

Draft 2 1-31-01.

## Tests of Used Unbonded Pad Caps.

By Richard D. Gaynor, Gary M. Mullings and Fernando Rodriquez \*

### Introduction

In the course of work on the ASTM "Standard Practice for Use of Unbonded Caps in Determination of Compressive Strength of Hardened Concrete Cylinders" C1231 a total of 290 used pad caps were collected from 51 laboratories. The wear on the pads was rated by visual inspection on a scale of 1 to 5 and tested for Shore A durometer hardness and specific gravity. Pictures of selected pads are provided to help quantify the wear scale. Then 50 and 70 durometer pads were selected to cover the range of wear ratings and used to test 6 by 12 in. (152 by 305 mm) cylinders with strengths of 5600 psi (39 MPa) and 8000 psi (55 MPa). A total of 80 cylinders were then tested. When compared to new pads, in no case did pad wear significantly reduce compressive strength!

### C1231

The ASTM C 1231 Standard Practice for the Use of Unbonded Caps in Determination of Compressive Strength of Hardened Concrete Cylinders is under the jurisdiction of Subcommittee C09.61 on Strength of Committee C9 on Concrete and Aggregates. The standard C1231 was first published in 1993, revised in 1999 and in 2000. Table 1 summarizes some of the more important changes made in C1231 in the recent revisions. This latest version C1231-00<sup>e1</sup> requires the use of a specific neoprene, has defined acceptable strength ranges for 50, 60, and 70 durometer hardness pads and sets a maximum number of reuses. These apply for concrete strengths up to 7000 psi. If cylinders with strengths from 7000 to 12000 psi are to be tested then the user or supplier of the caps must provide data from qualification tests. Use of unbonded caps for testing concrete with strengths over 12,000 psi is not permitted.

### Collection and testing pads

With the acceptance of this latest revision a Task Group of Subcommittee C09.61 sent a request for used pad caps to some 600 laboratories in the US and Canada. The initial thoughts were that it might be possible to include pictures of worn pads in the standard to help laboratories to determine when pads needed to be replaced and eliminate the need to count the number of reuses of a set of pads. In response to that request the task Group received 290 individual pads, (145 pairs of pads) from 51 laboratories. The Task Group assembled at the NAA/NRMCA Joint Research Laboratory in College Park Maryland and rated the wear on the 290 pads.

The pads were rated on a scale of 1 for an essentially new pad to 5 for a pad where the outside 1/2 in. of the pad was granulated for the full thickness of the pad. (In the wear rating process precautions were taken to keep the source of the pad, the supplier of the pad, the number of uses the durometer hardness and other details strictly confidential. Although the six persons rating the pads all agreed on only 22 of the individual pads they agreed within less than one rating number on 186 of the 290 pads.

The distribution of the ratings for the 290 pads was:

<u>Wear Rating</u>	<u>% of pads</u>
1 to 2	17
2 to 3	36
3 to 4	33
4 to 5	15

The average ratings of the 50, 60 and 70 durometer pads were 3.5, 3.4 and 2.6 respectively. Under the then current test method the maximum number of reused of a pad without qualification testing was 100 uses.

Figure 1 provides pictures of the pads to illustrate the wear rating system. These are 6 in diameter pads with wear increasing from little wear on the bottom most pad to high wear on the top pad. When a pad is viewed from the surface which is in contact with the end of the cylinder the raveled edge does not extend inward along a diameter very much until the rating is perhaps 3 to 4. Attempts to measure across a diameter from one raveled edge to the other diameter did not provide a useful index of wear. A close inspection of Figure 1 shows that the clean portion of the 1/2 in. thick edge of the pad seems to decrease with wear but an attempt to measure this thickness of this clean area was difficult and would no provide a useable index of wear. In examining the this granulated edge of the pad it was noted that the pad often tended to develop a separation parallel to the surface in contact with the surface in contact with the concrete cylinder.

ASTM C1231 requires replacing pads "which have cracks or splits exceeding 3/8 in [10mm] in length regardless of depth." Most of the pads develop a system random map cracking spaced 3/8 to 3/4 in. [10 to 20 mm] across the surface of the pad in contact with the concrete cylinder. When the pad is bent to expose the crack, the depth of the cracks is negligible. Very few of the pads had cracks in the 6 in diameter surface of any measurable depth. Figure 1 provides an edge view of selected pads. As pads are used the depth of the granulation and splitting of the edge of the pad increases and this may be a relatively good measure of wear. Some users turn a pad over to use both sides. The 4.0 rated pad in Figure 1 has been used on both sides. The 4.5 and 5.0 pads were probably used on both sides but because of the extensive wear this was difficult to determine.

