NORTH CAROLINA
Department of Transportation

AASHTO UPDATE

And How Changes Affect NCDOT

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Summary

- Next editions of AASHTO LRFD Bridge Design (9^{th}) and Bridge Construction (5^{th}) Specs will be in 2020 – No More Interims!
- Biggest geotech code changes in 2018/19 Agenda Items address the following:
  - Settlement of Shallow Foundations
  - Design and Construction of Soil Nail Walls (New Articles/Sections)
  - Internal Stability and other "Stuff" for MSE Walls (Overall Rewrite)

Settlement Changes/Additions (2018)

- Revised Differential Settlement Limits (Angular Distortion) based on NCHRP Project 12-103 (2017), *Bridge Superstructure Tolerance to Total and Differential Foundation Movements*
- Added Load Factors for γ_{SE} based on SHARP 2 Implementation Report (2016), *Incorporation of Foundation Movements in AASHTO LRFD Bridge Design Process*
- Added Schmertmann Method
- Added Construction Point Settlement Analysis Method

Angular Distortion Limits

Type of Bridge	Angular Distortion Limits, Δ/L	
	Moulton et al. (1985)	**Current AASHTO**
Continuous Span	**0.004** (4.8" in 100')	**0.004** (4.8" in 100')
Simple Span	**0.005** (6.0" in 100')	**0.008** (9.6" in 100')
For rigid frames, perform case-specific analysis		

2018 AASHTO Agenda Item

Movement Case	Limits for Ride Quality
For movements occurring at the abutment of simply supported bridges with an approach slab	$\frac{\delta}{L_a} + \frac{\delta}{L_s} < 1/250$
For movements occurring at the abutment of continuous bridges with an approach slab	$\frac{\delta}{L_a} + \frac{2\delta}{L_s} < 1/250$
For movements occurring at the pier of multiple-span simply-supported bridges	$\frac{2\delta}{L_s} < 1/250$
For movements occurring at the pier of continuous bridges	$\frac{2\delta}{L_s} < 1/250$

Where:

δ = absolute support movement

L_a = length of approach slab

L_s = length of span

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Type of Superstructure	Applicable Cross-Section from Table 4.6.2.2.1-1	Tolerance Estimate (in.)	Range of Applicability
Concrete Deck, Reinforced Concrete Slab on Steel Beams	a (also b and c, however this expression may provide more conservative estimates for these bridge types as these types are typically constructed outside the range of applicability)	<u>Strength I & Service II</u> $\Delta = 0.55 \frac{L}{S} - 2.6$	$40ft \le L \le 160ft$ $5ft \le S \le 12ft$ $0 \le Skew \le 45°$ $36ft \le Width \le 72ft$ $20 \le L/d \le 30$
Concrete Deck, Reinforced Concrete Slab on Prestressed Concrete Beams	k (also d through j, however this expression may provide more conservative estimates for these bridge types as these types are typically constructed outside the range of applicability, or will have a lower cross-sectional stiffness than the bridges studied in the research)	<u>Service III</u> $\Delta =$ ~~0.0005~~ 0.0006 $L + 0.17$ <u>Strength I</u> $\Delta = 0.13 \frac{L}{S} - 0.17$	$40ft \le L \le 160ft$ $5ft \le S \le 12ft$ $0 \le Skew \le 45°$ $36ft \le Width \le 72ft$ $20 \le L/d \le 30$

Application of NCHRP Project 12-103 Recommendations

Example bridge w/ 150 ft long span, 10 ft girder spacing and 25 ft long approach slab

Continuity	Limits for Ride Quality
Simple-Span	Referencing Table 10.3, the limits of tolerable support movement for a simple span steel or prestressed concrete multi-girder bridge can be determined by evaluating the following inequalities: For movements occurring at the abutment of a simply supported bridge: $\frac{\Delta}{L_a}+\frac{\Delta}{L_s}<1/250$ $\frac{\Delta}{25*12}+\frac{\Delta}{150*12}<1/250$ $\boldsymbol{\Delta = 1.03\ inches}$ ■ For movements occurring at the pier of multiple-span simply-supported bridges: $\frac{2\Delta}{L_s}<1/250$ $\frac{2\Delta}{150*12}<1/250$ $\boldsymbol{\Delta = 3.6\ inches}$ ■

