

Study of Non-Shrink Keyway Grout for Strength

Ohio Department of Transportation

Objective: The objective of this study was to determine the strength of non-shrink grout under various molding conditions and make necessary changes to the testing procedure in the current specifications.

Introduction: Non-shrink grout is used to fill the shear key and the gap between the prestressed concrete box beams. ODOT has noticed cracks in the some of the grout materials in prestressed beams. This research project was undertaken to determine the performance of non-shrink grout under various molding conditions. Current ODOT specification requires that three 3in. x 6 in. cylinders be made and sent to Office of Materials Management lab for testing. The minimum required compressive strength of the cylinders is 5,000 psi before allowing construction or vehicular traffic on the structure. However, ASTM specification C1107, “Standard Specification for Packaged Dry, Hydraulic-Cement Grout (non-shrink)” pertains to restrained cube molds.

Two commercial brand materials were selected from the OMM’s approved list. They are: Conset made by Chemmasters and CG-86 made by W. R. Meadows.

Test Procedure:

The various molding conditions included in this study and the number of specimens used for various items are as follows:

Moist Cured tested at an age of 3, 7 and 28 days (photos:

- 18 - 3 in. x 6 in. restrained ends of cylinders from expansion
- 18 - 3 in. x 6 in. unrestrained end from expansion
- 96 - half cylinders (3 in. x 3 in.) cut out from restrained cylinders
- 96 - half cylinders cut out from unrestrained cylinders
- 18- 2 in. x 2 in. cubes cut from restrained and unrestrained cylinders
- 18 - 2 in. x 2 in. cubes cast from molds (both restrained and unrestrained)

Cylinders with restrained ends were molded immediately after mixing. For unrestrained cylinders two sets were made. One immediately after mixing and the other 5 minutes after mixing.

Dry Cured specimens tested at 1 and 7 days

- 4 - 3 in. x 6 in. unrestrained
- 8 - half cylinders cut out from unrestrained cylinders
- 8 – 2 in. x 2 in. cubes cut from the unrestrained cylinders

In addition, one restrained and one unrestrained 3 in. x 6 in. cylindrical specimens for each material were tested for expansion using extensometer.

Mix Design:

The mix design was made in accordance with the manufacturer's instructions.

A total of six mixes were made for each material. Each mix consisted of the following proportions:

Conset: Grout - 100 pounds
Water - 8.6 liters (9 pints per bag of grout)

CG-86: Grout - 100 pounds
Water - 6.5 litres (6.75 pints per bag of grout)

A total of six batches of the mix were made.

Mixing Procedure:

For Conset, 80% of the required water was added to the pre-wet mixer. With mixer blades operating, the required amount of grout was added in to the mixer. Mixing was done for about 1 minute followed by the addition of remaining water. Mixing was carried out for another 3 minutes. (Photo: 1)

For CG-86, 100% of the required water was added to the pre-wet mixer followed by the addition of 100% grout material. Mixing was carried out for 3 minutes.

The grout material was filled to the top of the molds, then, vibrated for 10 seconds on the table vibrator. The surface was finished by cutting off the excess with the straight edge of a trowel. (photo: 2)

For the specimens restrained against expansion, steel plate was placed on top of the cylinder molds, and then, concrete prism blocks were placed on top of the plates. (Photo: 3)

All molds were stripped at 72 ± 1 hour after molding and then, the cylindrical specimens were placed in the moist room whereas the cube molds were placed in the moist cabinets. Pad caps were used for all the compression tests of the cylinders.

It was noticed that all the unrestrained cylinders had expanded by as much as $\frac{1}{4}$ in. Test specimens were tested at 3, 7 and 28 days with the exception of specimens that were cured outside the moist room which were tested for just 28th day strength. In addition, one 3 in. x 6 in. cylinder was tested for expansion with the use of extensometer. The setup for this is shown in photo 10.

Conset cylinders showed expansion within a few hours after mixing. W.R. Meadows CG-86 cylinders showed shrinkage within 5 minutes after mixing.

Summary of the test results is shown in the following table:

Comparison of Test Results - Moist Cured Specimens

				CONSET			CG-86		
				3 Days	7 Days	28 Days	3 Days	7 Days	28 Days
Restrained from Expansion	Cylinders 3 x 6	0 Mins. After mixing	R0	3,378	3,757	4,608	6,893	6,797	9,298
	Cylinders 3 x 3 Top	0 Mins. After mixing	R0	3,662	3,127	3,968	6,297	7,005	8,418
	Cylinders 3 x 3 Bottom	0 Mins. After mixing	R0	3,842	3,970	5,135	6,288	7,613	7,882
	Cubes from Cylinders - TOP	0 Mins. After mixing	R0	3,393	3,023	4,263	5,325	5,017	6,152
	Cubes from Cylinders - BOTTOM	0 Mins. After mixing	R0	3,355	3,053	4,417	5,270	5,585	6,313
	Cubes from MOLDS	0 Mins. After mixing	R0	4,857	4,652	6,718	6,345	6,598	9,052
Unrestrained from Expansion	Cylinders 3 x 6	0 Mins. After mixing	U0	2,002	2,127	2,447	6,970	7,662	9,858
		5 mins. After mixing	U5	2,973	2,842	3,893	7,015	7,805	9,485
	Cylinders 3 x 3 (Top)	0 Mins. After mixing	U0	1,755	1,823	2,288	7,338	7,253	9,173
		5 mins. After mixing	U5	2,075	2,388	2,927	6,718	7,940	9,177
	Cylinders 3 x 3 (Bottom)	0 Mins. After mixing	U0	3,242	3,585	4,327	6,854	6,353	6,700
		5 mins. After mixing	U5	3,430	4,057	5,028	6,876	6,642	6,622
	Cubes from Cylinders - TOP	0 Mins. After mixing	U0	3,290	2,685	3,948	6,260	6,933	6,735
		5 mins. After mixing	U5	2,667	3,027	3,825	5,628	6,667	7,707
	Cubes from Cylinders - BOTTOM	0 Mins. After mixing	U0	2,833	2,950	4,078	5,992	6,282	8,568
		5 mins. After mixing	U5	3,482	3,360	4,253	6,052	7,020	9,825
	Cubes from MOLDS	0 Mins. After mixing	U0	4,235	4,728	6,653	6,433	6,282	8,568
		5 mins. After mixing	U5	4,208	3,928	6,097	7,900	7,020	9,825