For 50 and 70 durometer pads very few laboratories exceeded 110 reuses. Half of the pads were 60 durometer hardness and the average number of uses was 119 for the group. Only 7 labs used the pads for more than 200 uses. A third of the pads received were 4 in. (100mm) pads and they were from 13 of the 51 laboratories providing used pads.

A more detailed report of the results of the rating process is available on request

### Testing Used Pads for Effects on Compressive Strength

The next step in the process was to use some of the pads and see if and how much pad wear effects measured compressive strength. The NAA/ NRMCA Joint Research Laboratory offered to do testing outlined below and to fund half of its cost conducting the program.

Additional support was provided by:

Deslauriers

Gilson Company, Inc.

ELE International, Inc.

Test Mark Industries

River Valley Testing

PSI

#### Selection of pads for test.

Pairs of pads with wear ratings and durometer hardness indicated in Table 3 were selected and used to test 5600 psi and 8000 psi concrete. New pads were used as the control. Since there were 5 cylinders for each test condition, each pair of pads selected for test was subjected to an additional five reuses with the 5600 psi [39 MPa] concrete and then another 5 reuses with the 8000 psi [55 MPa] concrete.

To provide a snug fit of the pads into the retaining rings it was necessary to use steel retaining rings with an inside diameter of 6 3/16 in. (157mm) and another set of aluminum rings with an inside diameter of 6 5/16 in. (160 mm). The new pads and most of the worn pads fit the smaller steel ring. Nominally these rings are 103 and 105% of the diameter of a 6 in. diameter cylinder.

#### Concrete Strength Levels

Different mix proportions were used for each strength level and supplementary cylinders were broken to estimate the age when the required strength levels would be reached. The 5000 psi (35MPa) gained strength faster than we had expected so that when it was tested at 27 days age it had an average compressive strength of 5592 psi or nominally 5600 psi (39 MPa). The 8000 psi (55MPa) concrete was tested at 26 days age and the actual strength was 7941 psi.

#### Concrete mixing

The concretes were made with a local low alkali Type I/II cement, a 3/4 in. (19.0 mm) crushed basalt coarse aggregate and a local siliceous sand. The 8000 psi (55 MPa) concrete also contained 5 oz/ cwt of cement of both a water reducer and a high range water reducer. The concretes had a nominal slump of 3 to 4 inches

The concrete required to make forty five 6 by 12 in. cylinders was mixed by compositing three 3.5 ft<sup>3</sup> batches. The three batches were mixed as rapidly as possible and blended together on the dampened laboratory floor. Between batches the concrete was covered with polyethylene film. The concrete was then mixed frequently and continuously while specimens were being made. An appropriate modest amount placed in a flat bottom tray. The concrete for molding the cylinders was sampled by two operators from the smaller tray with flat-bottomed scoops. The cylinders were made in two layers and compacted by internal vibration. About one hour was required complete the process from start of mixing to completion of molding cylinders.

Table 2. Summary of Batches and Tests. Series D325.

Concrete Strength	Batches per Str.	Pad Characteristics		Number of 6x12 Cylinders per		
		Shore A	Wear	Strength	Set of pads	Total cyl.
5000 8000	3	50 70	New 1.5 to 2.0 2.5 to 3.0 3.5 to 4.5	40	5	80 <sup>(1)</sup>
2		2	4		5	

(1) Five extra cylinders made to track development of each strength at each level.

Cylinder densities were measured at about 14 days and used to evaluate whether cylinders with low or high density might be replaced with one of the extra cylinders. Two of the 5600 psi cylinders were replaced and the extra cylinders were used in their place, but none of the 8000 psi concrete cylinders were substituted.

Cylinders were assigned randomly to the 40 possible test conditions. Specimens were tested on a 1,000,000 lb. (4,450,000 N) capacity compression testing machine. Occasionally pad capped cylinders will crack prematurely and the load drops and then increases and the specimen ultimately fails at a much higher maximum load. To avoid this possibility the loading was continued after the peak load, generally until the load had dropped to at least half of the earlier peak load. Since the cylinders were wrapped in canvas using Velcro strips it was not possible to see the extent of cracking until the completion of loading.

The two sets of rings with somewhat different inside diameters were used to accommodate the different pad diameters. Cylinder diameters were measured on all specimens.

### Strength Test Results

Table 3 summarizes the results of the effect of used pads on compressive strength. The coefficient of variation of the 40 tests made of each concrete strength was about 1.8%. This is considered quite uniform in spite of the fact that this calculation includes the effects, if any, of pad wear and durometer of the pads. Based on averages of tests of 5 pads, the worn pads tested from 100.7 to 98.1 percent of the strength obtained with new pads! None of these differences are of practical or statistical significance! Clearly this was not the expected result.

