MICHIGAN DEPARTMENT OF TRANSPORTATION

STUDY OF COMPRESSIVE STRENGTH OF CONCRETE CYLINDERS TESTED WITH NEOPRENE CAPPING VERSUS HYDROSTONE CAPPING

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INTRODUCTION

Michigan Department of Transportation (MDOT) tests many concrete specimens for compressive strength. Field personnel use these test results for accepting concrete products on construction projects. The Department tests concrete cylinders according to ASTM C39, Standard Test Method for Compressive Strength of Cylindrical Concrete Specimens. Currently the Lansing Materials and Technology (M&T) Division testing laboratory uses a hydrostone capping system for this procedure. District M&T laboratories use a sulfur capping system. The disadvantages of using either the hydrostone or the sulfur capping systems are as follows:

1. Hydrostone capping requires several hours to set.
2. Sulfur capping must be prepared at a high temperature.
3. Sulfur used for capping emits an unpleasant odor, which requires ventilation.
4. Both systems require labor for capping preparation.

AASHTO T22, Standard Method of Test For Compressive Strength of Cylindrical Concrete Specimens, allows the use of a neoprene capping system for compression tests on cylindrical concrete specimens in its annex. The advantages of the neoprene capping system are time savings and ease of use. Lansing M&T elected to study neoprene capping to ensure that reliable test results could be obtained.

STUDY METHODS

The Lansing M&T concrete testing laboratory made 35 companion cylinders for testing at 7, 14, 21, and 28 days. The laboratory used high and low strength concrete mix designs, as listed in Table 5, for the cylinder pairs. The laboratory tested one cylinder of the pair using the neoprene capping system and the other using the hydrostone capping system. Compression test data for the two groups are listed in Table 1.

The neoprene capping system consists of two steel extrusion controllers lined with neoprene pads. The steel extrusion controllers have recessed centers, allowing placement over the concrete cylinder ends. These controllers hold the neoprene pads and prevent them from expanding excessively under the compressive load. Neoprene pads accommodate surface irregularities in cylinder ends, and have the necessary toughness to withstand repeated use.

The Department conducted a survey of the 35 states participating in the AASHTO electronic bulletin board to determine the level of usage of the neoprene capping system. The survey inquired whether the state allows the use of the neoprene capping system for concrete compressive strength determination, and if used, what restrictions are cited. It also asked if comparison testing was conducted and, if affirmative, requested results. Findings of the survey are summarized in the following section.

DISCUSSION OF TEST RESULTS

The investigators used a two sided t-Test for paired data to analyze the statistical significance of the difference in compressive strength for the two capping procedures. Analysts performed the procedure on the complete set of 35 sample pairs and within the individual cure day groups. Analysts also performed the two sided t-Test on the difference between the mean compressive strengths within the individual cure day groups. All of the t-Tests were performed at the 95 percent confidence level.

The t-value for the t-Test for the 35 sets of paired data is listed in Table 1. Results of the investigation of the entire set of data indicates that there is no statistical difference between the two procedures.

The t-values for the t-Test of paired data within the individual cure day group are listed in Table 2. Results of investigations of individual cure day groups indicate that there is no statistical difference between the two procedures at any of the cure times.

The t-value for the t-Test for the difference between means within the individual cure day groups is listed in Table 3. Results of the investigation of means indicate that there is no statistical difference between the two procedures at any of the cure times.

The investigators determined the critical t-value and the calculated t-value for the previously mentioned procedures. All t-values are listed in Table 4. The absolute value of the calculated t-value is compared with the critical t-value, indicating no statistical difference in all cases.

The investigators also analyzed responses to the survey that was sent out to states participating in the AASHTO electronic bulletin board. Findings of the survey of states are summarized below.

- Eighteen out of the thirty five states receiving the survey responded to the survey.

- Fifteen out of the eighteen states responding allow the use of neoprene capping for concrete compressive strength determination.

