STONE LABORATORY TEST REPORT

Report No.: 22-0082.02-R1
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Prepared for: Mr. Justin Lindblad
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1432 Teton
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Product: Natural Travertine Product – Yellowstone Frost

Scope: The Natural Institute (NSI) was contracted by Yellowstone Rock to perform physical properties evaluations for one natural travertine product (Yellowstone Frost). The scope of testing included absorption, density, compressive strength, modulus of rupture, flexural strength, abrasion resistance, and slip resistance (dynamic coefficient of friction [DCoF]), and petrographic analysis. Testing was performed at the NSI laboratory located in Oberlin, Ohio.

Methods: The products were evaluated in accordance with the following test method(s):

ASTM C97/C97M-2018, *Standard Test Method for Absorption and Bulk Specific Gravity of Dimension Stone*

ASTM C170/C170M-2017, *Standard Test Method for Compressive Strength of Dimension Stone*

ASTM C880/C880M-2018, *Standard Test Method for Flexural Strength of Dimension Stone*

ASTM C1353/C1353M-20, *Standard Test Method for Abrasion Resistance of Dimension Stone Subjected to Foot Traffic Using a Rotary Platform Abraser*

ASTM C1527/C1527M-11(2018), *Standard Specification for Travertine Dimension Stone*

ASTM C99/C99M-18*, Standard Test Method for Modulus of Rupture of Dimension Stone*

ANSI A326.3-2018, *American National Standard Test Method for Measuring Dynamic Coefficient of Friction of Hard Surface Flooring Materials*

ASTM C1721-21a, *Standard Guide for Petrographic Examination of Dimension Stone*

Test Materials: Test materials were provided by Yellowstone Rock and were received in good condition for testing. Specimens were tested as received other than preconditioning as required by the applicable test method(s) prior to testing. Representative test materials shall be retained by the NSI for a period of four years.

Test Witness Record

Name	Company
R. Lawson	NSI
Scott D. Scallorn	NSI

Test Procedure(s): Unless otherwise stated, all specimen conditioning and testing was conducted in standard laboratory conditions. Test photos are located on pages 14-16 of this report. Equipment calibration certificates are available upon request.

ASTM C97 - Absorption and Density Evaluation

The absorption and density evaluations were conducted in accordance with the procedures detailed in ASTM C97. The specimens were oven-dried at 60°C to a stable mass condition (minimum 48 hours), reacclimated to ambient lab temperature and weighed on an Ohaus digital balance (SN: B614316489) for determination of dry condition mass. They were then immersed in filtered water for 48 hours prior to individual removal, surface drying with a damp cloth and determination of wet condition mass. The specimens were then suspended in the water within a wire cage and weighed for determination of immersed condition mass. Absorption (%) and bulk specific gravity were calculated for each specimen as per the equations in ASTM C97, Section 9. Test results were averaged for the series and evaluated against the performance criteria presented in ASTM C1527, Table 1.

ASTM C170 – Compressive Strength Evaluation

The compressive strength evaluation was conducted on a Test Mark compression tester (SN: 160618) in accordance with the procedures detailed in ASTM C170. Dry condition specimens were oven-dried at 60°C for a minimum of 48 hours and cooled to ambient prior to testing. Wet condition specimens were immersed in water for 48 hours prior to individual removal and testing. Compressive strength was calculated for each specimen as per the equation in ASTM C170, Section 10.1. Test results were averaged for the series and evaluated against the performance criteria presented in ASTM C1527, Table 1.

ASTM C880 – Flexural Strength Evaluation

The Flexural strength evaluation was conducted on a ATS Universal Test Machine (SN: 16-14900-1) employing a 12.5-kip load cell (SN: 561414A) in accordance with the procedures detailed in ASTM C880. Specimens were tested in both oven-dry and wet conditions. Dry condition specimens were oven-dried at 60°C for a minimum of 48 hours and cooled to ambient prior to testing. Wet condition specimens were immersed in water for 48 hours prior to individual removal and testing. Specimens were supported at a test span of 12.5 in. and loaded at quarter point (6.25 in. loading span) until failure. Flexural strength was calculated for each specimen as per the equation in ASTM C880, Section 10.1. Test results were averaged for the series and evaluated against the performance criteria presented in ASTM C1527, Table 1.

