PCA Portland Cement Association

CONCRETE TECHNOLOGY *Today*

Final Issue!
See page 8

Portland Cement Characteristics–2004

By P. D. Tennis, consultant, and J. I. Bhatty, CTLGroup, Inc.

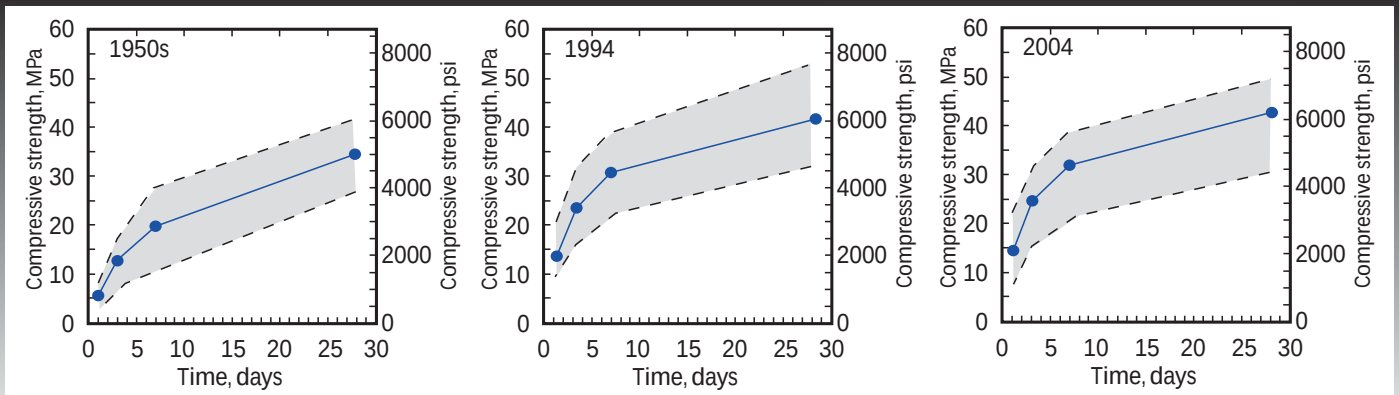

Figure 1. Mean C 109 mortar cube strengths of Type II cements in (a) 1950s; (b) 1994; and (c) 2004. Dashed lines represent maximum and minimum values, solid lines with circles are mean values. Note the relative increase in early-age strengths for modern cements compared to cements manufactured in the 1950s. Strengths have not changed significantly over the past 10 years.

CT053 — December 2005
Vol. 26, No. 3

Contents

Concrete Technology Today is available on the Internet at www.concretetechnologytoday.org

It has been 10 years since data was collected in an attempt to comprehensively document physical and chemical characteristics of portland cement available in North America (Gebhardt 1995). This interval provides a reasonable timeframe to compare historical data with more recent data on cement characteristics.

Survey Strategy

Surveys were distributed to all 123 cement plants in the U.S. and Canada. A total of 92 plants responded, a return rate of about 75%. The 2004 survey was broader than previous surveys (Tennis 1999; Gebhardt 1995) in that data on portland, masonry, and blended cements was collected; altogether, characteristics of 363 cements were provided. An additional change from previous surveys was that yearly average production data for cements was requested, rather than mill test certificates. Mill test reports represent a 'snapshot' of production characteristics and may represent daily, weekly, or monthly averages (or some other convenient timeframe), which vary from plant to plant. By collecting yearly average data, more appropriate comparisons can be made.

continued on page 2

Table 1. Chemical and Phase Composition and Fineness of ASTM C 150/AASHTO M 85 Portland Cements in 2004

Cement type*	Chemical composition, %						Loss on ignition, %	Na_2O eq.	Potential phase composition, %				Blaine fineness, m^2/kg
	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	SO_3			C_3S	C_2S	C_3A	C_4AF	
I (mean)	**20.17**	**5.07**	**2.66**	**63.23**	**2.51**	**3.26**	**1.52**	**0.70**	**56.9**	**14.8**	**8.9**	**8.2**	**384**
I (SD**)	0.66	0.54	0.44	1.04	1.02	0.62	0.48	0.26	4.57	3.71	1.81	1.37	19.3
II (mean)	**20.85**	**4.62**	**3.32**	**63.66**	**1.98**	**2.91**	**1.39**	**0.56**	**56.5**	**17.1**	**6.7**	**10.1**	**377**
II (SD)	0.52	0.37	0.40	0.84	0.92	0.39	0.40	0.26	3.93	3.48	0.88	1.20	20.0
III (mean)	**20.38**	**4.84**	**2.86**	**63.33**	**2.21**	**3.60**	**1.51**	**0.61**	**56.2**	**16.2**	**7.8**	**8.8**	**556**
III (SD)	0.70	0.64	0.59	0.93	0.93	0.55	0.41	0.27	4.13	3.91	2.14	1.80	55.5
V (mean)	**21.61**	**3.80**	**3.87**	**63.85**	**2.18**	**2.34**	**1.29**	**0.45**	**57.7**	**18.4**	**3.5**	**11.8**	**389**
V (SD)	0.67	0.35	0.67	0.66	0.91	0.28	0.44	0.12	3.47	3.93	1.17	2.03	42.5