In 5600 psi concrete the 50 durometer pads tested 61 psi higher than those tested with 70 durometer pads. This is based on averages of tests of 20 cylinders in each comparison. For the 8000 psi concrete the comparable difference was 8 psi. At these cylinder strengths pad durometer hardness had no effect on strength. However, 50 durometer pads will wear more rapidly than 60 or 70 durometer pads, particularly at higher strength levels.

### Future Studies

One possibility might be to try to develop a better theoretical understanding of how and why the unbonded system works. This might be done by a graduate student using a finite element analysis. Apparently this has been used by some of the large rubber companies. We have made some initial contact with members of ASTM committee D 11 on Rubber that are promising.

Never-the-less there are a number of questions about the use of unbonded caps that can be explored with empirical tests made by users of pad caps in their routine work. A number of the State DOT and commercial laboratories have expressed an interest in doing additional work if it can be integrated into their routine work. One possibility is that all concrete laboratories routinely break duplicate cylinders at 28 days and the laboratory might test one of these cylinders with the standard set of pads and the other cylinder with another set of rings and pads or sulfur compound. Some of the conditions that might be compared include:

1. At present there is a difference in the allowable tolerances on the inside diameter of the rings between ASTM and AASHTO. Hopefully that can be resolved.
2. ASTM requires use of ½ in. thick pads. Is that thickness the most appropriate for 4, 3, or 2 in diameter cylinders? A recent Japanese study<sup>(1)</sup> recommended for their 4x8 in (100x200 mm) cylinders a pad thickness of 10 mm (roughly 3/8 in) however both ¼ and ½ in. thick pads were equal in 7 of the 9 comparisons and in no case thinner or thicker pads more than 3% less than the 10 mm (3/8 in) pads.
3. Is the performance of unbonded system affected by:
  - the roughness of the interior of the ring or by
  - wet rings or by
  - use of talcum or other materials in the ring
4. Does oiling the inside of the ring to prevent rusting affect the movement of the rubber during loading and affect measured strength?
5. Currently C1231 does not permit use of unbonded caps to test drilled cores. Use is only permitted for molded cylinders made under C31 or C192.
  - 5.1 Tests are needed to determine if the unbonded system will perform properly with short cores with a length to diameter ratio less than 2.0
  - 5.2 When cores are drilled there is a tendency for the drill to break through the final 1/8 in. and produce a ragged corner around the end of the core. Will this affect strength?
  - 5.3 Currently C1231 requires the inside diameter of the restraining ring to be between 102 and 107 percent of the diameter of the cylinder. Since the common 4 in. diameter core drill produces a 3.75 in. (95mm) diameter core a different ring would be required it than for the drill that produces a 4 in diameter core.

#### References

1. Tohru Yoshikane, K. Suzuki, F. Teraishi, and W. Hirai "A Study on Compressive Strength Tests of Concrete Using the Unbonded Capping System", (Translation from Concrete Research and Technology, Vol. 9, No. 2, July 1998.

Table 1. Requirements for Use of Neoprene Pads.  
ASTM C1231-00<sup>e1</sup>

Cylinder Compressive Strength, psi	Shore A Durometer Hardness	Qualification Tests Required	Maximum Reuses
1500 to 6000	50	none	100
2500 to 7000	60	none	100
4000 to 7000	70	none	100
7000 to 12,000	70	required	50
Greater than 12,000	[80]	not permitted	

Table 3. Effect of Pad Wear on Compressive Strength -Series D325.

Shore A	Pads Used Pad Wear	5600 psi [39 MPa] Concrete				8000 psi [55 MPa] Concrete			
		Avg., psi	Std. Dev., psi	W/cond, CV, %	% new pads	Avg., psi	Std. Dev., psi	CV, %	% new pads
50	New =1.0	5645	73	1.3%	100.0%	7939	100	1.3%	100.0%
	2.0	5634	86	1.5%	99.8%				
	2.8	5563	115	2.1%	98.5%	7923	223	2.8%	99.8%
	3.9	5646	57	1.0%	100.0%	7841	101	1.3%	98.8%
	4.6					8074	114	1.4%	101.7%
70	New =1.0	5614	89	1.6%	100.0%	7930	70	0.9%	100.0%
	1.8	5562	118	2.1%	99.1%	7983	149	1.9%	100.7%
	2.6	5508	168	3.1%	98.1%	7958	183	2.3%	100.4%
	3.9	5561	62	1.1%	99.0%	7875	65	0.8%	99.3%
ALL 40 tests		5592	104	1.86%		7941	140	1.76%	

Note 1. Compressive strength of 6x12 in. cylinders are averages of tests of 5 cylinders.  
C V %, is coefficient of variation.

Figure 1. Wear Rating of Pads - Series D 325