Compressive Strength of Non-Shrink Grout Cylinders - Air Cured

		Date Made	Date Tested	Strength in psi								
				3 x 6 Cylinders			3 x 3 Cylinders (top)			3 x 3 Cylinders (Bottom)		
				1	2	Average	3	4	Average	5	6	Average
Chemmasters - CONSET	1 Day	1/28/08	1/29/08	2,120	2,090	2,105	1,380	1,320	1,350	2,220	2,320	2,270
	7 Days	1/28/08	2/4/08	2,610		2,610	2,401	2,654	2,528	3,880	4,300	4,090
W.R. Meadows CG - 86	1 Day	1/29/08	1/30/08	4,560	4,530	4,545	4,280	4,220	4,250	4,490	4,320	4,405
	7 Days	1/29/08	2/5/08	7,950		7,950	6,710	6,730	6,720	7,700	7,870	7,785

Conclusions:

ASTM specification 1107 refers to restrained cube molds. This study was conducted to see if the strength of any of the other methods used are comparable to the strength of restrained cube molds. A summary of observations is outlined below:

The following table shows percentage difference in values with respect to the corresponding cube mold results which were obtained by the standard ASTM method:

				CONSET			CG-86		
				3 Days	7 Days	28 Days	3 Days	7 Days	28 Days
Restrained from Expansion	Cylinders 3 x 6	0 Mins. After mixing	R0	-30%	-19%	-31%	9%	3%	3%
	Cylinders 3 x 3 Top	0 Mins. After mixing	R0	-25%	-33%	-41%	-1%	6%	-7%
	Cylinders 3 x 3 Bottom	0 Mins. After mixing	R0	-21%	-15%	-24%	-1%	15%	-13%
	Cubes from Cylinders - TOP	0 Mins. After mixing	R0	-30%	-35%	-37%	-16%	-24%	-32%
	Cubes from Cylinders - BOTTOM	0 Mins. After mixing	R0	-31%	-34%	-34%	-17%	-15%	-30%
	Cubes from MOLDS (ASTM)	0 Mins. After mixing	R0	4,857	4,652	6,718	6,345	6,598	9,052
Unrestrained from Expansion	Cylinders 3 x 6	0 Mins. After mixing	U0	-59%	-54%	-64%	10%	16%	9%
		5 mins. After mixing	U5	-39%	-39%	-42%	11%	18%	5%
	Cylinders 3 x 3 (Top)	0 Mins. After mixing	U0	-64%	-61%	-66%	16%	10%	1%
		5 mins. After mixing	U5	-57%	-49%	-56%	6%	20%	1%
	Cylinders 3 x 3 (Bottom)	0 Mins. After mixing	U0	-33%	-23%	-36%	8%	-4%	-26%
		5 mins. After mixing	U5	-29%	-13%	-25%	8%	1%	-27%
	Cubes from Cylinders - TOP	0 Mins. After mixing	U0	-32%	-42%	-41%	-1%	5%	-26%
		5 mins. After mixing	U5	-45%	-35%	-43%	-11%	1%	-15%
	Cubes from Cylinders - BOTTOM	0 Mins. After mixing	U0	-42%	-37%	-39%	-6%	-5%	-5%
		5 mins. After mixing	U5	-28%	-28%	-37%	-5%	6%	9%
	Cubes from MOLDS	0 Mins. After mixing	U0	-13%	2%	-1%	1%	-5%	-5%
		5 mins. After mixing	U5	-13%	-16%	-9%	25%	6%	9%

Conset cylinders showed expansion within a few hours after mixing. Whereas W.R. Meadows CG-86 cylinders showed shrinkage within 5 minutes after mixing..

Air Cured Specimens: None of the Conset Cylinders met the required strength of 5,000 psi. However, W.R. Meadows reached this strength in 3 days (these specimens were in the mold for 3 days outside the curing room).

Moist Cured Specimens: Except for the 28 day cube molds, none of the Conset specimens reached 5,000 psi.

Most of the restrained Conset specimens showed lower strengths than the unrestrained specimens.

Most of the unrestrained CG-86 specimens exhibited higher strength than the corresponding restrained specimens.