ASTM C1353 – Abrasion Resistance Evaluation

The abrasion resistance evaluation was conducted in accordance with the procedures detailed in ASTM C1353. The specimens were oven-dried at 60°C for a minimum of 48 hours and cooled prior to determination of pre-abrasion mass on an Ohaus digital balance (SN: B614316489) The specimens were then evaluated on a Taber Industries rotary platform abraser (SN: 20161679) employing H-22 Calibrade abrasive wheels with 1,000 grams of downward force applied to each for a total of 1000 wear cycles. Upon completion of cycling, post-exposure mass was determined for each specimen. Employing the bulk specific gravity results obtained from ASTM C97 evaluation, Index of Abrasion was calculated for each specimen as per the equation in ASTM C1353, Section 9.1. Test results were averaged for the series and evaluated against the performance criteria presented in ASTM C1527, Table 1.

ASTM C99 – Modulus of Rupture Evaluation

The Modulus of Rupture (MoR) evaluation was conducted on a ATS Universal Test Machine (SN: 16-14900-1) employing a 12.5-kip load cell (SN: 561414A) in accordance with the procedures detailed in ASTM C99. Specimens were tested in both oven-dry and wet conditions. Dry condition specimens were oven-dried at 60°C for a minimum of 48 hours and cooled to ambient prior to testing. Wet condition specimens were immersed in water for 48 hours prior to individual removal and testing. Specimens were supported at a test span of 7.0 in. and loaded at midspan until failure. Flexural strength was calculated for each specimen as per the equation in ASTM C99, Section 11.1.

ANSI A326.3 Dynamic Coefficient of Friction (DCoF) Evaluation

The DCoF evaluation was conducted in accordance with the procedures detailed in ANSI A326.3, section 8. Specimens were evaluated with a BOT 3000E tribometer (Serial No.: VS 901265800196) in wet condition (employing a 0.05% SLS solution). Four 10 in. long travel passes were taken at a 90° offset to one another and the resultant DCoF measurements averaged for each specimen.

Mean individual specimen results were averaged for the test series and evaluated against the ANSI A326.3, Section 3.1 recommended wet condition performance criteria of 0.42.

ASTM C1721 - Petrographic Evaluation

The petrographic analysis was performed in accordance with ASTM C1721 by a qualified outsource laboratory (Minerology, Inc.). The full report is designated as “23004.YellowstoneFrost” and was reported independently.

Specimen Details

Test Method	Quantity	Nominal Dimensions	Description
ASTM C97	5	3.0 in. cubes	Cream tone natural travertine
ASTM C170	20	3.0 in. cubes	
ASTM C880	20	4 in. x 15 in. x 1.25 in.	
ASTM C1353	3	4 in. square x 0.375 in.	
ASTM C99	20	4 in. x 8 in. x 2.25 in.	
ANSI A326.3	3	12 in. square x 0.375 in.	
ASTM C1721	1	4 in. square x 1.25 in.	

Test Results

ASTM C97 – Absorption & Density Evaluation

Specimen No.	Measured Mass (g)			Absorption (%)	Bulk Specific Gravity	Density (lbs/ft^3)
	Oven-Dry	48-Hour Wetted	Immersed Suspended			
1	982.48	1,009.72	579.42	2.77	2.283	142.5
2	1,068.95	1,079.04	641.79	0.94	2.445	152.6
3	1,034.30	1,050.81	618.46	1.60	2.392	149.3
4	947.13	1,004.06	574.89	6.01	2.207	137.8
5	985.16	1,014.98	581.92	3.03	2.275	142.0
Series Average				**2.87**	**2.320**	**144.8**
Standard Deviation				2.0	0.10	6.0
Coefficient of Variation (%)				67.9	4.1	4.1

ASTM C1353 – Abrasion Resistance Evaluation

Specimen No.	Bulk Specific Gravity	Mass (g)			Wear Cycles Completed	Index of Abrasion
		Initial	End	Loss		
1	2.320	211.90	193.43	18.47	1,000	4.6
2		207.73	191.92	15.81		5.4
3		223.21	208.85	14.36		5.9
Series Average						**5.3**
Standard Deviation						0.7
Coefficient of Variation (%)						12.5

ANSI A326.3 - Dynamic Coefficient of Friction (Wet)

Specimen No.	Test Orientation				Wet Condition DCoF
	0°	90°	180°	270°	
1	0.74	0.71	0.73	0.71	0.72
2	0.72	0.72	0.72	0.72	0.72
3	0.73	0.73	0.74	0.72	0.73
Series Average					**0.72**
Standard Deviation					0.01
Coefficient of Variation (%)					1.4

