WHRP
Wisconsin Highway Research Program




Correlation of ASTM D4833 and D6241 Geotextile Puncture Test Methods and Results for Use on WisDOT Projects

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Outline

- Problem statement
- Objective
- Background
- Results
- Proposed Specifications
- Conclusions

Problem Statement

- WisDOT is interested in how changes in ASTM standards for puncture testing of geotextiles can be incorporated within DOT specifications.
- There is little understanding how the results from D6241 (new) correlate to D4833 currently used.
- Also interest in understanding how UV/elevated temperature exposure and freeze-thaw influence the puncture resistance.

Objective

Multi-phase approach to investigate how geotextiles respond to ASTM puncture standards.

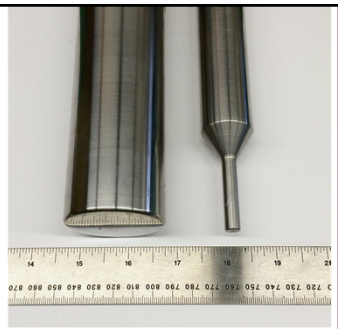
Primary objective is to help WisDOT develop new puncture strength recommendations.

Background

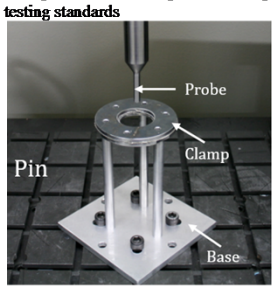
- Geotextiles are used in numerous infrastructure applications including separation, filtration, reinforcement, protection or drainage. Mostly are made of polymeric materials that can be woven or non-woven.
- One of the main characterization parameters is the puncture strength which correlates the ability of the material to withstand the installation and service conditions.

Measure	ASTM D4833 (Pin)	ASTM D6241 (CBR)
Probe Diameter	8 mm ± 0.1mm	50 mm ± 1mm
Probe Chamfer/Edge	45°, 0.8 mm	2.5 mm ± 0.5 mm
Specimen Minimum Outer Diameter	100 mm	Clamp outer dia. + 10 mm
Specimen Unsupported Diameter (Clamp Inner Diameter)	45 mm ± 0.025 mm	150 mm
Compression Speed	300 mm ± 10 mm/min	50 mm/min
Maximum Allowable Slippage	None allowed	5 mm
Number of Tests	15	10
Lab Temperature	21 ± 2°C	21 ± 2°C
Lab Relative Humidity	65 ± 5%	50-70%
Test Conclusion	Break	Break
Resistance Reported	Maximum	Maximum

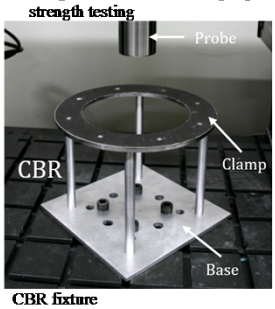
(a) Comparison of ASTM pin and CBR puncture testing standards



