NCHRP Project 21-11

Improved Test Methods & Practices for Characterizing Steel Corrosion Potential of Earthen Materials

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NCHRP 21-11 WORKPLAN

- PHASE I (Tasks 1-4) – Collect Existing Information
  - Identify knowledge gaps
  - Develop a detailed work plan to improve methods for sampling and testing and characterization of corrosiveness of earthen materials.
- PHASE II (Tasks 5 & 6) – Implement Work Plan Developed in Phase I
  - Study Laboratory and field tests for measurement of electrochemical parameters, and characterizing steel corrosion
  - Draft protocol for characterizing corrosiveness of earthen materials
  - Formulate a detailed work plan to evaluate practical application of proposed protocol

NCHRP 21-11 WORKPLAN (Continued)

- Phase III (Tasks 7, 8 & 9) – Implement Work Plan Developed in Phase II.
  - Conduct trails in active construction projects
  - Shadow specification to compare with current practice
  - Demonstrate and evaluate recommendations and protocols for sampling, testing and characterizing corrosiveness of earthen materials.
  - Initiate training with personnel from State DOTs

NCHRP 21-11: INTERIM REPORT EXISTING INFORMATION

I) Laboratory Test Methods

II) Field Test Methods

III) Methods for Observing Performance/Corrosion

IV) Existing Performance Data & Correlation with Corrosion Potential

V) Screening Techniques and Characterizations

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LABORATORY TEST METHODS

- **pH** – field testing ASTM G57; lab testing AASHTO T 289 or ASTM 4972, SCDOT T143, ASTM D18, TX-128-E
- **SO_4 & Cl^-** - ion exchange chromatography (ASTM 4327)
- **Resistivity**
  - Fill Material – lab testing
    - AASHTO T288
    - ASTM G187
    - TX-129-E
    - ASTM WK2461 – SP, GP (well drained)
    - Leach Test – USGS, TX-620-M, SCDOT T143

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Resistivity Test Techniques

- Tests performed on extracts
- Tests performed on mixtures of soil and water
  - As received
  - Saturated
  - Drainage allowed or undrained

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RESISTIVITY MEASUREMENTS WITH SOIL BOX

- Water added in Increments – "minimum resistivity" – AASHTO T 288, LDOTD TR 4529-88, FM-551, ADOT 236c, TX 129E, CTM 643, WSDOT T 417, PA Test Method No. 128
- Saturated or As-Received – ASTM G187, French Practice
- Saturated and Drained – ASTM WK24261

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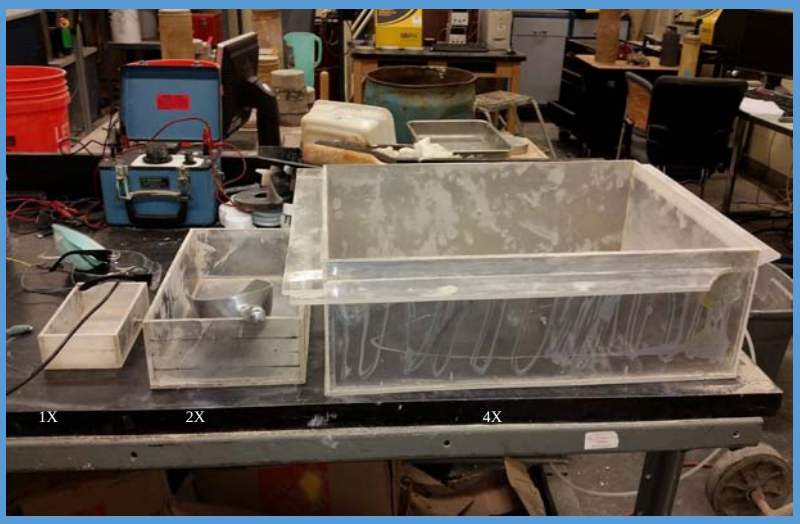
SOIL BOXES



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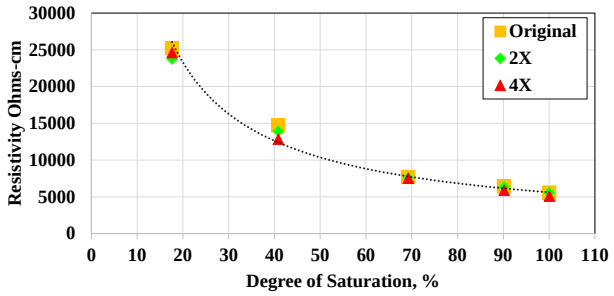
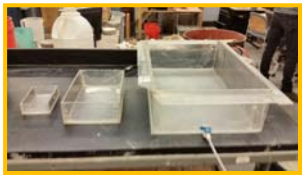
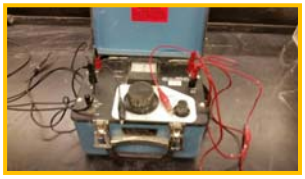
Resistivity Tex-129-M (Tex-129-E Modified)