Extensometer Readings:

Expansion of Unrestrained Conset specimens was slightly higher than unrestrained specimens. Whereas CG-86 specimens showed shrinkage in the order of) 0.1 plus inches.



PHOTO 1: Mixing Operation of the Grout



PHOTO 2: Molding of the Cylindrical Specimens and the table vibrator



PHOTO 3: Setting up of the Restraining system to prevent expansion



PHOTO 4: Restrained Cylindrical Specimens



PHOTO 5: Cube Molds



PHOTO 6: Cube Molds

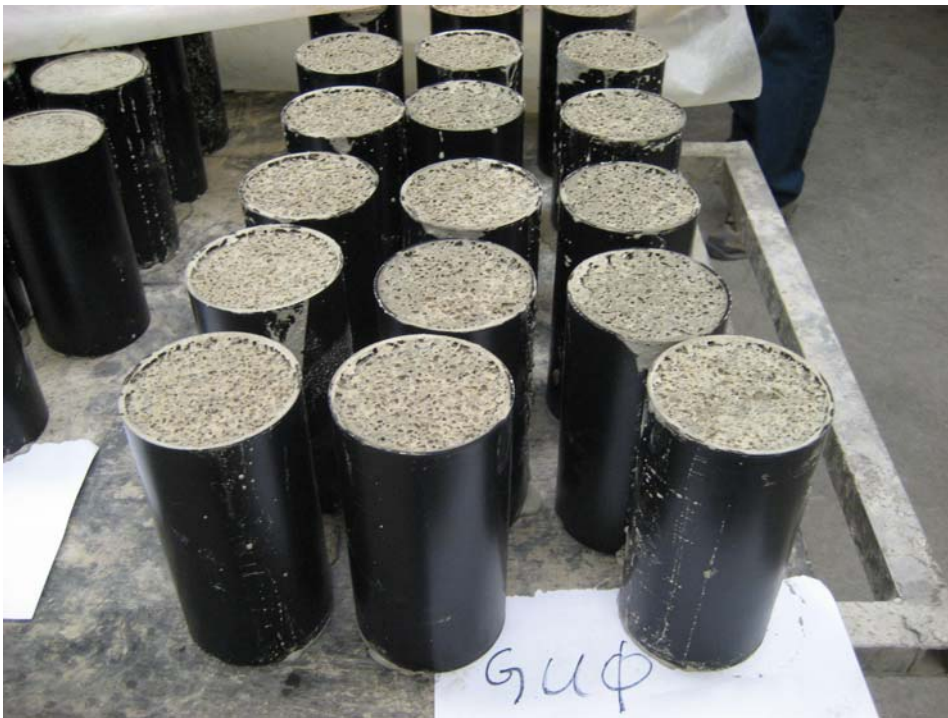


PHOTO 7: Shrinkage of W.R. Meadows – CG-86 Cylindrical Specimens



PHOTO 8: Shrinkage of W.R. Meadows – CG-86 Cylindrical Specimens



PHOTO 9: Compression testing of the cores



PHOTO 10: Extensometer setup to measure expansion/shrinkage of cylindrical specimens

Comparison of Test Results

				CONSET			CG-86		
				3 Days	7 Days	28 Days	3 Days	7 Days	28 Days
Restrained from Expansion	Cylinders 3 x 6	0 Mins. After mixing	R0	3,378	3,757	4,608	6,893	6,797	9,298
	Cylinders 3 x 3 Top	0 Mins. After mixing	R0	3,662	3,127	3,968	6,297	7,005	8,418
	Cylinders 3 x 3 Bottom	0 Mins. After mixing	R0	3,842	3,970	5,135	6,288	7,613	7,882
	Cubes from Cylinders - TOP	0 Mins. After mixing	R0	3,393	3,023	4,263	5,325	5,017	6,152
	Cubes from Cylinders - BOTTOM	0 Mins. After mixing	R0	3,355	3,053	4,417	5,270	5,585	6,313
	Cubes from MOLDS	0 Mins. After mixing	R0	4,857	4,652	6,718	6,345	6,598	9,052
Unrestrained from Expansion	Cylinders 3 x 6	0 Mins. After mixing	U0	2,002	2,127	2,447	6,970	7,662	9,858
		5 mins. After mixing	U5	2,973	2,842	3,893	7,015	7,805	9,485
	Cylinders 3 x 3 (Top)	0 Mins. After mixing	U0	1,755	1,823	2,288	7,338	7,253	9,173
		5 mins. After mixing	U5	2,075	2,388	2,927	6,718	7,940	9,177
	Cylinders 3 x 3 (Bottom)	0 Mins. After mixing	U0	3,242	3,585	4,327	6,854	6,353	6,700
		5 mins. After mixing	U5	3,430	4,057	5,028	6,876	6,642	6,622
	Cubes from Cylinders - TOP	0 Mins. After mixing	U0	3,290	2,685	3,948	6,260	6,933	6,735
		5 mins. After mixing	U5	2,667	3,027	3,825	5,628	6,667	7,707
	Cubes from Cylinders - BOTTOM	0 Mins. After mixing	U0	2,833	2,950	4,078	5,992	6,282	8,568
		5 mins. After mixing	U5	3,482	3,360	4,253	6,052	7,020	9,825
	Cubes from MOLDS	0 Mins. After mixing	U0	4,235	4,728	6,653	6,433	6,282	8,568
		5 mins. After mixing	U5	4,208	3,928	6,097	7,900	7,020	9,825