(b) Plungers used for CBR and pin puncture strength testing



(c) Pin puncture fixture

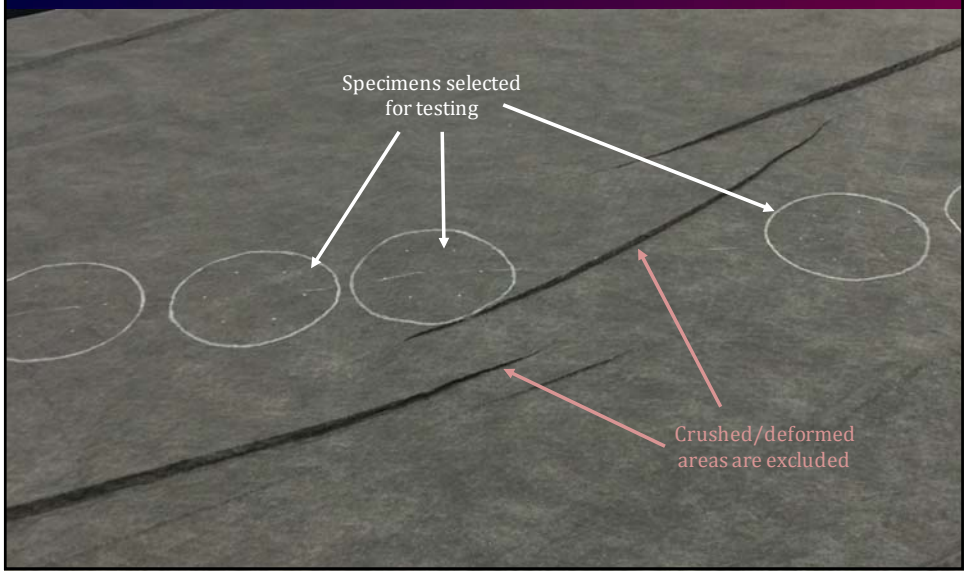


(d) CBR fixture

Experimental Program

- Phase 1 (125 tests): PP woven, non-woven with mass/area of 4 – 12 oz/yd^2. Understand fundamental failure mechanics between woven/non-woven also includes freeze-thaw.
- Phase 2 (405 tests): WisDOT specimens from 29 different projects with variety in application type, fabric and weave structure. Main bulk of database to compare puncture strength from D6241 and D4833.
- Phase 3 (60 tests): Using WisDOT provided specimens from 6 types exposed to elevated temperature, moisture and UV testing. Develop guidance for UV exposure.

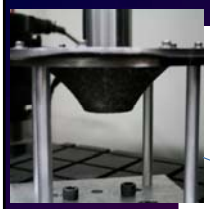
Phase 1 Results
Sampling Plan

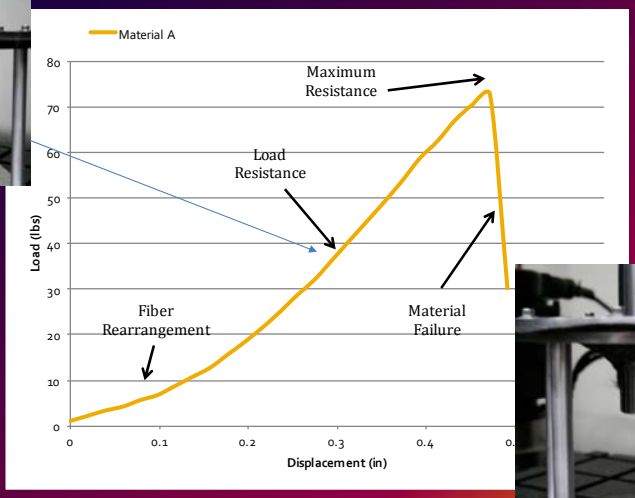


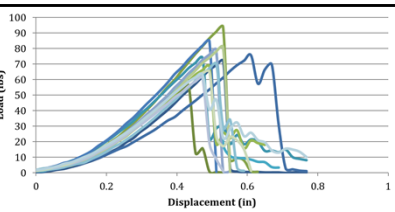
Phase 1 Results
Test Matrix

Geotextile Designation	Material Type	Weave Type	Use/Application	Mass/Unit Area, oz/yd² (g/m²)
A	PP	Nonwoven	Drainage, Separation	4 (136)
B	PP	Woven	Separation	4 (136)
C	PP	Nonwoven	Drainage, Separation	8 (271)
D	PP	Woven	Filtration, Separation	8 (271)
E	PP	Nonwoven	Drainage, Separation	12 (406)

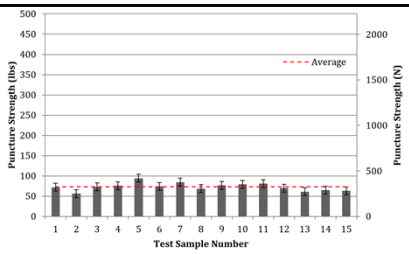
Phase 1 Results
Non-woven Load – Displacement Response