**See Table 5 for groupings of cement types.*

***SD=Standard deviation*

Table 2. Chemical and Phase Composition and Fineness of Portland Cements in 1994

Cement type	Chemical composition, %						Loss on ignition, %	Na_2O eq.	Potential phase composition, %				Blaine fineness, m^2/kg
	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	SO_3			C_3S	C_2S	C_3A	C_4AF	
I (mean)	**20.55**	**5.41**	**2.59**	**63.91**	**2.09**	**3.03**	**1.37**	**0.61**	**53.7**	**18.4**	**10.0**	**7.9**	**369**
I (SD*)	0.63	0.37	0.50	1.03	1.06	0.25	0.44	0.23	4.87	4.30	1.39	1.46	23.7
II (mean)	**21.19**	**4.59**	**3.50**	**63.82**	**2.14**	**2.69**	**1.16**	**0.51**	**54.2**	**19.9**	**6.3**	**10.6**	**377**
II (SD)	0.63	0.37	0.50	1.03	1.06	0.25	0.43	0.18	5.15	4.97	0.92	1.51	46.5
III (mean)	**20.58**	**4.95**	**2.77**	**63.75**	**2.24**	**3.53**	**1.31**	**0.56**	**54.7**	**17.8**	**8.5**	**8.4**	**548**
III (SD)	0.71	0.60	0.65	1.08	1.02	0.51	0.37	0.22	5.57	4.94	2.23	1.95	46.5
V (mean)	**21.85**	**3.92**	**4.17**	**63.80**	**2.15**	**2.28**	**1.02**	**0.48**	**53.8**	**22.1**	**3.4**	**12.6**	**372**
V (SD)	0.75	0.62	0.69	1.07	1.03	0.41	0.28	0.13	6.07	5.56	1.20	2.03	30.6

**SD=Standard deviation*

Note: 1994 and 1998 surveys were conducted on different bases, thus the above results may not be directly comparable.

Table 3. ASTM C 109 Mortar Strengths of Portland Cements in 2004, MPa

Cement type	1 day	3 days	7 days	28 days
I (mean)	**15.8**	**26.3**	**33.0**	**41.3**
I (SD*)	2.82	2.40	2.48	3.55
II (mean)	**14.9**	**25.2**	**32.4**	**42.9**
II (SD)	2.57	2.62	2.86	3.64
III (mean)	**25.0**	**34.9**	**41.2**	**49.3**
III (SD)	3.39	3.61	3.81	4.44
V (mean)	**12.8**	**23.3**	**30.9**	**43.6**
V (SD)	1.83	3.23	4.20	4.66

**SD=Standard deviation*

Table 4. ASTM C 109 Mortar Strengths of Portland Cements in 1994, MPa

Cement type	1 day	3 days	7 days	28 days
I (mean)	**14.8**	**24.9**	**32.2**	**41.1**
I (SD*)	3.04	2.35	2.37	3.52
II (mean)	**13.7**	**23.8**	**30.9**	**41.7**
II (SD)	2.21	2.80	3.03	3.59
III (mean)	**24.1**	**34.7**	**41.0**	**48.4**
III (SD)	3.80	2.93	3.07	3.54
V (mean)	**12.0**	**21.6**	**28.5**	**40.4**
V (SD)	2.52	3.80	3.60	3.13

**SD=Standard deviation*

continued from page 1

Results

Numbers of cement types are reported in Table 5. Type II cements representing 36% of portland cements are produced at about 85% of cement plants in the U.S. and Canada. Blended cements—with data on 17 different products reported—are somewhat less available. For ASTM C 91 masonry cements, 110 cements meeting requirements of Type S, N, or M, were reported. ASTM C 91 cements overwhelmingly predominate over those in the newer specifications C 1328 (3 cements) and C 1329 (8 cements). This article focuses on portland cement characteristics—a future article in *Masonry Today*, will discuss characteristics of masonry cements (www.cement.org/masonry).

Tables 1 through 4 list summary data for the 2004 survey, as well as those for the 1994 survey. Tables 1 and 2 provide data on chemical and phase composition and fineness, while Tables 3 and 4 provide C 109 mortar cube strengths. Slight increases in C_3S contents and decreases in C_2S contents are consistent with a slight drop in average SiO_2. There were slight increases in loss-on-ignition values, Blaine finenesses, and sulfate contents. Average cube strengths at 1 day increased by about 6.5% compared to 1994, as shown in Figure 2.

