Improvement Implementation costs:

- Construction
  - Roadway removal
  - Installation
  - LTP (some methods)
  - Roadway construction

- Work zone delay costs
  - Comparable to current approach over long term
Current Approach:
- Construction
  - Increased frequency of repaving
  - Additional maintenance (patching, cracksealing, etc.)
- Work zone delay costs
- Roadway condition costs
  - Vehicle operating costs
    - Vehicle wear and tear
  - Fuel costs
  - Tire wear
- Safety and accident related costs
- Societal costs (emissions & ride quality)
  - Not quantified
Long Term Cost Benefit Analysis

- Increased $$$$$ due to
  - Greater repaving frequency
  - Additional maintenance

Difficult to quantify due to lack of record
Long Term Cost Benefit Analysis

Roadway condition costs:
Vehicle operating costs (VOCs):

Estimated using spreadsheet:


Uses value of International Roughness Index (IRI)
Safety and accident related costs:

- poor road conditions = greater probability of accidents

Used traffic accident data & increased probability due to road condition study

- Quantified the increase in risk due to difference in IRI values
- Then associated increased risk with accident costs
Long Term Cost Benefit Analysis

- Considers traffic growth over time

SUM 224
Long Term Cost Benefit Analysis

STA44

Diagram showing cost over time for Alternative 1 with different values of ΔIRI (1, 2, 3, 4) compared to Alternative 2. Alternative 2 is indicated as more cost-effective.
Long Term Cost Benefit Analysis

- Per foot of roadway
- Per 1000 vehicles in traffic volume
- Constant traffic volume
- Designed for speeds < 50mph and >= 50 mph
Conclusions

- Use of Ground Improvement is relatively new concept to many DOTs for remediation of roadway settlements
- Many methods are adequate in remediating excessive settlement due to deep problem soils in a wide range of Ohio site conditions
- Much more affordable relative to deep foundations
- Application is overall more cost effective than current practice
- Up-front costs are needed for the implementation. Therefore it may not be feasible for all sites due to the allocation of funds needed.
Recommendations

- Identifying sites that are causing same issue on larger scale
- Keeping detailed records of specific maintenance and repaving schedules for further pavement life analysis
- Identify site in which problem soils more shallow and up front cost may be more reasonable
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Thank You

Questions