Conset Non-Shrink Grout Strength 3 Day Test Results - Tested on 1/31/08

					Date Made	Date Tested	Strength in psi							CG-86
							1	2	3	4	5	6	Average	Average
Restrained from Expansion	Cylinders 3 x 6	0 Mins. After mixing	CR0	3 Days	1/28/08	1/31/08	3,090	3,850	3,490	2,940	3,520	-	3,378	6,893
	Cylinders 3 x 3 Top	0 Mins. After mixing	CR0	3 Days	1/28/08	1/31/08	3,160	3,440	3,780	3,700	3,640	4,250	3,662	6,297
	Cylinders 3 x 3 Bottom	0 Mins. After mixing	CR0	3 Days	1/28/08	1/31/08	3,530	3,890	3,920	4,150	3,960	3,600	3,842	6,288
	Cubes from Cylinders - TOP	0 Mins. After mixing	CR0	3 Days	1/28/08	1/31/08	3,450	3,800	3,040	3,060	3,930	3,080	3,393	5,325
	Cubes from Cylinders - BOTTOM	0 Mins. After mixing	CR0	3 Days	1/28/08	1/31/08	2,060	3,750	3,410	3,200	3,680	4,030	3,355	5,270
	Cubes from MOLDS	0 Mins. After mixing	CR0	3 Days	1/28/08	1/31/08	4,780	4,860	4,760	4,980	4,870	4,890	4,857	6,345
Unrestrained from Expansion	Cylinders 3 x 6	0 Mins. After mixing	CU0	3 Days	1/28/08	1/31/08	1,750	1,810	1,870	1,730	2,970	1,880	2,002	6,970
		5 mins. After mixing	CU5	3 Days	1/28/08	1/31/08	3,090	2,980	3,170	3,050	2,890	2,660	2,973	7,015
	Cylinders 3 x 3 (Top)	0 Mins. After mixing	CU0	3 Days	1/28/08	1/31/08	2,230	1,710	1,710	1,540	1,840	1,500	1,755	7,338
		5 mins. After mixing	CU5	3 Days	1/28/08	1/31/08	2,260	1,970	1,710	2,310	2,380	1,820	2,075	6,718
	Cylinders 3 x 3 (Bottom)	0 Mins. After mixing	CU0	3 Days	1/28/08	1/31/08	3,060	3,280	3,050	3,380	3,200	3,480	3,242	6,854
		5 mins. After mixing	CU5	3 Days	1/28/08	1/31/08	3,440	3,310	3,450	3,480	3,440	3,460	3,430	6,876
	Cubes from Cylinders - TOP	0 Mins. After mixing	CU0	3 Days	1/28/08	1/31/08	3,350	2,570	3,700	3,260	3,590	3,270	3,290	6,260
		5 mins. After mixing	CU5	3 Days	1/28/08	1/31/08	2,990	2,610	2,860	1,980	2,800	2,760	2,667	5,628
	Cubes from Cylinders - BOTTOM	0 Mins. After mixing	CU0	3 Days	1/28/08	1/31/08	2,520	2,530	3,410	3,390	2,480	2,670	2,833	5,992
		5 mins. After mixing	CU5	3 Days	1/28/08	1/31/08	3,640	2,840	3,430	3,830	3,760	3,390	3,482	6,052
	Cubes from MOLDS	0 Mins. After mixing	CU0	3 Days	1/28/08	1/31/08	4,560	4,600	4,790	1,730	4,940	4,790	4,235	6,433
		5 mins. After mixing	CU5	3 Days	1/28/08	1/31/08	4,430	3,800	4,480	4,180	4,250	4,110	4,208	7,900