	Steel	Prestressed Concrete	
Continuity	**Strength I & Service II**	**Service III**	**Strength I**
Continuous	$\Delta = 0.55\frac{L}{S}-2.6$ $\Delta = 0.55\frac{(150*12)}{(10*12)}-2.6$ $\Delta = \mathbf{5.65\ inches}$ ■	$\Delta =$ ~~0.0005~~ 0.0006 $L + 0.17$ $\Delta =$ ~~0.0005~~ 0.0006 $(150*12)+0.17$ $\Delta =$ **1.~~07~~.25 inches** ■	$\Delta = 0.13\frac{L}{S}-0.17$ $\Delta = 0.13\frac{(150*12)}{(10*12)}-0.17$ $\Delta = \mathbf{1.78\ inches}$ ■

Current AASHTO LRFD Load Combinations and Load Factors

Load Combination Limit State	*DC DD DW EH EV ES EL PS CR SH*	*LL IM CE BR PL LS*	*WA*	*WS*	*WL*	*FR*	*TU*	*TG*	*SE*	Use One of These at a Time				
										EQ	*BL*	*IC*	*CT*	*CV*
Strength I (unless noted)	γ_p	1.75	1.00	—	—	1.00	0.50/1.20	γ_{TG}	γ_{SE}	—	—	—	—	—
Strength II	γ_p	1.35	1.00	—	—	1.00	0.50/1.20	γ_{TG}	γ_{SE}	—	—	—	—	—
Strength III	γ_p	—	1.00	1.00	—	1.00	0.50/1.20	γ_{TG}	γ_{SE}	—	—	—	—	—
Strength IV	γ_p	—	1.00	—	—	1.00	0.50/1.20	—	—	—	—	—	—	—
Strength V	γ_p	1.35	1.00	1.00	1.00	1.00	0.50/1.20	γ_{TG}	γ_{SE}	—	—	—	—	—
Extreme Event I	1.00	γ_{EQ}	1.00	—	—	1.00	—	—	—	1.00	—	—	—	—
Extreme Event II	1.00	0.50	1.00	—	—	1.00	—	—	—	—	1.00	1.00	1.00	1.00
Service I	1.00	1.00	1.00	1.00	1.00	1.00	1.00/1.20	γ_{TG}	γ_{SE}	—	—	—	—	—
Service II	1.00	1.30	1.00	—	—	1.00	1.00/1.20	—	—	—	—	—	—	—
Service III	1.00	γ_{LL}	1.00	—	—	1.00	1.00/1.20	γ_{TG}	γ_{SE}	—	—	—	—	—
Service IV	1.00	—	1.00	1.00	—	1.00	1.00/1.20	—	1.00	—	—	—	—	—
Fatigue I— *LL, IM & CE* only	—	1.75	—	—	—	—	—	—	—	—	—	—	—	—
Fatigue II— *LL, IM & CE* only	—	0.80	—	—	—	—	—	—	—	—	—	—	—	—

Force Effect due to Settlement (SE)

- Article 3.12 – "Force Effects due to Superimposed Deformations: TU, TG, SH, CR, SE, PS"
- Article 3.12.6 states "Force effects due to extreme values of differential settlement among substructures and within individual substructure units shall be considered."
- Commentary 3.12.6 says "Force effects due to settlement may be reduced by considering creep. Analysis for the load combinations in Tables 3.4.1-1 and 3.1.4-2 which include settlement should be repeated for settlement of each possible substructure unit settling individually, as well as combinations of substructure units settling, that could create critical force effects in the structure."

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Table 3.4.1-5—Load Factors for Permanent Loads Due to Foundation Movements, γ_{SE}

Foundation Movement and Movement Estimation Method	*SE*
Immediate Settlement	
• Hough method	1.00
• Schmertmann method	1.40
• Local owner approved method	*
Consolidation settlement	1.00
Lateral Movement	
• Soil-structure interaction method (P-y or Strain Wedge)	1.00
• Local owner approved method	*
*To be determined by the owner based on local geologic conditions.	