ASTM C170 – Compressive Strength Evaluation – Wet Condition, Perpendicular Loading

Specimen No.	Test Condition	Specimen Dimensions (in)		Loading Area (in^2)	Failure Load (lb_f)	Compressive Strength (psi)
		Length	Width			
PP-W-1	Perpendicular to stone rift orientation Wet Condition	3.01	3.01	9.04	35,760	3,960
PP-W-2		3.01	3.00	9.03	53,160	5,890
PP-W-3		3.01	3.00	9.03	47,880	5,300
PP-W-4		2.99	3.02	9.03	49,500	5,480
PP-W-5		3.01	3.00	9.04	32,030	3,540
Series Average						**4,830**
Standard Deviation						1,023
Coefficient of Variation (%)						21.2

ASTM C170 – Compressive Strength Evaluation – Wet Condition, Parallel Loading

Specimen No.	Test Condition	Specimen Dimensions (in)		Loading Area (in^2)	Failure Load (lb_f)	Compressive Strength (psi)
		Length	Width			
PP-D-1	Perpendicular to stone rift orientation Dry Condition	3.01	3.00	9.02	44,600	4,940
PP-D-2		3.01	2.99	9.01	44,440	4,930
PP-D-3		3.00	3.01	9.04	42,260	4,670
PP-D-4		3.02	2.99	9.03	33,160	3,670
PP-D-5		2.99	3.00	8.98	44,400	4,940
Series Average						**4,630**
Standard Deviation						549
Coefficient of Variation (%)						11.9

ASTM C170 – Compressive Strength Evaluation – Wet Condition, Perpendicular Loading

Specimen No.	Test Condition	Specimen Dimensions (in)		Loading Area (in^2)	Failure Load (lb_f)	Compressive Strength (psi)
		Length	Width			
LL-W-1	Parallel to stone rift orientation Wet Condition	3.01	2.99	9.00	49,180	5,460
LL-W-2		3.02	3.00	9.07	27,370	3,020
LL-W-3		3.04	3.01	9.15	56,080	6,130
LL-W-4		3.00	3.01	9.01	43,230	4,800
LL-W-5		3.05	3.00	9.12	25,700	2,820
Series Average						**4,450**
Standard Deviation						1472
Coefficient of Variation (%)						33.1

ASTM C170 – Compressive Strength Evaluation – Dry Condition, Parallel Loading

Specimen No.	Test Condition	Specimen Dimensions (in)		Loading Area (in^2)	Failure Load (lb_f)	Compressive Strength (psi) [2]
		Length	Width			
LL-D-1	Parallel to stone rift orientation Dry Condition	3.02	3.01	9.10	25,560	2,810
LL-D-1		3.02	3.03	9.14	48,210	5,270
LL-D-1		3.02	3.02	9.12	28,640	3,140
LL-D-1		3.02	3.02	9.10	35,060	3,850
LL-D-1		2.99	3.01	9.00	34,670	3,850
Series Average						**3,780**
Standard Deviation						946
Coefficient of Variation (%)						25.0

ASTM C880 – Flexural Strength Evaluation – Wet Condition, Perpendicular Loading

Specimen Details		Support Span (in)	Specimen Dimensions (in)		Failure Load (lb_f)	Flexural Strength (psi)
No.	**Test Condition**		**Width**	**Depth**		
PP-W-1	Perpendicular to stone rift orientation Wet Condition	12.5	3.95	1.32	265	360
PP-W-2			3.96	1.22	138	220
PP-W-3			3.96	1.24	259	400
PP-W-4			3.99	1.35	285	370
PP-W-5			3.97	1.32	280	380
Series Average						**350**
Standard Deviation						72
Coefficient of Variation (%)						20.6

ASTM C880 – Flexural Strength Evaluation – Dry Condition, Perpendicular Loading

Specimen No.	Test Conditions	Support Span (in)	Specimen Dimensions (in)		Failure Load (lb_f)	Flexural Strength (psi)
			Width	**Depth**		
PP-D-1	Perpendicular to stone rift orientation Dry Condition	12.5	3.95	1.33	286	380
PP-D-2			3.97	1.28	246	350
PP-D-3			3.97	1.26	322	480
PP-D-4			3.90	1.23	263	410
PP-D-5			3.96	1.35	459	590
Series Average						**440**
Standard Deviation						96
Coefficient of Variation (%)						21.8