- Fifteen out of the fifteen states that allow the use of neoprene capping indicate that they are satisfied with its performance.

- Thirteen out of the eighteen states that responded to the survey conducted comparison testing. In twelve out of thirteen cases, the comparison studies resulted in the states permitting the use of neoprene capping.

- Six out of the fifteen states that allow the use of neoprene capping place restrictions on its use. A list of restrictions is cited below.

- Five out of the fifteen states that allow the use of neoprene capping indicate problems related its use. A list of problems is cited below.

Restrictions:

- Use a protective cage around specimen when testing.
- Limit use of neoprene pad to 100 tests per side.
- Use steel controllers (rather than aluminum).
- Prohibit use of neoprene capping on cylinders with strengths greater than 6000 psi.
- Require all laboratories to conform to requirements of AASHTO T-22.
- Require a pad durometer hardness of 60 ± 5 and/or a pad tensile strength of 2500 psi.
- Prohibit use on critical applications such as detensioning or 28 day acceptance for prestress concrete.

Problems:

- Cylinders fail more severely.
- Cylinders spall resulting in a false peak.
- Pads do not meet durometer hardness requirement.
- Cylinders not meeting planeness, smoothness, and roundness requirements must be tested by conventional capping techniques.

CONCLUSION

The statistical analysis shows that there is no significant difference between the neoprene and hydrostone concrete cylinder capping techniques at the 95 percent confidence level. The survey of states indicates that other states use a neoprene capping system and are satisfied with the results.

Based on the results of the statistical analysis and the survey of states, neoprene capping will be permitted with some restrictions. Concrete cylinders with an anticipated strength over 6000 psi or under 1500 psi must be tested by using the hydrostone or sulfur capping techniques. Concrete cylinders used in testing prestressed concrete for detensioning and 28 day strength must also be tested by using the hydrostone or sulfur capping techniques. The procedure for using neoprene capping is given in Appendix A. To allow the use of neoprene capping, the 1990 Standard Specifications for Construction must be modified by the special provision given in Appendix B.

ACTION PLAN

Action items relative to using a neoprene capping system to determine the compressive strength of concrete cylinders are as follows:

1. Issue the Michigan Test Method (MTM) for Use of Unbonded Caps in Determination of Compressive Strength of Hardened Concrete Cylinders. This will be done through the Engineer of District Support.

2. Transmit the Special Provision for Determination of Compressive Strength of Hardened Concrete Cylinders to Design Division for use as a frequently used special provision. Convert this special provision to a Supplemental Specification. This will be done through the Engineer of Specifications.

3. Issue a Materials and Technology Instructional Memorandum relative to the use of neoprene capping systems. This will include the corresponding MTM and special provisions as attachments.

6-11-93

NEOPRENE ECON-O-CAP VS HYDROSTONE
COMPRESSIVE STRENGTH COMPARISON
MICHIGAN DEPARTMENT OF TRANSPORTATION
("ECON-O-CAP" Unbonded Capping System tested, from **Deslauriers Inc.**)