CG-86 Non-Shrink Grout Strength 3 Day Test Results - Tested on 2-1-08

					Date Made	Date Tested	Strength in psi						
							1	2	3	4	5	6	Average
Restrained from Expansion	Cylinders 3 x 6	0 Mins. After mixing	CR0	3 Days	1/29/08	2/1/08	6,840	7,170	6,320	6,500	7,360	7,170	6,893
	Cylinders 3 x 3 Top	0 Mins. After mixing	CR0	3 Days	1/29/08	2/1/08	6,400	6,590	6,670	5,830	6,710	5,580	6,297
	Cylinders 3 x 3 Bottom	0 Mins. After mixing	CR0	3 Days	1/29/08	2/1/08	6,270	6,300	6,650	6,530	6,170	5,810	6,288
	Cubes from Cylinders - TOP	0 Mins. After mixing	CR0	3 Days	1/29/08	2/1/08	4,890	6,380	4,350	5,260	5,800	5,270	5,325
	Cubes from Cylinders - BOTTOM	0 Mins. After mixing	CR0	3 Days	1/29/08	2/1/08	4,020	5,970	4,570	5,500	5,930	5,630	5,270
	Cubes from MOLDS	0 Mins. After mixing	CR0	3 Days	1/29/08	2/1/08	6,200	6,480	6,370	6,640	6,340	6,040	6,345
Unrestrained from Expansion	Cylinders 3 x 6	0 Mins. After mixing	CU0	3 Days	1/29/08	2/1/08	6,970	6,410	6,960	7,160	6,990	7,330	6,970
		5 mins. After mixing	CU5	3 Days	1/29/08	2/1/08	6,390	7,200	7,000	7,170	7,200	7,130	7,015
	Cylinders 3 x 3 (Top)	0 Mins. After mixing	CU0	3 Days	1/29/08	2/1/08	7,660	7,460	7,360	7,020	7,210	7,320	7,338
		5 mins. After mixing	CU5	3 Days	1/29/08	2/1/08	7,080	6,230	7,150	7,230	6,750	5,870	6,718
	Cylinders 3 x 3 (Bottom)	0 Mins. After mixing	CU0	3 Days	1/29/08	2/1/08	6,716	6,656	6,656	6,821	6,864	7,412	6,854
		5 mins. After mixing	CU5	3 Days	1/29/08	2/1/08	7,230	6,395	7,082	7,412	6,960	6,177	6,876
	Cubes from Cylinders - TOP	0 Mins. After mixing	CU0	3 Days	1/29/08	2/1/08	6,120	5,730	6,440	6,500	6,030	6,740	6,260
		5 mins. After mixing	CU5	3 Days	1/29/08	2/1/08	5,610	4,250	5,530	6,430	5,500	6,450	5,628
	Cubes from Cylinders - BOTTOM	0 Mins. After mixing	CU0	3 Days	1/29/08	2/1/08	6,000	6,380	5,500	5,270	6,410	6,390	5,992
		5 mins. After mixing	CU5	3 Days	1/29/08	2/1/08	5,970	6,040	5,650	6,370	5,950	6,330	6,052
	Cubes from MOLDS	0 Mins. After mixing	CU0	3 Days	1/29/08	2/1/08	6,580	6,290	6,570	6,470	6,750	5,940	6,433
		5 mins. After mixing	CU5	3 Days	1/29/08	2/1/08	8,120	8,240	7,960	7,570	7,730	7,780	7,900

Conset Non-Shrink Grout Strength 7 Day Test Results - 2/4/08

					Date Made	Date Tested	Strength in psi						
							1	2	3	4	5	6	Average
Restrained from Expansion	Cylinders 3 x 6	0 Mins. After mixing	CR0	7 Days	1/28/08	2/4/08	3,370	3,110	3,880	3,350	4,580	4,250	3,757
	Cylinders 3 x 3 Top	0 Mins. After mixing	CR0	7 Days	1/28/08	2/4/08	3,490	2,560	2,680	3,010	3,170	3,850	3,127
	Cylinders 3 x 3 Bottom	0 Mins. After mixing	CR0	7 Days	1/28/08	2/4/08	3,840	4,110	4,210	3,820	3,770	4,070	3,970
	Cubes from Cylinders - TOP	0 Mins. After mixing	CR0	7 Days	1/28/08	2/4/08	2,910	2,780	2,640	3,050	3,590	3,170	3,023
	Cubes from Cylinders - BOTTOM	0 Mins. After mixing	CR0	7 Days	1/28/08	2/4/08	2,870	3,090	2,960	3,060	3,450	2,890	3,053
	Cubes from MOLDS	0 Mins. After mixing	CR0	7 Days	1/28/08	2/4/08	4,670	4,650	4,910	4,650	4,470	4,560	4,652
Unrestrained from Expansion	Cylinders 3 x 6	0 Mins. After mixing	CU0	7 Days	1/28/08	2/4/08	2,380	2,140	2,080	2,100	2,070	1,990	2,127
		5 mins. After mixing	CU5	7 Days	1/28/08	2/4/08	2,300	2,370	2,700	3,170	3,340	3,170	2,842
	Cylinders 3 x 3 (Top)	0 Mins. After mixing	CU0	7 Days	1/28/08	2/4/08	1,670	1,850	1,830	1,970	1,830	1,790	1,823
		5 mins. After mixing	CU5	7 Days	1/28/08	2/4/08	2,400	2,600	2,370	2,450	2,330	2,180	2,388
	Cylinders 3 x 3 (Bottom)	0 Mins. After mixing	CU0	7 Days	1/28/08	2/4/08	3,970	3,520	3,280	3,080	3,690	3,970	3,585
		5 mins. After mixing	CU5	7 Days	1/28/08	2/4/08	4,120	4,100	4,070	3,780	3,970	4,300	4,057
	Cubes from Cylinders - TOP	0 Mins. After mixing	CU0	7 Days	1/28/08	2/4/08	2,750	2,310	2,650	2,030	3,600	2,770	2,685
		5 mins. After mixing	CU5	7 Days	1/28/08	2/4/08	3,550	2,920	2,730	2,790	3,370	2,800	3,027
	Cubes from Cylinders - BOTTOM	0 Mins. After mixing	CU0	7 Days	1/28/08	2/4/08	2,970	2,770	2,650	2,970	3,490	2,850	2,950
		5 mins. After mixing	CU5	7 Days	1/28/08	2/4/08	3,620	3,100	3,440	3,010	3,180	3,810	3,360
	Cubes from MOLDS	0 Mins. After mixing	CU0	7 Days	1/28/08	2/4/08	4,790	4,170	4,650	4,820	5,040	4,900	4,728
		5 mins. After mixing	CU5	7 Days	1/28/08	2/4/08	3,950	4,100	3,870	3,860	4,080	3,710	3,928