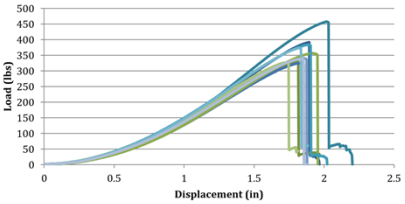




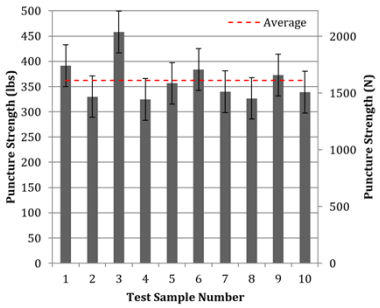
(a) Pin load-displacement curve



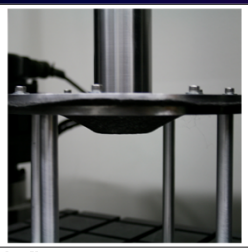
(b) Pin bar chart – (error bars indicate standard deviations)



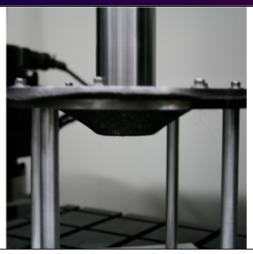
(c) CBR load-displacement curve



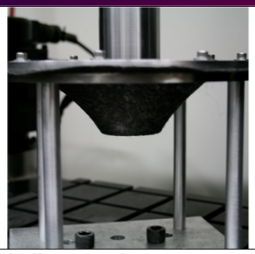
(d) CBR bar chart – (error bars indicate standard deviations)



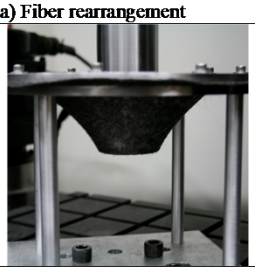
(a) Fiber rearrangement



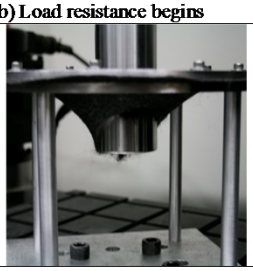
(b) Load resistance begins



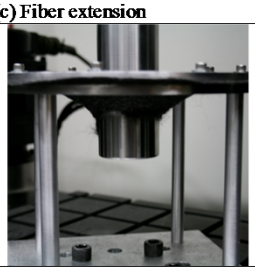
(c) Fiber extension



(d) Material voids become apparent



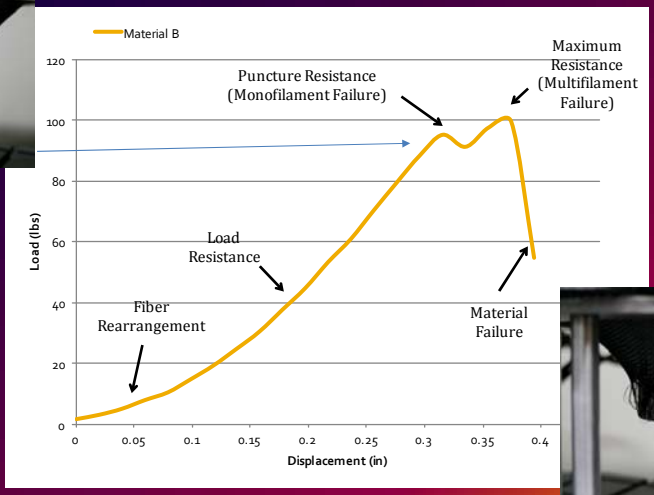
(e) Puncture

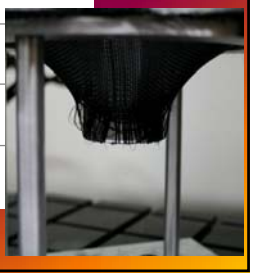


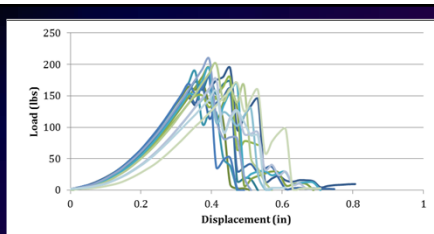
(f) Recoil

Nonwoven geotextile – CBR puncture strength test

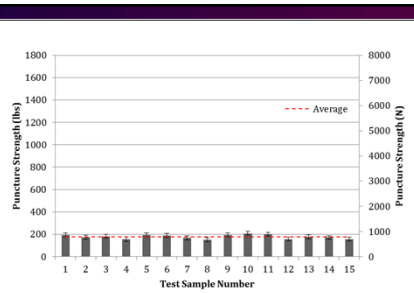
Phase 1 Results
Woven Load – Displacement Response