How does this affect past practice?

- Consider the impact of the value of γ_{SE} on a load combination:
  - Load factor γ_{SE} is only one component in a load combination
  - Load factor $\gamma_{SE} = 1.40$ does not mean that the total force effects will increase by 40%
- Samtani & Kulicki compared past practice to proposed (40% increase in γ_{SE}) for an example bridge with varying span lengths and the results are summarized as follows:
  - 0.6 to 1.8% increase in moments for Service I load combination
  - 0.5 to 1.2% increase in moments for Strength I load combination
  - 0.2 to 0.9% increase in shears for Service I load combination
  - 0.1 to 0.6% increase in shears for Strength I load combination

Soil Nail Wall Additions

- New Article in Section 11 of LRFD Bridge Design Specs for Soil Nail Wall Design (2018) based on FHWA GEC 7 (2015) and NCHRP Project 24-21 (2016), *Proposed Specifications for LRFD Soil-Nailing Design and Construction*
  - Global stability moved to strength limit state for all retaining walls
  - Facing design is included in retaining wall section
- New Section/Article in LRFD Bridge Const Specs for Soil Nails/Soil Nail Walls (2019)

2018 AASHTO Agenda Item

- Pullout LRFD Equation

  $\phi_{po} R_{PO} \geq \gamma_p T_{maxsn}$ (11.12.5.2-1)

- Tension LRFD Equation

  $\phi_T R_T \geq \gamma_p T_{maxsn}$ (11.12.6.1-1)

- Facing Flexure LRFD Equation

  $\phi_{FF} R_{FF} \geq \gamma_p T_{osn}$ (11.12.6.2.2-1)

  T_{osn} = Tensile Force @ Nail Head = T_{maxsn} (Assumed)

- Facing Punching LRFD Equation

  $\phi_{FP} R_{FP} \geq \gamma_p T_{osn}$ (11.12.6.2.3-1)

- Headed-Stud In Tension LRFD Equation

  $\phi_{FH} R_{FH} \geq \gamma_p T_{osn}$ (11.12.6.2.4-1)

Limit Equilibrium Analysis w/ LRFD

- How?
- Internal, Compound, Global Stability?
- Method (Spencer, Bishop, Janbu, etc.), i.e., Shape of Failure Plane?
- Factor of Safety?
- Nominal or Factored T_{maxsn}?
- Computer Software?

2018 AASHTO Agenda Item C11.12.2

"Available computer programs used for soil nail wall stability analysis typically provide values of T_{maxsn} in each soil nail row that corresponds to the target level of safety. The T_{maxsn} values obtained may vary depending on the volume of soil between the wall face and the critical surface (which is a function of the slope stability FS), the type of surface analyzed (e.g., circular, log spiral, two part wedge, etc.), and the distribution of force along the length of the nails. How these factors affect the results may vary depending on the software used for the wall design. The designer should consider these factors when selecting values for T_{maxsn} to be used in the limit state equations specified in Articles 11.12.5 and 11.12.6 for designing the nails for tensile and pullout resistance, and the strength of the facing needed."