Conset Non-Shrink Grout Strength 7 Day Test Results - Tested on 2/4/08

					Date Made	Date Tested	Strength in psi						
							1	2	3	4	5	6	Average
Restrained from Expansion	Cylinders 3 x 6	0 Mins. After mixing	CR0	7 Days	1/28/08	2/4/08	3,370	3,110	3,880	3,350	4,580	4,250	3,757
	Cylinders 3 x 3 Top	0 Mins. After mixing	CR0	7 Days	1/28/08	2/4/08	3,490	2,560	2,680	3,010	3,170	3,850	3,127
	Cylinders 3 x 3 Bottom	0 Mins. After mixing	CR0	7 Days	1/28/08	2/4/08	3,840	4,110	4,210	3,820	3,770	4,070	3,970
	Cubes from Cylinders - TOP	0 Mins. After mixing	CR0	7 Days	1/28/08	2/4/08	2,910	2,780	2,640	3,050	3,590	3,170	3,023
	Cubes from Cylinders - BOTTOM	0 Mins. After mixing	CR0	7 Days	1/28/08	2/4/08	2,870	3,090	2,960	3,060	3,450	2,890	3,053
	Cubes from MOLDS	0 Mins. After mixing	CR0	7 Days	1/28/08	2/4/08	4,670	4,650	4,910	4,650	4,470	4,560	4,652
Unrestrained from Expansion	Cylinders 3 x 6	0 Mins. After mixing	CU0	7 Days	1/28/08	2/4/08	2,380	2,140	2,080	2,100	2,070	1,990	2,127
		5 mins. After mixing	CU5	7 Days	1/28/08	2/4/08	2,300	2,370	2,700	3,170	3,340	3,170	2,842
	Cylinders 3 x 3 (Top)	0 Mins. After mixing	CU0	7 Days	1/28/08	2/4/08	1,670	1,850	1,830	1,970	1,830	1,790	1,823
		5 mins. After mixing	CU5	7 Days	1/28/08	2/4/08	2,400	2,600	2,370	2,450	2,330	2,180	2,388
	Cylinders 3 x 3 (Bottom)	0 Mins. After mixing	CU0	7 Days	1/28/08	2/4/08	3,970	3,520	3,280	3,080	3,690	3,970	3,585
		5 mins. After mixing	CU5	7 Days	1/28/08	2/4/08	4,120	4,100	4,070	3,780	3,970	4,300	4,057
	Cubes from Cylinders - TOP	0 Mins. After mixing	CU0	7 Days	1/28/08	2/4/08	2,750	2,310	2,650	2,030	3,600	2,770	2,685
		5 mins. After mixing	CU5	7 Days	1/28/08	2/4/08	3,550	2,920	2,730	2,790	3,370	2,800	3,027
	Cubes from Cylinders - BOTTOM	0 Mins. After mixing	CU0	7 Days	1/28/08	2/4/08	2,970	2,770	2,650	2,970	3,490	2,850	2,950
		5 mins. After mixing	CU5	7 Days	1/28/08	2/4/08	3,620	3,100	3,440	3,010	3,180	3,810	3,360
	Cubes from MOLDS	0 Mins. After mixing	CU0	7 Days	1/28/08	2/4/08	4,790	4,170	4,650	4,820	5,040	4,900	4,728
		5 mins. After mixing	CU5	7 Days	1/28/08	2/4/08	3,950	4,100	3,870	3,860	4,080	3,710	3,928