Bigger Boxes and Varying Degree of Saturation

Resistivity Box Size	Gradation			Constituent				Tex-129-E
	Type AS	Type BS	Type DS	Gravel	Coarse Sand	Fine Sand	Fines	
Original		✓			✓	✓	✓	✓
2X		✓			✓			
4X	✓	✓	✓	✓				
Grading Number (GN) = $(P_{1in.}+P_{3/4}+P_{3/8}+P_{\#4}+P_{\#10}+P_{\#40}+P_{\#200})/100$								
GN	2.8	4.2	2.6	2.4	4	6	7	5







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DIFFERENCES IN TEST BOX METHODS

METHOD	AIR/OVEN DRY	SIZED FRACTION	MIXING	MOISTURE CONDITION
AASHTO T288	air dry or oven dry at < 60°C	< 2 mm; crushing not allowed	Water added in increments, mixed thoroughly with soil, then placed in box; 1st increment cures for 12 hours.	saturated (?)
ASTM G187	No	> Gravel and small stones are removed from the sample	Unless tested as-received, water is added and mixed as soil is placed within the box in layers.	as-received or saturated
ASTM WK2461	Sample soaked for 24 hours prior to testing (not if testing as-received)	All sizes	Similar to G187, but use water that was used to soak the sample	As received, or saturated then drained
TX- 129E	oven dry at 60°C	< 2.36 mm; crushing allowed	Water added in increments, mixed thoroughly with soil, then placed in box; no curing.	saturated

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CONDUCTIVITY MEASUREMENTS ON EXTRACTS

- NV T 235B – Method for Determination of Minimum Resistivity of Soil
- NC – Analysis of No. 57 Washed Stone Backfill (MT Chemical Procedure C-ELEC)
- SC T 143 – Method of Preparing Coarse Aggregate Sample for pH and Resistivity Testing in the Laboratory (same as method used by NC)
- USGS FIELD LEACH TEST (FLT)
- TX-620-M - Proposed

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TEX-620-M





a)weigh out material.
b)mix with water using rice shaker test machine.
c)measure pH, conductivity.
d)filter sample
e)IC system – SO_4 and CL^-.

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DIFFERENCES IN TEST METHODS PERFORMED WITH EXTRACTS

METHOD	SAMPLE SIZE (grams)	DILUTION RATIO (H_20:solids)	MIXING	SETTLING TIME (hours)	FILTER
NC/SC 143T	2000	1:1	Mix and stand for 30 minutes, then agitate for 3 min. at 0, 2 and 4 hour intervals.	20	YES
NV T235B	100 g passing the #4 sieve	2:1	Agitate until solids are completely in suspension.	24	NO; Decanted
TX-620-M	100g Dried	10:1	Shake vigorously for 30 minutes	1	NO; Tip of electrode placed 5 cm into the mixture

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TEST METHODS FOR pH

METHOD	SIZE (g)	RATIO	MIXING	STAND hours	FILTER
1.) ASTM D 4972	10 (air dried, passing 2 mm sieve)	1:1	Mix thoroughly	1	NO
2.) TX-128-E	30 used (passing #40 sieve)	5:1	Stir upon mixing, every 15 minutes for one hour after, and immediately before electrode immersion.	0	NO
3.) CorrTest (21-06)	40 to 60 (greater than 10 mm removed by hand)	1:1	Stir to thoroughly disperse soil.	0.5	NO
4.) SC DOT T 143	2000 (passing 37.5 mm sieve)	1:1	Mix and stand for 30 minutes, then agitate for 3 min. at 0, 2 and 4 hour intervals.	20	YES
5.) TX-620-M	Varies	10:1	Mechanically shake for 30 minutes.	1	NO
6.) ASTM D18	≥200 (bring to SSD state after obtaining sample)	2:1	Stir for at least 1 minute upon mixing. Stir for 1 minute every 15 minutes for 1 hour after. Stir immediately before emersion of electrode.	0	NO

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SCREENING/CHARACTERIZATION

- Percentiles
- Parameter thresholds
- Rating/multi-variant
- MSE
- SN
- Piles
- Culverts

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Summary of Screening Techniques and Characterizations

UNIVARIATE – Binary Systems	MULTIVARIATE
1. AASHTO (1992) - Galvanized Steel	1. German DVGW GW 9 –Pipelines
2. PTI – Prestressing Steel (High Strength)	2. AWWA (DIP) – 10 Point Method
3. Burec (2009) Resistivity - 10th Percentile – DIP and CIP	3. Jones (1985) – steel soil reinforcements
4. FHWA (2003) – Solid Bar Soil Nails – Carbon Steel	4. Clouterre (1993) – Soil Nails
5. European Standard – EN 12501-2 (2003)	5. Brady and McMahon (1994), UK – Galvanized steel structures/Culverts
	6. Beavers and Durr (1998), NACE (2001) – Steel Piles
	7. AGA (1983) – Hot-dipped Galvanized Steel
	8. Demisse (2015) - Bayes Network - waterlines

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Parameter	AASHTO Test Method	Requirement
ρ_{min}	T 288	>3000 Ω-cm
pH	T 289	5 to 10
Sulfates	T 290	<200 ppm
Chlorides	T 291	<100 ppm