NCDOT Soil Nail Wall Approach

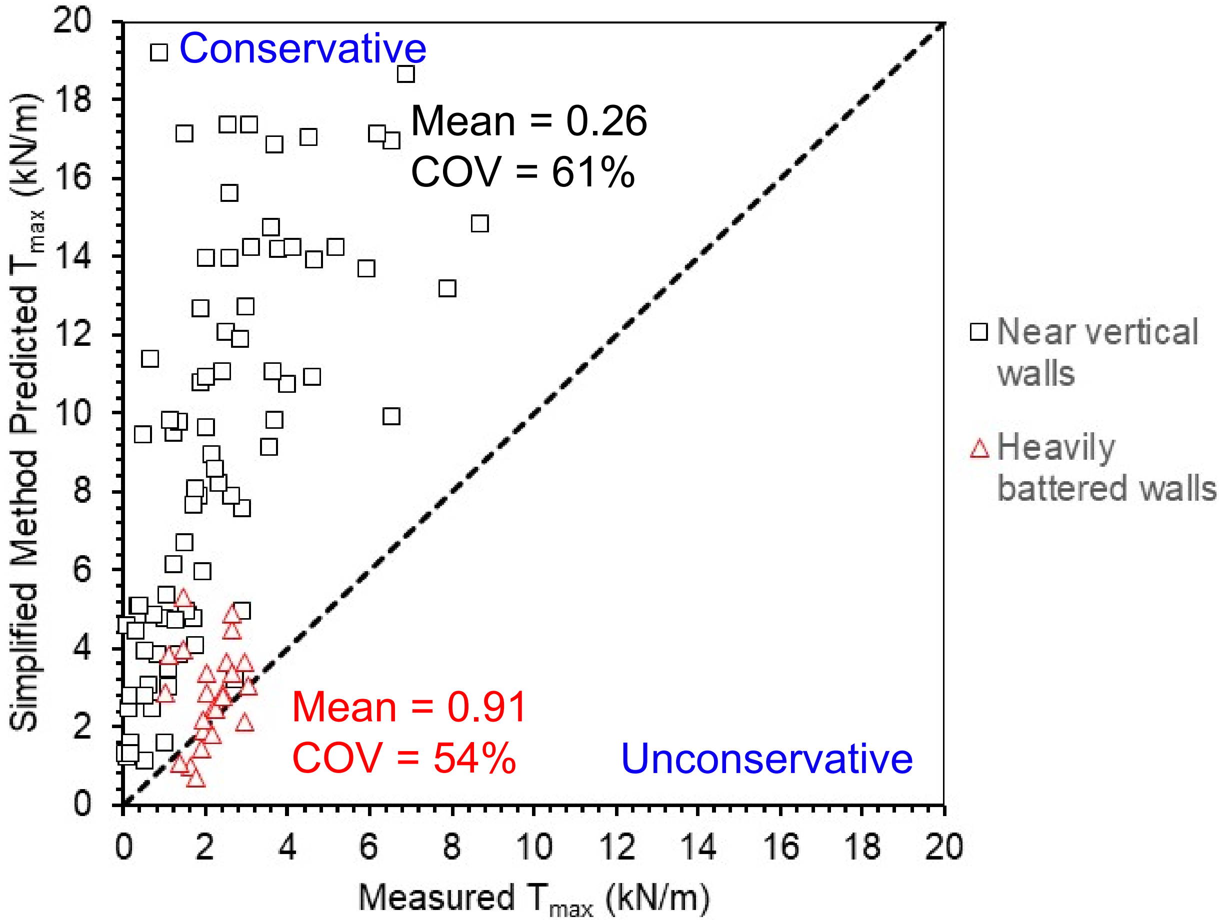
- Similar Approach to MSE walls
- Prefer Computer Software Program Snail but…..
- Computer Software Program Slide can be used to approximate Snail
- Soil nail wall designs will either be based on the new Snail or checked with Slide to approximate Snail T_{maxsn}

MSE Wall Changes/Additions (2019)

- Why are we doing this?
  - Some parts of current code are 20 years or more out of date
  - A lot of research has been done since
  - Current internal stability methods are very conservative for geogrid reinforcement
  - Current code does not address polymer straps, i.e., geostrips
  - Current code language and organization needs improvement and clarification