W. R. Meadows CG-86 Non-Shrink Grout Strength 7 Day Test Results - Tested on 2-5-08

		Tested at 0 or 5 minutes after mixing	Notation		Date Made	Date Tested	Strength in psi						
							1	2	3	4	5	6	Average
Restrained from Expansion	Cylinders 3 x 6	0 Mins. After mixing	CR0	7 Days	1/29/08	2/5/08	6,930	6,800	6,080	6,830	7,150	6,990	6,797
	Cylinders 3 x 3 Top	0 Mins. After mixing	CR0	7 Days	1/29/08	2/5/08	4,950	7,860	7,400	7,760	6,300	7,760	7,005
	Cylinders 3 x 3 Bottom	0 Mins. After mixing	CR0	7 Days	1/29/08	2/5/08	7,680	7,780	7,920	8,070	6,870	7,360	7,613
	Cubes from Cylinders - TOP	0 Mins. After mixing	CR0	7 Days	1/29/08	2/5/08	5,970	6,220	2,340	5,830	5,340	4,400	5,017
	Cubes from Cylinders - BOTTOM	0 Mins. After mixing	CR0	7 Days	1/29/08	2/5/08	6,620	5,240	5,540	6,530	3,910	5,670	5,585
	Cubes from MOLDS	0 Mins. After mixing	CR0	7 Days	1/29/08	2/5/08	7,150	6,490	6,160	6,690	6,360	6,740	6,598
Unrestrained from Expansion	Cylinders 3 x 6	0 Mins. After mixing	CU0	7 Days	1/29/08	2/5/08	8,030	8,060	7,570	6,810	7,870	7,630	7,662
		5 mins. After mixing	CU5	7 Days	1/29/08	2/5/08	8,120	7,820	7,510	7,820	6,930	8,630	7,805
	Cylinders 3 x 3 (Top)	0 Mins. After mixing	CU0	7 Days	1/29/08	2/5/08	7,270	7,450	6,910	7,290	7,160	7,440	7,253
		5 mins. After mixing	CU5	7 Days	1/29/08	2/5/08	9,010	6,990	8,370	7,880	8,820	6,570	7,940
	Cylinders 3 x 3 (Bottom)	0 Mins. After mixing	CU0	7 Days	1/29/08	2/5/08	7500	7400	7430	8100	7980	7330	6,353
		5 mins. After mixing	CU5	7 Days	1/29/08	2/5/08	7630	6880	8120	6780	7510	8300	6,642
	Cubes from Cylinders - TOP	0 Mins. After mixing	CU0	7 Days	1/29/08	2/5/08	6,130	6,050	6,090	6,850	6,440	6,560	6,933
		5 mins. After mixing	CU5	7 Days	1/29/08	2/5/08	5,520	6,980	7,300	7,050	5,980	7,020	6,667
	Cubes from Cylinders - BOTTOM	0 Mins. After mixing	CU0	7 Days	1/29/08	2/5/08	6,680	6,920	6,390	7,070	7,520	7,020	6,282
		5 mins. After mixing	CU5	7 Days	1/29/08	2/5/08	6,610	5,680	6,740	6,690	6,890	7,390	7,020
	Cubes from MOLDS	0 Mins. After mixing	CU0	7 Days	1/29/08	2/5/08	6,310	6,180	6,300	6,070	6,370	6,460	6,282
		5 mins. After mixing	CU5	7 Days	1/29/08	2/5/08	7,430	6,730	6,780	5,990	6,910	8,280	7,020

Conset Non-Shrink Grout Strength 28 Day Test Results - Tested on 2/25/08

					Date Made	Date Tested	Strength in psi											
												1	2	3	4	5	6	Average
Restrained from Expansion	Cylinders 3 x 6	0 Mins. After mixing	CR0	28 Days	1/28/08	2/25/08	3,960	3,820	5,280	3,980	5,300	5,310	4,608					
	Cylinders 3 x 3 Top	0 Mins. After mixing	CR0	28 Days	1/28/08	2/25/08	4,180	4,350	3,160	4,040	4,430	3,650	3,968					
	Cylinders 3 x 3 Bottom	0 Mins. After mixing	CR0	28 Days	1/28/08	2/25/08	5,380	5,380	5,050	4,990	5,130	4,880	5,135					
	Cubes from Cylinders - TOP	0 Mins. After mixing	CR0	28 Days	1/28/08	2/25/08	4,730	4,080	5,010	4,260	3,790	3,710	4,263					
	Cubes from Cylinders - BOTTOM	0 Mins. After mixing	CR0	28 Days	1/28/08	2/25/08	4,040	5,280	4,740	3,200	4,480	4,760	4,417					
	Cubes from MOLDS	0 Mins. After mixing	CR0	28 Days	1/28/08	2/25/08	6,380	6,700	6,770	6,600	7,110	6,750	6,718					
Unrestrained from Expansion	Cylinders 3 x 6	0 Mins. After mixing	CU0	28 Days	1/28/08	2/25/08	2,390	2,520	2,560	2,350	2,430	2,430	2,447					
		5 mins. After mixing	CU5	28 Days	1/28/08	2/25/08	3,320	3,830	3,830	3,980	3,970	4,430	3,893					
	Cylinders 3 x 3 (Top)	0 Mins. After mixing	CU0	28 Days	1/28/08	2/25/08	2,080	2,240	2,330	2,560	2,290	2,230	2,288					
		5 mins. After mixing	CU5	28 Days	1/28/08	2/25/08	2,290	3,320	2,710	3,220	3,070	2,950	2,927					
	Cylinders 3 x 3 (Bottom)	0 Mins. After mixing	CU0	28 Days	1/28/08	2/25/08	4,610	4,070	4,100	4,320	4,140	4,720	4,327					
		5 mins. After mixing	CU5	28 Days	1/28/08	2/25/08	5,140	5,130	5,000	5,150	4,920	4,830	5,028					
	Cubes from Cylinders - TOP	0 Mins. After mixing	CU0	28 Days	1/28/08	2/25/08	3,190	5,060	3,900	4,210	3,530	3,800	3,948					
		5 mins. After mixing	CU5	28 Days	1/28/08	2/25/08	3,430	4,180	3,780	4,240	3,590	3,730	3,825					
	Cubes from Cylinders - BOTTOM	0 Mins. After mixing	CU0	28 Days	1/28/08	2/25/08	4,400	3,640	3,810	3,860	3,840	4,920	4,078					
		5 mins. After mixing	CU5	28 Days	1/28/08	2/25/08	4,690	4,430	3,430	4,290	4,560	4,120	4,253					
	Cubes from MOLDS	0 Mins. After mixing	CU0	28 Days	1/28/08	2/25/08	6,710	6,810	6,790	6,350	6,590	6,670	6,653					
		5 mins. After mixing	CU5	28 Days	1/28/08	2/25/08	5,780	5,630	6,150	6,320	6,510	6,190	6,097					