AASHTO Electrochemical Requirements for Mechanically Stabilized Earth Fill Used with Galvanized Steel Reinforcements

Criteria Used in the US for Assessing Ground Corrosion Potential Relative to SBSN's (after FHWA, 2003)

Test	Units	Strong Corrosion Potential (Aggressive)	Mild to no Corrosion Potential (Non-Aggressive)	ASTM Standard	AASHTO Test Method
pH	-	pH < 4.5 or pH > 10	5.5 < pH < 10	G51	T289-91
Resistivity	ohm-cm	< 2,000	> 5,000	G57	T288-91
Sulfates	ppm	> 200	< 200	D516	T290-91
Chlorides	ppm	> 100	< 100	D512	T291-91
Stray current	-	Present	-	-	-
Note: ppm indicates parts per million; refer to ASTM (2010) and AASHTO (2010) for latest versions of test standards and methods.					

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German Gas and Water Works Engineers' Association Standard (DVGW GW9)

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ITEM	MEASURED VALUE	MARKS
Soil Composition	Calcareous, marly limestone, sandy marl, not stratified sand	+2
	Loam, sandy loam (loam content 75% or less), marly loam, sandy clay soil (silt content 75% or less)	0
	Clay, marly clay, humus	-2
	Peat, thick loam, marshy soil	-4
Ground water level at buried position	None	0
	Exist	-1
	Vary	-2
Resistivity	> 10,000 Ω-cm	0
	5000 Ω-cm – 10,000 Ω-cm	-1
	2300 Ω-cm – 5000 Ω-cm	-2
	1000 Ω-cm – 2300 Ω-cm	-3
	> 10000 Ω-cm	-4

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ITEM	MEASURED VALUE	MARKS
Moisture Content	20% or less	0
	20% or more	-1
pH	6 or more	0
	6 or less	-2
Sulfide and Hydrogen Sulfide	None	0
	Trace	-2
	Exist	-4
Carbonate	5% or more	+2
	1% to 5%	+1
	< 1%	0
Chloride	< 100 ppm	0
	> 100 ppm	-1

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ITEM	MEASURED VALUE	MARKS
Sulfate	< 200 ppm	0
	500 ppm – 200 ppm	-1
	1000 ppm – 500 ppm	-2
	> 1000 ppm	-3
Cinder & Coke	None	0
	exist	-4

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DVGW GW9 – Characterization of Corrosivity

SCORE	CHARACTERIZATION
> 0	Noncorrosive
0 to -4	Slightly Corrosive
-5 to -10	Corrosive
< -10	Very Corrosive

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Soil Corrosivity/Aggressiveness (Carbon Steel) DIN 50 929 Part 3

Total Score		General Corrosion Rate	Range	Localized (Pitting) Corrosion Rate	Range
		µm/yr		µm/yr	
≥ 0	Ia	5	2.5 – 10	30	15 – 60
-1 to -4	Ib	10	5 – 20	60	30 – 120
-5 to -10	II	20	10 – 40	200	100 – 400
< -10	III	60	30 - 120	400	200 - 800

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SAMPLNG PLAN

STATE	# OF SOURCES	DESCRIPTION
CA	6	Gravel fill at northern sites, fine sand southern sites
FL	2	Fine sand
KY	2	Coarse Aggregate
NV	2	Sand and Gravels; High sulfates
NY	4	Well graded sands and gravels
NC	2	No 57 Stone
TX	6	Coarse Aggregate – Different Gradations
SC	2	Light weight fil and Granular Base
OH	2	Well graded sands and gravels
ARK	1	Coarse fill
BC	1	Natural gravel – poorly graded

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SITES IN NORTH CAROLINA - RALEIGH

I-540 & Triangle Town Center
Constructed 2004
CR ≈ 5 µm/yr

US 1 West – Wake Forest
Constructed 2005
CR ≈ .25 µm/yr

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General Organization of Testing for Task 5

Issue (I):
Evaluate Test Methods Used to Measure Electrochemical Properties

1. Compare results from different tests – i.e., few sources, many tests (5.1 & 5.2).
2. Compare Results from Different Materials – i.e., many sources, few replicates, and few tests (5.3).

Issue (II):
Characterize Corrosion Potential

1. Observe CR from laboratory tests – use same sources of materials included in Issue I (5.4).
2. Test fill obtained from sites with ongoing corrosion monitoring – these materials are included in Issue I (5.3).
3. Additional instrumentation and monitoring at selected field sites – materials tested in Issue I and in situ testing for resistivity (5.5)

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PRELIMINARY DRAFT PROTOCOL

1. Identify Application
2. Identify Earthen Material
3. Requirements for Sampling and Testing
4. Methods of Testing – Lab vs. Field
5. Data Check Quality Control
6. Screening/Characterization

CONCLUSIONS & DISCUSSION

- Sources of Materials for Task 5
- Sites for Field Trials
- Input on Preliminary Protocol
- Other Test Methods???

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