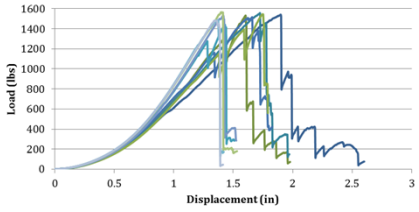




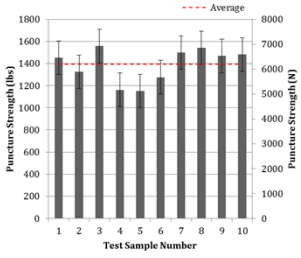
(a) Pin load-displacement curve



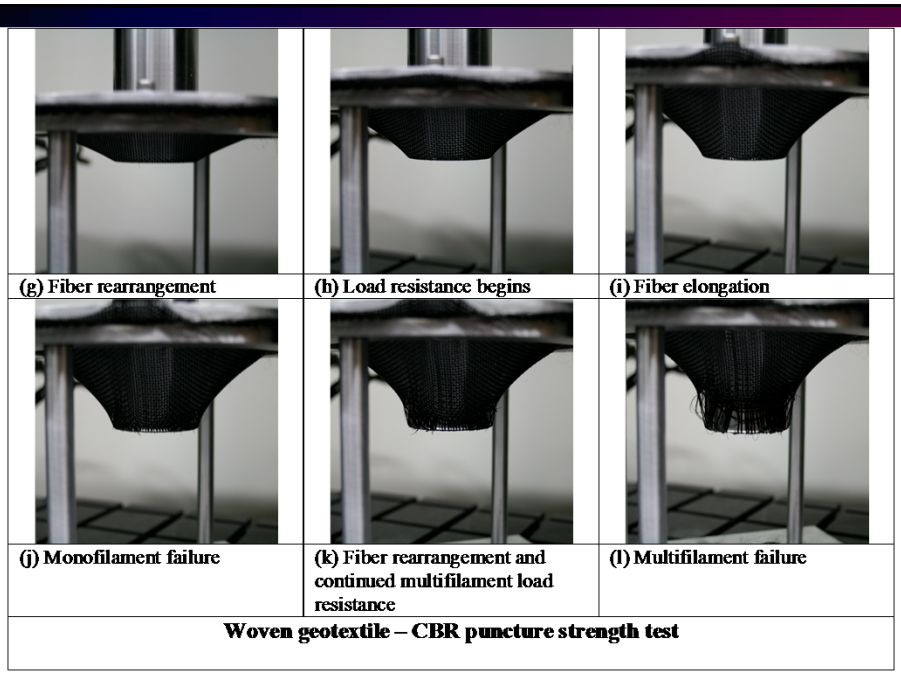
(b) Pin bar chart



(c) CBR load-displacement curve



(d) CBR bar chart – (error bars indicate standard deviations)



(g) Fiber rearrangement	(h) Load resistance begins	(i) Fiber elongation
(j) Monofilament failure	(k) Fiber rearrangement and continued multifilament load resistance	(l) Multifilament failure