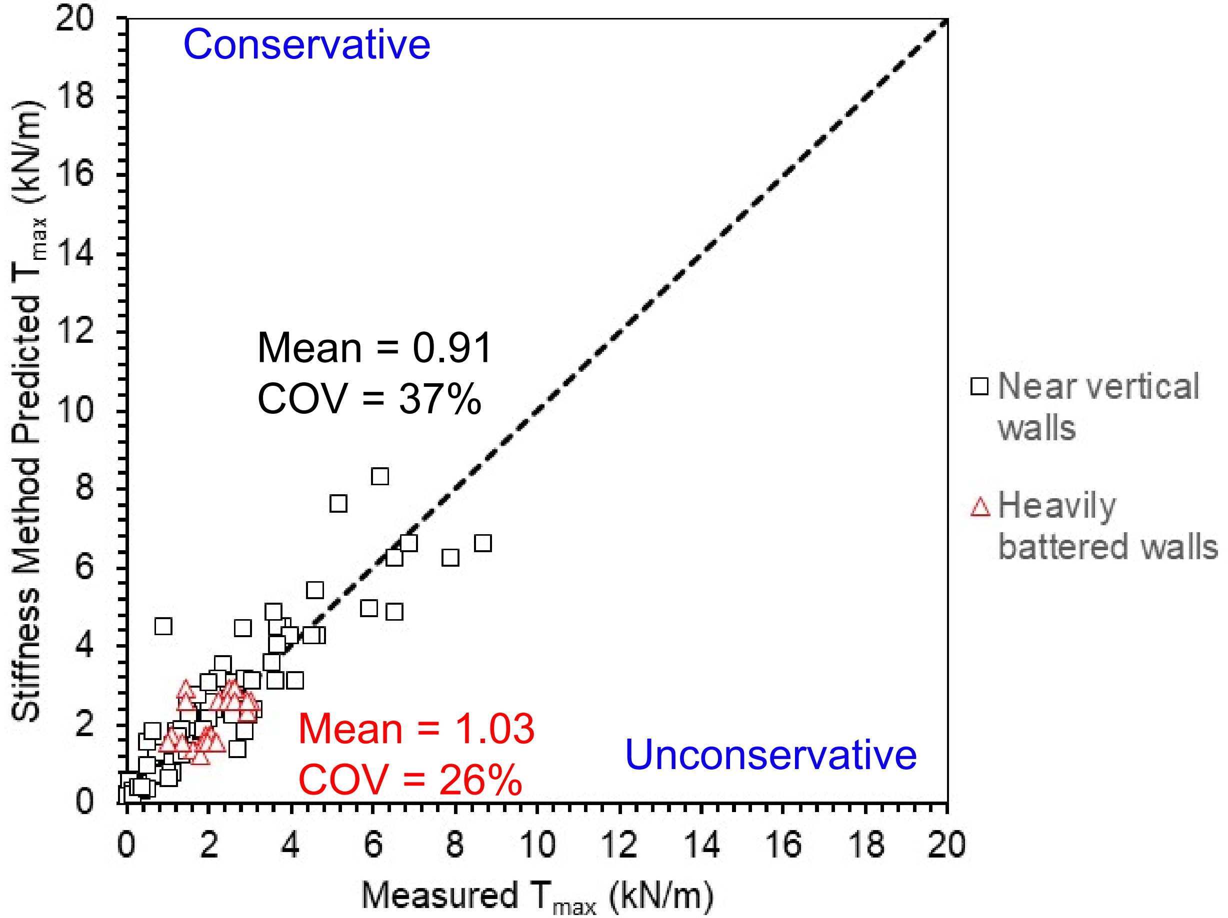
Predicted vs. Measured T_{max} for Geosynthetics

- Shows T_{max} for Simplified Method
- Plot includes all geosynthetic reinforced walls in database, except PET straps (sand backfill only)
- Heavily battered walls have face batter greater than 20°



Predicted vs. Measured T_{max} for Geosynthetics

- Shows T_{max} for Stiffness Method
- Plot includes all geosynthetic reinforced walls in database, except PET straps (sand backfill only)
- Heavily battered walls have face batter greater than 20°