A side-by-side comparison of the data shows that the mean values are similar, with no statistically significant changes in cement properties between 1994 and 2004.

Table 5: Cements in the Survey by Cement Type[a]

Portland Cements—ASTM C 150/AASHTO M 85[b]				**Survey total**
Type I	Type II	Type III	Type V	
52	79[c]	57	26[d]	219
Blended Cements—ASTM C 595/AASHTO M 240				
IS	IP	I(PM)	I(SM)	
1	7[e]	5	4	17
Hydraulic Cements—ASTM C 1157				
Type GU[f]				
6				6

[a]*No data was received for ASTM C 150 Type IV or C 595 Type P cements.*
[b]*Survey total does not include data on 5 white Type I cements, 5 Type IA cements, 1 Type IIA, nor 1 Type IIIA.*
[c]*Includes 62 cements sold as Type I/II, and 1 cement sold as I/II/III.*
[d]*Includes 11 cements sold as Type II/V, 1 cement sold as I/II/V, and 1 cement sold as I/II/III/V.*
[e]*Includes 1 cement sold as Type IP(MS)*
[f]*Includes 1 cement sold as Type GU/HE. Data not received for any other cement types defined by C 1157.*

References

Clifton, J. R. and Mathey, R. G., "Compilation of Data from Laboratory Studies," Interrelation Between Cement and Concrete Properties, Part 6, *Building Science Series 36*, National Bureau of Standards, Washington, D. C., August 1971.

Gebhardt, R. F., "Survey of North American Portland Cements: 1994," *Cement, Concrete, and Aggregates*, ASTM, West Conshohocken, Pennsylvania, December 1995, pages 145–189.

Tennis, P. D., "Portland Cement Characteristics -1998," *Concrete Technology Today*, Vol. 2, No. 2, PL992, Portland Cement Association, Skokie, Illinois, August 1999, pages 1–4. http://www.cement.org/tech/pdfs/pl992.pdf

"Portland Cement: Past and Present Characteristics," *Concrete Technology Today*, Vol. 17, No. 2, PL962, Portland Cement Association, Skokie, Illinois, July 1996, pages 1–3. http://www.cement.org/pdf_files/pl962.pdf

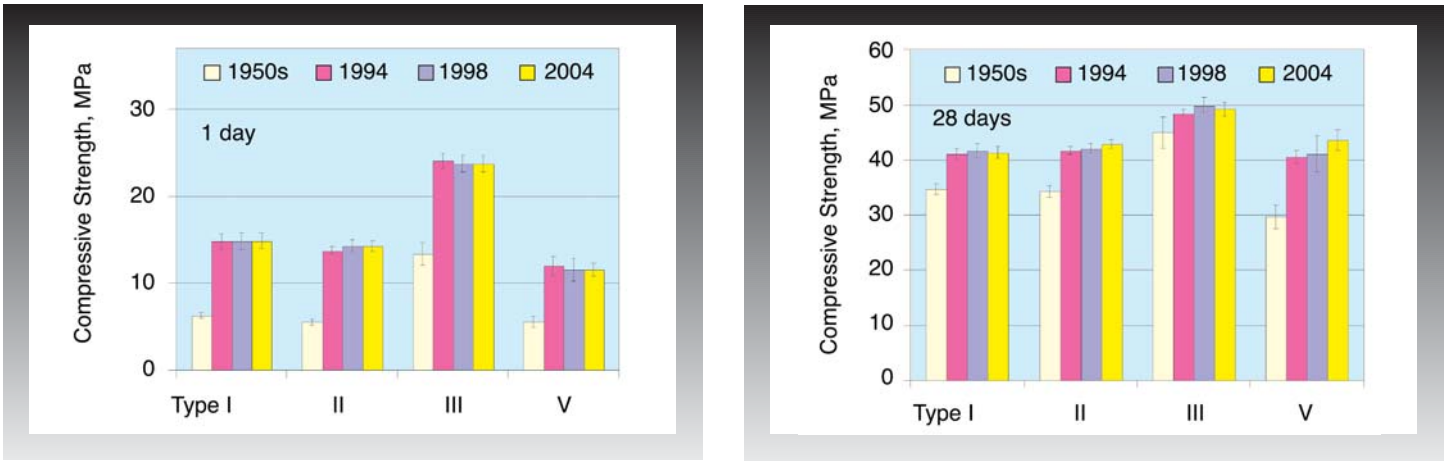

Figure 2. ASTM C 109 compressive strength at 1 day (left) and 28 days (right) for portland cements from various surveys. On average, 1-day and 28-day strengths have not changed significantly over the last 10 years. Data from the 1950s may not be directly related due to changes in the C 109 test procedure. Bars represent 95% confidence intervals.