ASTM C880 – Flexural Strength Evaluation – Wet Condition, Parallel Loading

Specimen Details		Support Span (in)	Specimen Dimensions (in)		Failure Load (lb_f)	Flexural Strength (psi)
No.	**Test Condition**		**Width**	**Depth**		
LL-W-1	Parallel to stone rift orientation Wet Condition	12.5	4.02	1.25	267	400
LL-W-2			4.05	1.26	318	470
LL-W-3			4.02	1.26	251	370
LL-W-4			4.01	1.20	156	250
LL-W-5			4.03	1.20	303	490
Series Average						**400**
Standard Deviation						95
Coefficient of Variation (%)						23.8

ASTM C880 – Flexural Strength Evaluation – Dry Condition, Parallel Loading

Specimen Details		Support Span (in)	Specimen Dimensions (in)		Failure Load (lb_f)	Flexural Strength (psi)
No.	**Test Condition**		**Width**	**Depth**		
LL-D-1	Parallel to stone rift orientation Wet Condition	12.5	4.01	1.20	125	200
LL-D-2			4.01	1.21	265	420
LL-D-3			4.02	1.18	151	250
LL-D-4			4.01	1.21	225	360
LL-D-5			4.04	1.26	330	480
Series Average						**340**
Standard Deviation						116
Coefficient of Variation (%)						34.1

ASTM C99 – Modulus of Rupture Evaluation – Wet Condition, Perpendicular Loading

Specimen Details		Support Span (in)	Specimen Dimensions (in)		Failure Load (lb_f)	Modulus of Rupture (psi)
No.	**Test Condition**		**Width**	**Depth**		
PP-W-1	Perpendicular to stone rift orientation Wet Condition	7.0	4.03	2.26	743	380
PP-W-2			4.02	2.25	1,006	520
PP-W-3			4.00	2.28	1,047	530
PP-W-4			3.95	2.27	1,037	530
PP-W-5			3.97	2.28	1,337	680
Series Average						**530**
Standard Deviation						106
Coefficient of Variation (%)						20.0

ASTM C99 – Modulus of Rupture Evaluation – Dry Condition, Perpendicular Loading

Specimen No.	Test Conditions	Support Span (in)	Specimen Dimensions (in)		Failure Load (lb_f)	Flexural Strength (psi)
			Width	**Depth**		
PP-D-1	Perpendicular to stone rift orientation Dry Condition	7.0	4.00	2.26	1,365	700
PP-D-2			4.04	2.26	1,220	620
PP-D-3			4.01	2.24	1,056	550
PP-D-4			4.03	2.27	1,568	800
PP-D-5			3.97	2.26	609	320
Series Average						**600**
Standard Deviation						181
Coefficient of Variation (%)						30.2

ASTM C99 – Modulus of Rupture Evaluation – Wet Condition, Perpendicular Loading

Specimen Details		Support Span (in)	Specimen Dimensions (in)		Failure Load (lb_f)	Modulus of Rupture (psi)
No.	**Test Condition**		**Width**	**Depth**		
LL-W-1	Parallel to stone rift orientation Wet Condition	7.0	4.00	2.26	1,013	520
LL-W-2			3.99	2.25	1,051	550
LL-W-3			3.98	2.26	1,173	610
LL-W-4			3.98	2.25	1,014	530
LL-W-5			3.97	2.24	747	390
Series Average						**520**
Standard Deviation						81
Coefficient of Variation (%)						15.6

ASTM C99 – Modulus of Rupture Evaluation – Dry Condition, Perpendicular Loading

Specimen No.	Test Conditions	Support Span (in)	Specimen Dimensions (in)		Failure Load (lb_f)	Flexural Strength (psi)
			Width	**Depth**		
LL-D-1	Parallel to stone rift orientation Dry Condition	7.0	4.01	2.27	1,552	790
LL-D-2			4.00	2.26	1,100	570
LL-D-3			3.98	2.25	773	400
LL-D-4			4.02	2.25	1,036	530
LL-D-5			3.98	2.26	1,052	540
Series Average						**570**
Standard Deviation						141
Coefficient of Variation (%)						24.7

Conclusion:

The test results were evaluated against the performance criteria presented in ASTM C1527, Table 1 and ANSI A326.3. The results of these evaluations are presented in the tables below:

ASTM C1527 Performance Evaluation Summary				
Physical Requirement	**Test Series Detail**		**Result**	
			Mean Test Value	**Class II (Exterior) Performance Evaluation**
C97 Absorption (%): Class I (Exterior), Class II (Interior): ≤2.5			2.87%	Fails to Meet as Stated
C97 Density (lbs/ft^3): Class I (Exterior), Class II (Interior): ≥144			144.8 lbs/ft^3	Meets as Stated
C170 Compressive Strength (psi): Class I (Exterior): ≥7,500 Class II (Interior): ≥5,000	Perpendicular	Wet	4,830	Fails to Meet as Stated
		Dry	4,630	
	Parallel	Wet	4,450	
		Dry	3,780	
C1353 Abrasion Resistance: Class I (Exterior), Class II (Interior): H_a ≥10			5.3	Fails to Meet as Stated
C880 Flexural Strength (psi): Class I (Exterior), Class II (Interior): ≥500	Perpendicular	Wet	350	Fails to Meet as Stated
		Dry	440	
	Parallel	Wet	400	
		Dry	340	
C99 Modulus of Rupture (psi): No Performance Criteria Stated	Perpendicular	Wet	530	Design Property Only
		Dry	600	
	Parallel	Wet	520	
		Dry	570	

ANSI A326.3 Performance Evaluation Summary			
Physical Requirement	**Test Series Detail**	**Result**	
		Mean Test Value	**Performance Evaluation**
ANSI A326.3 - Dynamic Coefficient of Friction (Wet): DCoF ≥0.42		0.72	Meets as Stated

ASTM C1527 – Travertine Properties Evaluation

The Yellowstone Frost Travertine product satisfied the ASTM C1527 performance requirements for a Class II (Interior) Travertine product for Density.

The Yellowstone Frost Travertine product failed to satisfy the ASTM C1527 performance requirements for a Class II (Interior) Travertine product for Absorption, Compressive Strength, Flexural Strength, and Abrasion Resistance.

There are no ASTM C1527 performance criteria for ASTM C99 modulus of rupture, so these values are reported as a design property only.

ANSI A326.3 – Dynamic Coefficient of Friction Evaluation

The Yellowstone Frost Travertine product (Honed Finish) satisfied the ANSI A326.3 recommended minimum wet condition performance criteria of 0.42 DCoF.

It has been our pleasure to provide this product testing service for your project. Please do not hesitate to contact us if you have any questions or require additional information. Contact information is listed below.