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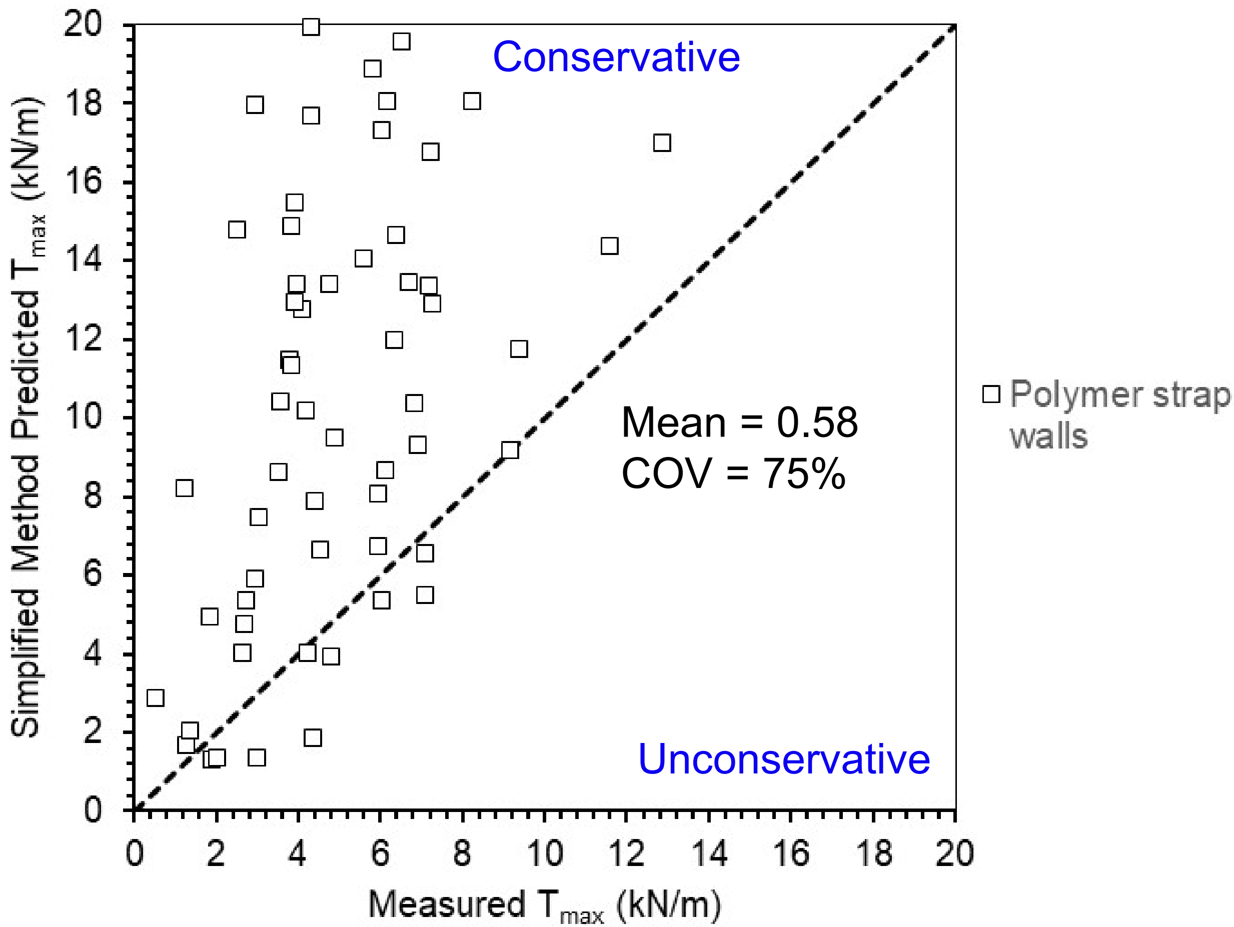