Woven geotextile – CBR puncture strength test

Correlations

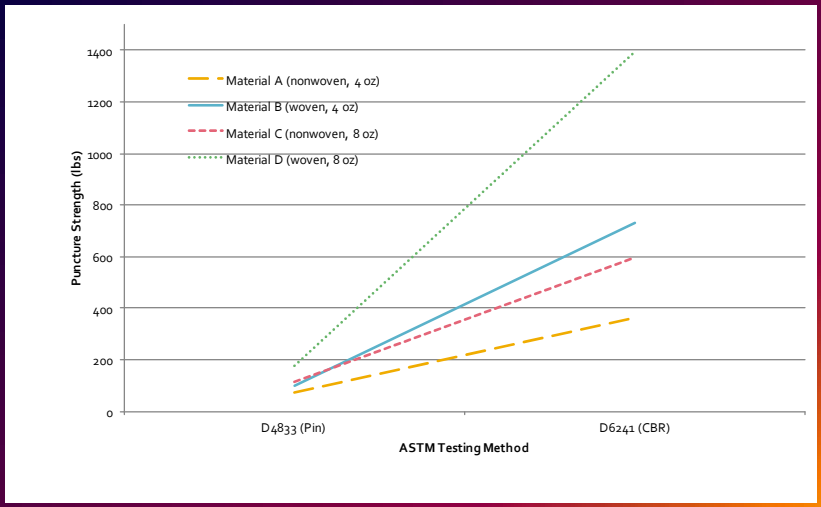
Non-woven

$$Strength_{CBR,estimated} = 5.270 \times Strength_{pin,measured}$$ Equation (1)

Woven

$$Strength_{CBR,estimated} = 7.378 \times Strength_{pin,measured}$$ Equation (2)

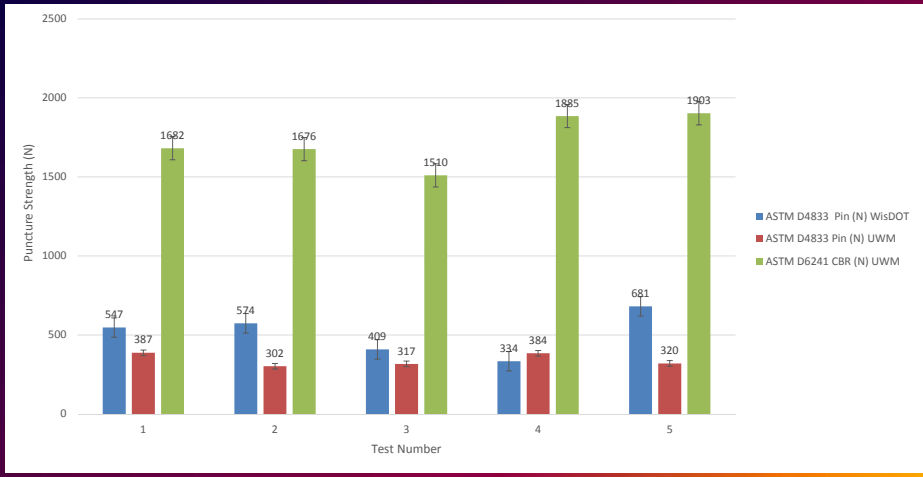
Phase 1 Results
Comparison of D6241 and D4833 on control material



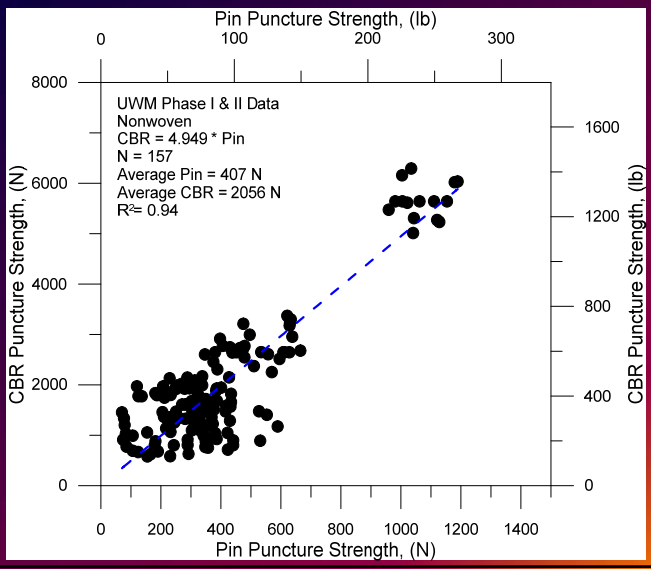
Phase 2 ASTM Comparison on WisDOT specimens

- 405 test specimens from 29 different projects across different types and manufacturers.
- Specimens tested at UWM to both ASTM D4833 and D6241. Compared to WisDOT records from D4833.

