ASTM C 1231

USE OF UNBONDED CAPS IN DETERMINATION OF COMPRESSIVE STRENGTH OF HARDENED CONCRETE CYLINDERS

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Scope

This practice covers requirements for a capping system using unbonded caps for testing molded concrete cylinders. This practice may require the user to conduct tests to qualify the unbonded capping system for certain strength levels.

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Unbonded caps may not be used for acceptance testing of concrete with compressive strength below 1500 or above 12000 psi.

The qualification tests require testing companion cylinders, one prepared according to AASHTO T 231 and one with unbonded caps. Statistical procedures are used to ensure that unbonded caps do not reduce strengths more than 2%.

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Significance

This practice may be used in lieu of capping as described in AASHTO T 231.

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Apparatus

Note: This FOP requires using pads made of neoprene having Shore A durometer hardness of 50 to 70. Materials other than neoprene must be specifically qualified according to the section on qualification of unbonded capping systems.

This practice requires the materials and equipment necessary to produce ends of hardened concrete cylinders that conform to the plane requirements of AASHTO T 22 and the capping requirements of AASHTO T 231. This may include grinding equipment or capping materials and equipment to produce neat cement paste, high strength gypsum plaster, or sulfur mortar caps.

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- **Pads:** Pads shall be 1/2 ±1/16 in. thick with a diameter not more than 1/16 in. less than the inside diameter of the controller. Pads shall be made from neoprene of Shore A durometer of 50, 60, or 70. The following information shall accompany the pads: Name of manufacturer or supplier; Shore A hardness; applicable strength range (see Table 1).

Table 1 – Requirements for Use of Neoprene Pads 07

Cylinder Compressive Strength, psi	Shore A Durometer Hardness	Qualification Tests Required	Maximum Reuses
Less than 1500	Not Permitted		
1500 to 6000	50	None	100
2500 to 7000	60	None	100
4000 to 7000	70	None	100
7000 to 12000	70	Required	50
Greater than 12000	Not Permitted		

Note: Maximum reuses may be less than shown in this table based on wear or cracking noted in the pads.

The user must maintain records to track the number of uses of the pads, when the pads were put into service, and the pad durometer. Qualification tests must be performed if strength testing above 7000 psi is conducted using pads.

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Pads and Retainers

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- **Retainers:** made of metal durable in repeated use. The cavity in the metal retainers shall have a depth at least twice the thickness of the pad. The inside diameter of the retainer shall be not less than 102% or greater than 107% of the cylinder. The surface of the metal retainer shall be plane to within 0.002 in. and shall be free of gouges, grooves, or indentations more than 0.010 in. deep or 0.05 in^2 surface area.

Specimens

Specimens shall be either 6 by 12 or 4 by 8 inch cylinders made according to AASHTO T 23 or R 39.

Specimens shall not be tested if any individual diameter of a cylinder differs from any other diameter of the same cylinder by more than 2 percent. Neither end of compressive test specimen shall depart from perpendicularity to the axis by more than 0.5° (see note).

Note: 0.5° is approximately equivalent to 1/8” in 12 inches.

If the ends of the specimen are not plane within 0.20 in. the specimen shall be corrected by sawing or grinding

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Caution: Concrete cylinders tested with unbonded caps rupture more violently than comparable cylinders tested with bonded caps.

Procedure

Record the date in service and track the number of pad uses.

Unbonded caps may be used on one or both ends of a cylinder in lieu of a cap or caps meeting the practice of AASHTO T 231, provided they have been properly qualified.

Examine the pads for excessive wear or damage. Replace pads that have cracks or splits exceeding 3/8 in. in length regardless of depth.

12 Center the unbonded cap on the cylinder and place the cylinder on the lower bearing block of the testing machine directly under the spherically seated (upper) bearing block. Carefully align the axis of the specimen with the center of thrust of the spherically seated block. The spherically seated block is to be rotated immediately prior to testing, to assure free movement. Apply the load continuously and without shock.

13 After application of load, but before reaching 10% of the anticipated specimen strength, check to see that the axis of the cylinder is within vertical tolerance of 1/8” in 12” and that the ends are centered within the retaining rings. A pause in load
14 application to check cylinder alignment is permissible.

15 Complete the load application, testing, calculation and reporting in accordance with AASHTO T 22.

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Qualification of Unbonded Capping Systems and Verification of Reuse of Pads

The compressive strength of molded cylinders tested with unbonded caps shall be compared with that of companion cylinders tested with ends ground or capped to meet requirements of AASHTO T 22 and the capping requirements of AASHTO T 231.

To be acceptable, tests must demonstrate that at a
17 95% confidence level ($\alpha = 0.05$), the average strength obtained using unbonded caps is not less than 98% of the average strength of companion cylinders capped or ground.

- 18 When required, qualification tests shall be conducted either by the supplier or user of the neoprene caps. The qualification testing shall be

conducted as described below on initial use of an unbonded cap at both the highest and lowest strength levels anticipated to establish an acceptable range of cylinder strength for use. Initial qualification tests shall include that after 100 uses the pads meet the confidence levels described above.

Note: Pad life may depend on the hardness and type of pad material, the strength of the concrete, the difference between the outside diameter of the cylinder and the inside diameter of the retaining ring, the unevenness and roughness of the ends of the cylinder, and other factors.