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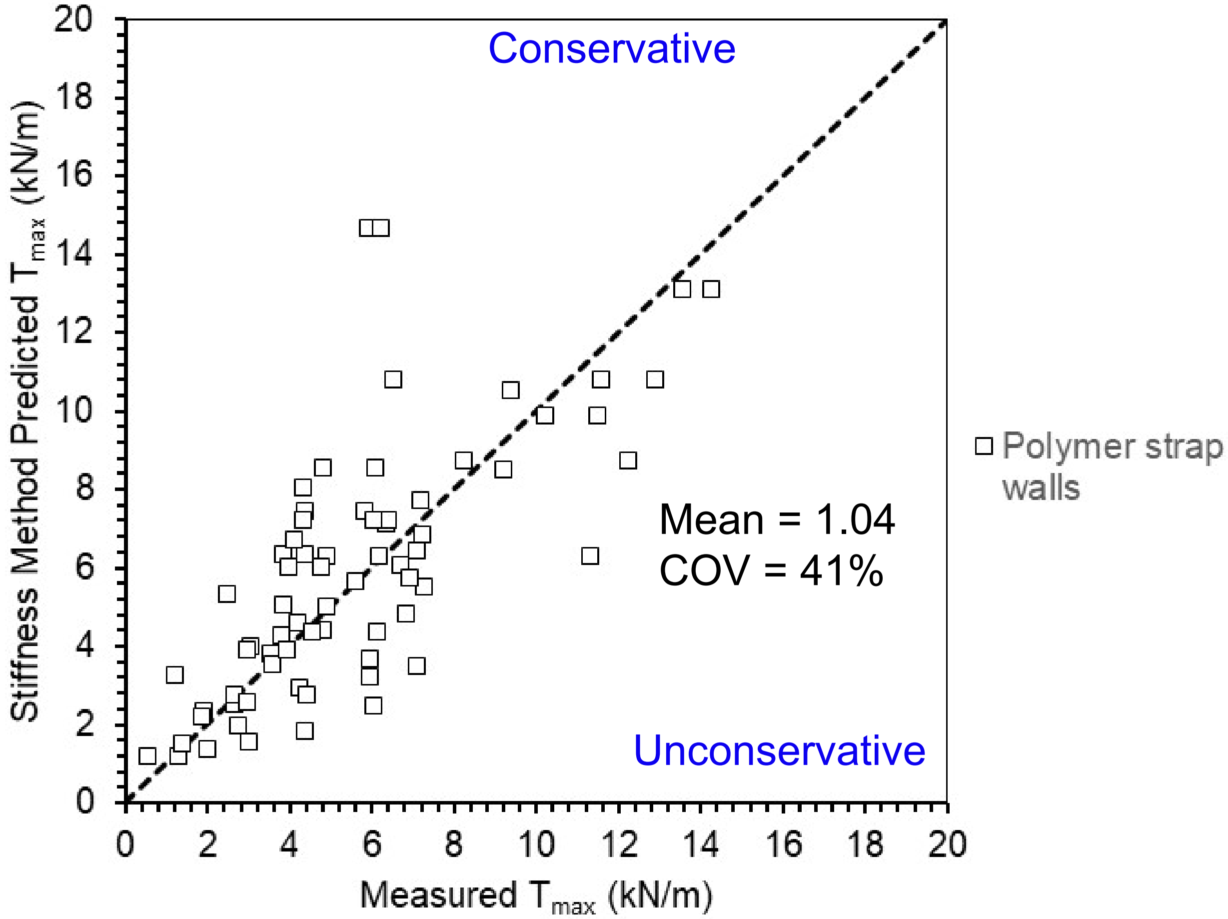
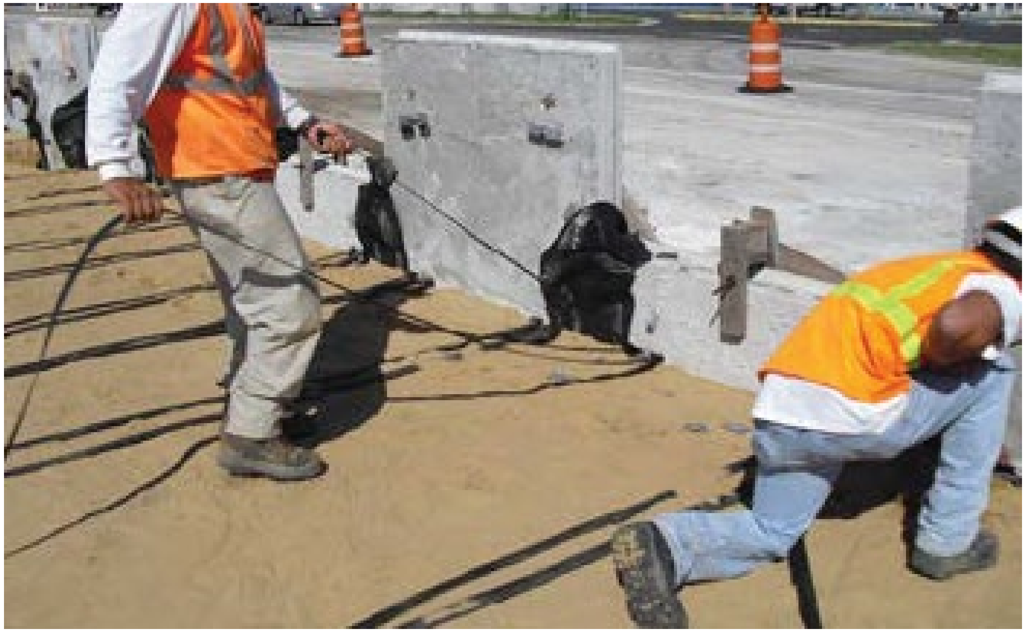