Mix #1, 28 day, 4.5 sack

	Hydrostone	Neoprene
	3450	3210
	3400	3480
	3430	3510
	3320	3400
Avg.	3400	3400

Mix #2, 28 day, 7.0 sack

	Hydrostone	Neoprene
	4490	4810
	4970	4910
	4840	4820
	4890	4710
Avg.	4800	4810

Mix #3, 21 day, 4.5 sack

	Hydrostone	Neoprene
	3820	3780
	4050	3800
	3950	3890
	3810	3900
Avg.	3910	3840

Mix #4, 21 day, 7.0 sack

	Hydrostone	Neoprene
	4690	4830
	4910	4700
	4910	4960
	4770	4720
Avg.	4820	4800

Mix #5, 14 day, 4.5 sack

	Hydrostone	Neoprene
	3630	3470
	3600	3670
	3190	3660
	3450	3600
Avg.	3470	3600

Mix #6, 14 day, 7.0 sack

	Hydrostone	Neoprene
	4800	4780
	4470	4580
	4870	4680
	4630	4800
Avg.	4690	4710

Mix #7, 7 day, 4.5 sack

	Hydrostone	Neoprene
	2860	2830
	2820	2940
	2800	2890
	2930	2950
Avg.	2850	2900

Mix #8, 7 day, 7.0 sack

	Hydrostone	Neoprene
	4120	4060
	4120	4110
	3990	4100
	4100	4110
Avg.	4080	4100

TABLE 1

Compressive Strength (psi)

	4.5 Sack		
	Neoprene	Hydrostone	N-H
Mix #1 28-Day	3210	3450	-240
	3480	3400	80
	3510	3430	80
	3400	3320	80
Mix #3 21-Day	3780	3820	-40
	3800	4050	-250
	3890	3950	-60
	3900	3810	90
Mix #5 14-Day	3470	3630	-160
	3670	3600	70
	3660	3190	470
	3600	3450	150
Mix #7 7-Day	2830	2860	-30
	2940	2820	120
	2890	2800	90
	2950	2930	20
	7.0 Sack		
Mix #2 28-Day	4810	4490	320
	4910	4970	-60
	4820	4840	-20
	4710	4890	-180
Mix #4 21-Day	4830	4690	140
	4700	4910	-210
	4960	4910	50
	4720	4770	-50
Mix #6 14-Day	4780	4800	-20
	4580	4470	110
	4680	4870	-190
	4800	4630	170
Mix #8 7-Day	4060	4120	-60
	4110	4120	-10
	4100	3990	110
	4110	4100	10
	1/20/93 Study		
7-Day Mix	2180	2200	-20
	2190	2230	-40
	2200	2240	-40
Average	3863.71	3850.00	13.71
Std Dev	833.853	843.59524	148.34
t-value			0.55

N: Neoprene
H: Hydrostone

TABLE 2

Compressive Strength (psi)

	4.5 Sack				7.0 Sack		
	Neoprene	Hydrostone	N–H		Neoprene	Hydrostone	N–H
Mix #1 28–Day	3210	3450	−240	Mix #2 28–Day	4810	4490	320
	3480	3400	80		4910	4970	−60
	3510	3430	80		4820	4840	−20
	3400	3320	80		4710	4890	−180
Average	3400.0	3400.0	0.0	Average	4812.5	4797.5	15.0
Std Dev	134.91	57.15	160.00	Std Dev	81.80	211.88	214.40
t–value			0.00	t–value			0.14
Mix #3 21–Day	3780	3820	−40	Mix #4 21–Day	4830	4690	140
	3800	4050	−250		4700	4910	−210
	3890	3950	−60		4960	4910	50
	3900	3810	90		4720	4770	−50
Average	3842.5	3907.5	−65.0	Average	4802.5	4820.0	−17.5
Std Dev	61.31	114.42	140.12	Std Dev	119.55	108.93	149.97
t–value			−0.93	t–value			−0.23
Mix #5 14–Day	3470	3630	−160	Mix #6 14–Day	4780	4800	−20
	3670	3600	70		4580	4470	110
	3660	3190	470		4680	4870	−190
	3600	3450	150		4800	4630	170
Average	3600.0	3467.5	132.5	Average	4710.0	4692.5	17.5
Std Dev	92.01	201.06	260.56	Std Dev	101.32	179.33	159.45
t–value			1.02	t–value			0.22
Mix #7 7–Day	2830	2860	−30	Mix #8 7–Day	4060	4120	−60
	2940	2820	120		4110	4120	−10
	2890	2800	90		4100	3990	110
	2950	2930	20		4110	4100	10
Average	2902.5	2852.5	50.0	Average	4095.0	4082.5	12.5
Std Dev	55.00	57.37	67.82	Std Dev	23.80	62.38	71.36
t–value			1.47	t–value			0.35