Phase 2
Typical Distribution from one project



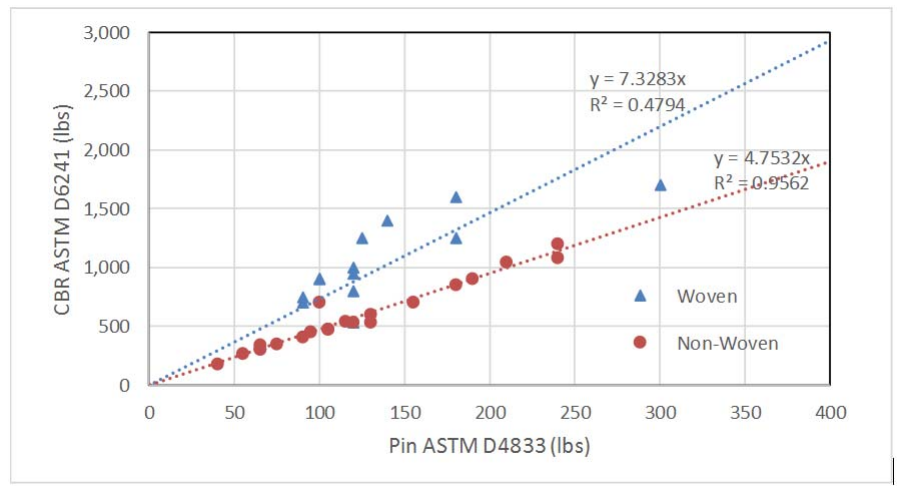
Phase 2
R^2 Correlations



Geotextile Test Result		Correlation: PS(CBR) = α × PS(Pin)	R^2
Phase I	Woven	PS(CBR) = 7.46 × PS(Pin)	0.98
	Nonwoven	PS(CBR) = 5.19 × PS(Pin)	0.98
Phase II	Woven	PS(CBR) = 4.28 × PS(Pin)	0.85
	Nonwoven	PS(CBR) = 5.57 × PS(Pin)	0.85
Combined (Phase I and Phase II)	Woven	PS(CBR) = 6.36 × PS(Pin)	0.91
	Nonwoven	PS(CBR) = 4.90 × PS(Pin)	0.92

PS(CBR): CBR Puncture Strength (N, lbs) from ASTM D6241
PS(Pin): Pin Puncture Strength (N, lbs) from ASTM D4833
α: Correlation Constant

Geotextile Industry Tests/Specifications



Current and Proposed WisDOT Specification limits

Geotextile Type	Minimum Puncture Strength (Average)			
	Current WisDOT Specifications Based on ASTM D4833 (Pin)		Proposed WisDOT Specifications Based on ASTM D6241 (CBR)	
	lbs.	N	lbs.	N
Subgrade Aggregate Separation (SAS)	70	300	340	1500
Marsh Stabilization (MS)	NA	NA	NA	NA
Drainage Filtration (DF), Schedule A	40	175	190	840
Drainage Filtration (DF), Schedule B	70	300	340	1500
Drainage Filtration (DF), Schedule C	70	311	340	1500
Subgrade Reinforcement (SR)	NA (145)*	NA (650)*	NA (700)**	NA (3100)**
Riprap (R)	80	350	390	1700
Heavy Riprap (HR)	100	440	490	2100
Modified Subgrade Aggregate Separation Type C (SAS-C)	70	300	340	1500
Embankment Stabilization (ES)	NA	NA	NA	NA

* Specification values are obtained from WisDOT project documents.

** Based on same data from WisDOT project documents

Conclusions

- All types of geotextiles exhibited puncture strength values, whether pin or CBR, that were consistent within each group
- Woven PP materials exhibit a CBR puncture strength approximately double that of nonwoven PP materials using D6241.
- Results from D6241 generally have a lower CV and hence less variability than the results from D4833.

Conclusions

- Statistical correlations were developed to estimate the CBR puncture strength values from the pin test with a reasonable accuracy.
- Equation 1 can be used to estimate the CBR puncture strength based on pin test puncture strengths of PP nonwoven materials only and Equation 2 can be used to estimate the CBR puncture strength based on pin test puncture strengths of PP woven materials only.

Conclusions

- CBR puncture strength test specifications were developed and proposed for WisDOT

Acknowledgements

- WHRP & WisDOT financial support
- WHRP Flexible TOC Chair Andrew Zimmer and POC members Jeffrey Horsfall, Robert Arndorfer
- TenCate Geosynthetics
- Jay Schabelski of Romus Inc