W. R. Meadows CG-86 Non-Shrink Grout Strength 28 Day Test Results - Tested on 2-26-08

		Tested at 0 or 5 minutes after mixing	Notation		Date Made	Date Tested	Strength in psi						
							1	2	3	4	5	6	Average
Restrained from Expansion	Cylinders 3 x 6	0 Mins. After mixing	GR0	7 Days	1/29/08	2/26/08	10,150	8,090	9,680	9,160	10,030	8,680	9,298
	Cylinders 3 x 3 Top	0 Mins. After mixing	GR0	7 Days	1/29/08	2/26/08	8,260	8,980	9,270	9,560	6,840	7,600	8,418
	Cylinders 3 x 3 Bottom	0 Mins. After mixing	GR0	7 Days	1/29/08	2/26/08	8,710	8,830	5,450	8,670	8,630	7,000	7,882
	Cubes from Cylinders - TOP	0 Mins. After mixing	GR0	7 Days	1/29/08	2/26/08	6,820	5,090	5,490	7,880	5,400	6,230	6,152
	Cubes from Cylinders - BOTTOM	0 Mins. After mixing	GR0	7 Days	1/29/08	2/26/08	6,890	6,870	5,510	7,050	5,980	5,580	6,313
	Cubes from MOLDS	0 Mins. After mixing	GR0	7 Days	1/29/08	2/26/08	10,120	8,460	7,560	9,220	9,980	8,970	9,052
Unrestrained from Expansion	Cylinders 3 x 6	0 Mins. After mixing	GU0	7 Days	1/29/08	2/26/08	9,710	10,230	9,880	9,590	10,180	9,560	9,858
		5 mins. After mixing	GU5	7 Days	1/29/08	2/26/08	9,910	9,680	8,060	10,160	9,980	9,120	9,485
	Cylinders 3 x 3 (Top)	0 Mins. After mixing	GU0	7 Days	1/29/08	2/26/08	8,740	9,230	9,240	9,380	10,140	8,310	9,173
		5 mins. After mixing	GU5	7 Days	1/29/08	2/26/08	9,740	9,160	9,120	9,060	8,860	9,120	9,177
	Cylinders 3 x 3 (Bottom)	0 Mins. After mixing	GU0	7 Days	1/29/08	2/26/08	9730	9360	9460	9370	9790	9520	6,700
		5 mins. After mixing	GU5	7 Days	1/29/08	2/26/08	9690	10200	10160	9250	10340	9290	6,622
	Cubes from Cylinders - TOP	0 Mins. After mixing	GU0	7 Days	1/29/08	2/26/08	6,060	5,480	7,270	7,370	6,770	7,250	6,735
		5 mins. After mixing	GU5	7 Days	1/29/08	2/26/08	9,030	6,280	6,410	5,100	7,090	5,820	7,707
	Cubes from Cylinders - BOTTOM	0 Mins. After mixing	GU0	7 Days	1/29/08	2/26/08	6,250	5,840	6,910	7,160	6,450	7,800	8,568
		5 mins. After mixing	GU5	7 Days	1/29/08	2/26/08	7,960	8,900	7,220	8,230	6,000	7,930	9,825
	Cubes from MOLDS	0 Mins. After mixing	GU0	7 Days	1/29/08	2/26/08	8,060	8,410	8,610	9,270	8,470	8,590	8,568
		5 mins. After mixing	GU5	7 Days	1/29/08	2/26/08	9,360	9,870	10,250	10,060	9,590	9,820	9,825

Compressive Strength of Non-Shrink Grout Cylinders - Air Cured

		Date Made	Date Tested	Strength in psi								
				3 x 6 Cylinders			3 x 3 Cylinders (top)			3 x 3 Cylinders (Bottom)		
				1	2	Average	3	4	Average	5	6	Average
Chemmaster s - CONSET	1 Day	1/28/08	1/29/08	2,120	2,090	2,105	1,380	1,320	1,350	2,220	2,320	2,270
	7 Days	1/28/08	2/4/08	2,610		2,610	2,401	2,654	2,528	3,880	4,300	4,090
W.R.. Meadows CG - 86	1 Day	1/29/08	1/30/08	4,560	4,530	4,545	4,280	4,220	4,250	4,490	4,320	4,405
	7 Days	1/29/08	2/5/08	7,950		7,950	6,710	6,730	6,720	7,700	7,870	7,785

Extensometer Readings

Time	CONSET				CG-86				Average Shrinkage
	0 Minutes		5 Minutes		0 Minutes		5 Minutes		
	Reading	Expansion	Reading	Expansion	Reading	Shrinkage	Reading	Shrinkage	
0 hours after mixing	0.1646		0.1393		0.1899		0.1580		
6 hours after mixing	0.2334	0.0688	0.2415	0.1022					
1 day after mixing	0.2358	0.0712	0.2407	0.1014	0.0528	-0.1371	0.0253	-0.1328	-0.1349
3 days after mixing	0.2331	0.0685	0.2215	0.0822	0.0105	-0.1794	0.1157	-0.0423	-0.1108
28 days after mixing	0.2544	0.0898	0.2314	0.0921	0.0156	-0.1743	0.1150	-0.0430	-0.1086