N: Neoprene
H: Hydrostone

TABLE 3

Compressive Strength (psi)

4.5 Sack					
Day Cure	Neoprene Average	Std Dev	Hydrostone Average	Std Dev	t-value
28	3400.0	134.91	3400.0	57.15	0.00
21	3842.5	61.31	3907.5	114.42	-1.00
14	3600.0	92.01	3467.5	201.06	1.20
7	2902.5	55.00	2852.5	57.37	1.26

7.0 Sack					
Day Cure	Neoprene Average	Std Dev	Hydrostone Average	Std Dev	t-value
28	4812.5	81.80	4797.5	211.88	0.13
21	4802.5	119.55	4820.0	108.93	-0.22
14	4710.0	101.32	4692.5	179.33	0.17
7	4095.0	23.80	4082.5	62.38	0.37

TABLE 4

Summary of t-values

	Critical	Calculated
Paired Data		
Complete set	2.03	0.55
28-Day/4.5 Sack	3.18	0.00
21-Day/4.5 Sack	3.18	-0.93
14-Day/4.5 Sack	3.18	1.02
7-Day/4.5 Sack	3.18	1.47
28-Day/7.0 Sack	3.18	0.14
21-Day/7.0 Sack	3.18	-0.23
14-Day/7.0 Sack	3.18	0.22
7-Day/7.0 Sack	3.18	0.35
Difference Between Means		
28-Day/4.5 Sack	2.44	0.00
21-Day/4.5 Sack	2.44	-1.00
14-Day/4.5 Sack	2.44	1.20
7-Day/4.5 Sack	2.44	1.26
28-Day/7.0 Sack	2.44	0.13
21-Day/7.0 Sack	2.44	-0.22
14-Day/7.0 Sack	2.44	0.17
7-Day/7.0 Sack	2.44	0.37

TABLE 5.

Concrete Mix Designs

7.0 Sack		
Material	Source	Weight
		(lbs/cyd)
Cement	Lafarge Type 1	658
Coarse Aggregate *	Pit No. 19–58	1890
Fine Aggregate *	Pit No. 19–58	1049
Water	Local	292

4.5 Sack		
Material	Source	Weight
		(lbs/cyd)
Cement	Lafarge Type 1	423
Coarse Aggregate *	Pit No. 19–58	1998
Fine Aggregate *	Pit No. 19–58	1269
Water	Local	247

Note: Air Content Design = 6.5 %

* Dry Weights

Appendix A

TEST METHOD FOR USE OF UNBONDED CAPS IN DETERMINATION OF COMPRESSIVE STRENGTH OF HARDENED CONCRETE CYLINDERS

1. Scope

1.1 This test method describes requirements for a capping system using unbonded caps for testing concrete cylinders in accordance with AASHTO T 22.

1.2 Unbonded caps are not to be used for testing of concrete with anticipated compressive strength below 1500 psi (10 MPa) or above 6000 psi (40 Mpa).

1.3 Unbonded caps are not to be used in testing concrete for strand detensioning strength or 28 day compressive strength of prestressed concrete.

2. Referenced Documents

AASHTO T 22	Standard Method of Test for Compressive Strength of Cylindrical Concrete Specimens
ASTM D 2240	Test Method for Rubber Property - Durometer Hardness

3. Terminology

3.1 Definition of terms:

3.1.1 Unbonded cap refers to a steel extrusion controller and an elastomeric pad.

3.1.2 Pad refers to an unbonded elastomeric pad.

4. Significance and Use

4.1 This method describes the use of elastomeric pads and steel extrusion controllers in testing hardened concrete cylinders. It may be used in lieu of bonded capping described in AASHTO T 22, section 6.2.

4.2 The elastomeric pads deform in initial loading to conform to the contour of the ends of the cylinder. They are restrained from excessive lateral spreading by metal rings to provide a uniform distribution of load from the bearing blocks to the ends of the concrete cylinder.