Respectfully submitted,



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Revision Log

No.	Date	Page(s)	Description
0	01/23/23	N/A	Initial report release

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Photographs

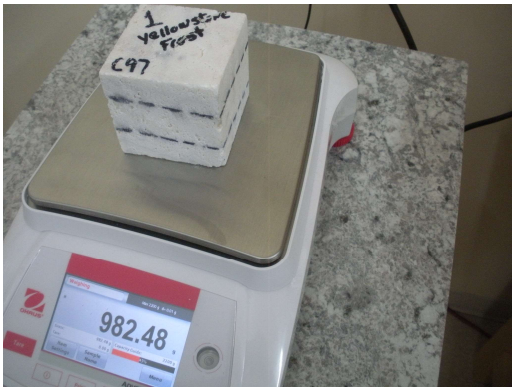


Photo No. 1
ASTM C97 – Test Apparatus

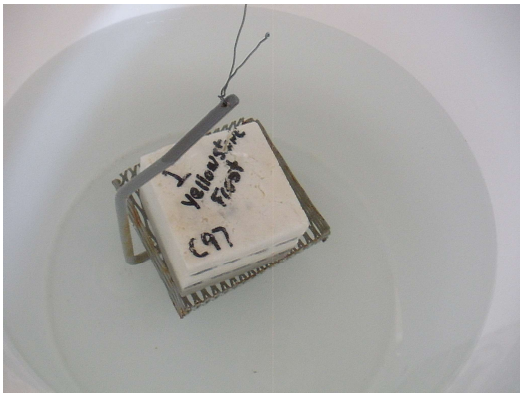


Photo No. 2
ASTM C97 – Suspended Mass Determination Depicted

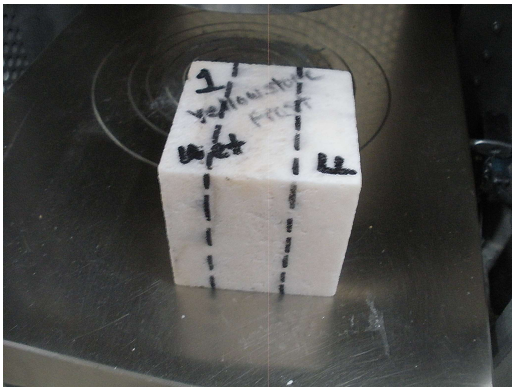


Photo No. 3
ASTM C170 – Pretest Condition Specimen



Photo No. 4
ASTM C170 – Representative Specimen Failure Mode

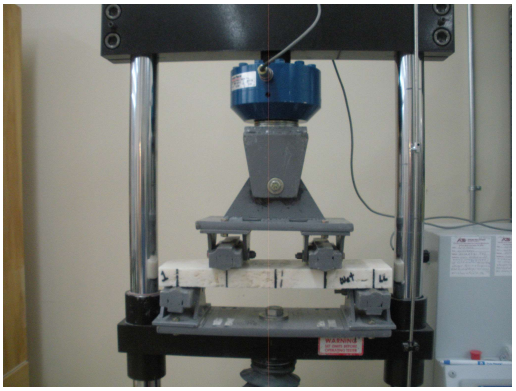


Photo No. 5
ASTM C880 – Test Setup



Photo No. 6
ASTM C880 – Representative Specimen Failure Mode



Photo No. 7
ASTM C1353 – Test Apparatus (Depicted with Pre-Abrasion Test Specimen)



Photo No. 8
ASTM C1353 – Representative Post-Abrasion Specimen Condition

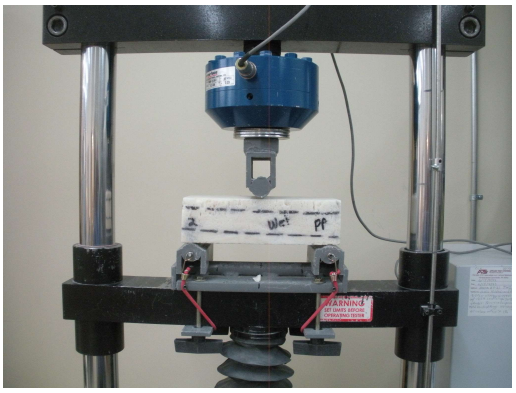


Photo No. 9
ASTM C99 – Test Setup

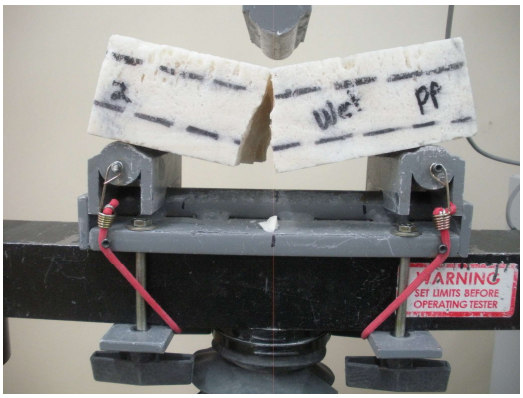


Photo No. 10
ASTM C99 – Representative Specimen Failure Mode

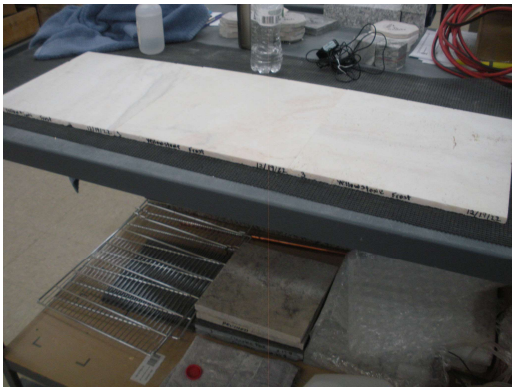


Photo No. 11
ANSI A326.3 – Test Setup

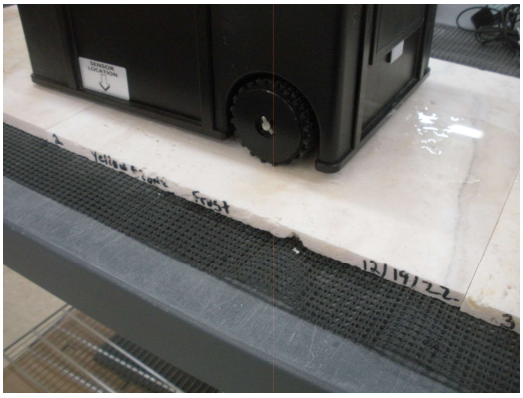


Photo No. 12
ANSI A326.3 – Test in Progress