- The maximum number of reuses of a pad is 100 (50 for strength above 7000 psi). When conducting qualification tests for strengths above 7000 psi, make such verification tests at the highest strength levels for which the pads are to be used.

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- Only those tests or reuses, which are within 2000 psi of the highest strength level to be qualified, will be included in the reuse count.

Specimen Preparation for Qualification and Pad Reuse Testing

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- Pairs of individual cylinders shall be made from a sample of concrete and cured as nearly alike as possible.

Note: The range of strengths permitted in qualification testing to define strength level is 1000 psi; but, in counting number of reuses only cylinders within 2000 psi of the highest strength level being qualified are included in the reuse count.

- A minimum of 10 pairs of cylinders shall be made at each strength level (many more pairs may actually be required). The “strength level” is the average of the strengths of the 20 or more cylinders whose strengths are within a range of 1000 psi.

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- More than one pair of cylinders can be made from a single concrete sample but the cylinders must come from a minimum of 2 samples made on different days for each concrete strength level.

22 **Calculation**

For each strength level, compute the difference in strength for each pair of cylinders, and compute the average strength of the cylinders with the reference caps and the average strength of the cylinders with unbonded caps as follows:

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$$d_i = x_{pi} - x_{si}$$

$$\bar{x}_s = (x_{s1} + x_{s2} + x_{s3} \ldots + x_{sn})/n$$

$$\bar{x}_p = (x_{p1} + x_{p2} + x_{p3} \ldots + x_{pn})/n$$

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where:

d_i = difference in strength of a pair of cylinders computed as the strength of the unbonded capped cylinder minus the strength of the cylinder prepared by T 231,

x_{pi} = cylinder strength using unbonded cap,

x_{si} = cylinder strength using practice T 231,

n = number of pairs of cylinders tested for the strength level,

$\bar{x}_s$ = average strength of T 231 capped cylinders for a strength level, and

$\bar{x}_p$ = average strength of unbonded capped cylinders for a strength level.

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Compute the average difference ($\bar{d}$) and standard deviation of the difference $\mathbf{s_d}$, for each strength level, as follows:

$$\bar{d} = (d_1 + d_2 \ldots + d_n)/n$$

$$s_d = \left[\sum \left(d_i - \bar{d}\right)^2 / (n-1)\right]^{1/2}$$

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To comply with this practice the following relationship must be satisfied:

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$$\bar{x}_p \geq 0.98\ \bar{x}_s + (ts_d)/(n)^{1/2}$$

where **t** is the value of "students t" for (n-1) pairs at α= 0.05 from table 2.

Table 2 – Values of "t"

(n-1)	t(α=0.05)[A]
9	1.833
14	1.761
19	1.729
100	1.662

[A] Use linear interpolation for other values of (n-1) or refer to appropriate statistical tables.

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Report

A sample report for pad qualification, including calculations, is shown below.

Sample Report and Calculation

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Cylinder Pair	Compressive Strength, psi		
	Neoprene Pad	**Sulfur Cap**	**Difference, d**
1	3605	3580	25
2	3605	3690	-85
3	3585	3595	-10
4	3570	3625	-55
5	3625	3640	-15
6	3660	3740	-80
7	3750	3720	30
8	3725	3720	5
9	3700	3725	-25
10	3805	3755	50
Averages	$\bar{x}_p$ 3663	$\bar{x}_s$ 3679	$\bar{d}$ -16
Std. Dev.			sd 46.06

Pad Material: Lot 3742, Shore A = 52, Thickness = 0.51”
Retaining Ring: Set A manufactured 1-87.
Concrete Cylinders: Job 1207, Nos. 1–10, January 2 to 5, 1987.
Sulfur Mortar: Lot 3420. Compressive Strength of 6985 psi.
Test Age: All Tests 28 days age.

Summary and Calculation

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Summary:
$\bar{x}_s$ = 3679 psi
$\bar{x}_p$ = 3663 psi
sd = 46.06 psi
n = 10
t = 1.833

Calculation:

$$3663 \geq (0.98)(3679) + (1.833)(46.06)/(10)^{1/2}$$

3663 > 3632 (system qualifies at 3670 psi)

Tips! 31

- Check durometer of pads against requirements for the strength of cylinders being tested.
- Record date pads were placed in service and the number of reuses (100 maximum up to 7000 psi; 50 maximum from 7000 to 12000 psi).
- Examine pads carefully for cracks or splits (3/8" maximum length regardless of depth).
- Check perpendicularity and alignment of cylinder after application of up to 10% of load.
- For strength levels above 7000 psi, qualification of the neoprene caps is required. 32
- Evaluate qualification data to assure 95% confidence that strengths using unbonded caps are at least 98% of those prepared according to T 231.

REVIEW QUESTIONS

1. What range of compressive strength does this FOP cover?

2. Describe required pad dimensions.

3. For a compressive strength of 9000 psi, the Shore A durometer pad hardness must be _____ and the maximum number of reuses may not exceed _____.

4. Describe the requirements for specimens (cylinders) tested under this FOP.

5. Describe the condition of an acceptable neoprene pad.

6. Describe the parameters defining an acceptable cap qualification. (Confidence level, minimum strength, definition of strength levels, etc.)