MSE Wall Changes/Additions (2019)

- Internal Stability Changes/Additions
  - Existing uncalibrated **Simplified Method** moved to Appendix (still acceptable but considered a “legacy” method)
  - Existing uncalibrated **Coherent Gravity Method** remains for steel reinforcement
  - New calibrated **Stiffness Method** added for all geosynthetic reinforcement (includes geogrids and geostrips)
  - **Limit Equilibrium Method** expanded and clarified for compound stability, complex geometry and very soft/weak foundation soil

MSE Wall Geostrip Reinforcement



MSE Wall Geostrip Reinforcement

Table 3 – pH Composition of Aggregate

Aggregate Material	Reinforcement or Connector Material	pH Requirement*		Test Method
		Min.	Max.	
Coarse or Fine	**Steel**	5	10	AASHTO T289 (fine), NCDOT Procedure (coarse), -See —Appendix B
~~**Coarse or Fine**~~	~~**Polyester Type (PET) Geogrid**~~	~~5~~	~~8~~	~~AASHTO T289 (fine), NCDOT Procedure (coarse), See Appendix B~~
Coarse or Fine	**Geosynthetic~~trip or Polyolefin Geogrid~~**	4.5	9	AASHTO T289 (fine), NCDOT Procedure (coarse), -See —Appendix B

*Based on the following:

- Section 11.10.6.4.2a of the AASHTO LRFD Bridge Design Specifications for steel reinforcement or connector material
- ~~Table 3-11 of the FHWA Design and Construction of Mechanically Stabilized Earth Walls and Reinforced Soil Slopes for PET geogrid reinforcement or connector material~~
- Section 11.10.6.4.2b of the AASHTO LRFD Bridge Design Specifications for ~~geostrip or polyolefin~~ geosynthetic~~grid~~ reinforcement or connector material

MSE Wall Geostrip Reinforcement

- AASHTO LRFD Bridge Design Spec (COBS T-15 Committee)
- AASHTO R 69 (COMP TS-4e Committee)
- AASHTO NTPEP REGEO (NTPEP Geosynthetics Committee)
- NCDOT Geosynthetic Reinforcement Evaluation Guidelines and QPL (M&T)
- NCDOT MSE Wall Aggregate Sampling and Testing Procedures (M&T)
- NCDOT MSE Wall System Approvals (Geotech)
- NCDOT MSE Wall Standard Provision, Notes and Cells (Geotech)

MSE Wall Software

- NCDOT is currently using **Simplified Method** for internal stability and Computer Software Program MSEW to check MSE wall designs
- This will continue in short term even with impending changes for geostrips
- Long term plan is to change to **Coherent Gravity Method** for steel and **Stiffness Method** for geosynthetics
- Current MSEW will work for **Coherent Gravity Method**
- Computer Software Program for **Stiffness Method**?

Questions?