5. Summary of Method

This method establishes requirements for the unbonded capping system. Except for the procedures for aligning specimens in the testing machine and initial application of load, conduct the testing, recording, and reporting according to the requirements of AASHTO T 22.

6. Materials and Apparatus

6.1 Use pads made of elastomeric material that will accommodate surface irregularities in ends of the cylinder and have the necessary toughness to withstand repeated use. The pads shall be 1/2 ± 1/16 in. (13 ± 2 mm) thick and the diameter shall not be more than 1/16 in. (2 mm) less than the inside diameter of the retaining ring. Use pads that have a Type A durometer hardness of 60 ± 5. Type A durometer hardness is defined by ASTM D2240. Use pads for a maximum of 100 tests per side. If the pad shows a crack or excessive wear, as described in section 8.1, then it shall be replaced.

6.2 Steel extrusion controllers must be durable in repeated use. The cavity in the metal retainers must have a depth of at least twice the thickness of the pad. The inside diameter of the retaining rings shall not be less than 102 percent or greater than 107 percent of the diameter of the cylinder. The surfaces of the metal retainers that contact the bearing blocks of the testing machine shall be plane to within 0.002 in. (0.05 mm). The bearing surfaces of the retainer shall not have gouges, grooves, or indentations greater than 0.010 in. (0.25 mm) deep or greater than 0.005 in^2 (32 mm^2) in surface area.

7. Test Specimens

7.1 Neither end of a cylinder may depart from perpendicularity to the axis by more that 0.5 degrees. No individual diameter of a cylinder may differ from any other diameter by more than 2 percent.

7.2 Depressions under a straight edge measured with a round wire gage across any diameter shall not exceed 0.20 in. (5 mm). If cylinder ends do not meet this tolerance, the cylinder shall not be tested using this method unless irregularities are corrected by sawing or grinding.

8. Procedure

8.1 Examine the pads for excessive wear or damage. Replace pads with cracks or splits exceeding 3/8 in. (10 mm) in length regardless of depth. Insert the pads in the retainers before the assembly is placed on the cylinder.

8.2 Center the unbonded caps on the cylinder and place the cylinder on the lower bearing block of the testing machine. Align the axis of the cylinder with the center of thrust of the testing machine. As the spherically seated block is brought to bear on the upper steel extrusion controller, rotate its movable portion by hand so that uniform seating is obtained. After application of load, but before reaching 10 percent of the anticipated specimen strength, check to see that the axis of the cylinder is vertical within a tolerance of 1/8 in. in 12 in. (3.2 mm in 300 mm). Also check to see that the ends of the cylinder are centered within the retaining rings. If the cylinder alignment does not meet these requirements, release the load, check compliance with 7.1 and recenter the specimen. Reapply load and recheck the specimen centering and alignment. A pause in load application to check cylinder alignment is permissible.

8.3 Complete the load application, testing, calibration, and reporting of results according to AASHTO T 22. Unbonded capped cylinders may develop early cracking but continue to carry increased load. Therefore, cylinders must be tested to complete failure.

Appendix B

MICHIGAN
DEPARTMENT OF TRANSPORTATION
BUREAU OF HIGHWAYS

SPECIAL PROVISION
FOR
DETERMINATION OF COMPRESSIVE STRENGTH OF HARDENED CONCRETE CYLINDERS

M&T:TJH:RDT **1 of 1** **02-01-94**

This specification modified the 1990 Standard Specifications Section 7.01.04.

Concrete cylinders may be compression tested according to AASHTO T22, Standard Method of Test for Compressive Strength of Cylindrical Concrete Specimens. Unbonded caps as allowed in the annex of AASHTO T22 are acceptable. Use unbonded caps according to MTM 206, Test Method for Use of Unbonded Caps in Determination of Compressive Strength of Hardened Concrete Cylinders.