



Research & Development Information

PCA R&D SN3354

Chemical and Physical Characteristics of US Hydraulic Cements: 2022

by James A. Farny

DOI: <https://doi.org/10.70909/pca.2025.SN3354>

Portland Cement Association
200 Massachusetts Ave NW, Suite 200
Washington, DC 20001

(202) 408-9494

www.cement.org

©Portland Cement Association 2025

All rights reserved

KEYWORDS

AASHTO M 85, AASHTO M 240, ASTM C91, ASTM C150, ASTM C595, ASTM C1157, ASTM C1328, ASTM C1329, blended cement, chemical characteristics, compressive strength, fineness, hydraulic cement, masonry cement, mortar cement, stucco cement, performance, physical characteristics, plastic cement, portland cement, portland-limestone cement, setting time, loss on ignition, insoluble residue, oxide analysis, phase composition, chloride content

ABSTRACT

This report summarizes responses to a survey on chemical and physical characteristics of hydraulic cements produced in the US. In the survey, yearly average data for cements produced in 2022 was requested for cements manufactured under ASTM C150/AASHTO M 85 (portland cements), ASTM C595/AASHTO M 240 (blended hydraulic cements), ASTM C1157 (hydraulic cements), ASTM C91 (masonry cements), ASTM C1328 (plastic (stucco) cements), and ASTM C1329 (mortar cements). The properties of interest include those required to meet the chemical and physical requirements of the respective ASTM/AASHTO specifications.

Survey forms were distributed to 95 cement plants operating in the US and 57 plants responded—a return rate of 60%, with data on 192 cements. Data for 82 ASTM C150/AASHTO M 85 portland cements was provided, and Type II cement, with 20 plants producing, was the most common portland cement type produced by number of plants. Data was received for 53 blended cements produced under ASTM C595/AASHTO M 240. A total of 43 plants reported producing Type IL cements, making it the most common blended cement type produced, by number of plants, as well as the most common type overall. For ASTM C91 masonry cements, data for a total of 49 cements were reported, with the most common type being Type S, with 19 plants producing. Two cements produced under C1157 were reported in the survey, but limited information was provided for them.

Survey results indicate that Type IL blended cements had similar performance to portland cements in strength development and setting times.

REFERENCE

Farny, James A., *Chemical and Physical Characteristics of US Cements: 2022*, SN3354, Portland Cement Association, Washington, D.C., USA, 2025, 37 pages. <https://doi.org/10.70909/pca.2025.SN3354>

TABLE OF CONTENTS

LIST OF TABLES	1
LIST OF FIGURES.....	2
INTRODUCTION.....	3
Overview	3
Historical Surveys	3
Methodology of Survey.....	4
SURVEY RESPONSE.....	5
Portland Cements (ASTM C150/AASHTO M 85).....	6
Blended Cements (ASTM C595/AASHTO M 240)	6
Masonry Cements (ASTM C91)	7
Hydraulic Cements (ASTM C1157)	7
Plastic (Stucco) Cements (ASTM C1328)	7
Mortar Cements (ASTM C1329)	7
SURVEY TOPICAL QUESTION.....	7
CHARACTERISTICS OF PORTLAND CEMENTS (ASTM C150/AASHTO M 85).....	8
Chemical and Phase Composition.....	8
Physical Properties	12
CHARACTERISTICS OF BLENDED CEMENTS (ASTM C595/AASHTO M 240).....	18
Constituent Content and Chemical Characteristics.....	18
Physical Properties	20
COMPARISON OF HYDRAULIC CEMENTS FOR GENERAL CONCRETE CONSTRUCTION.....	24
Physical Properties	24
CHARACTERISTICS OF MASONRY CEMENTS (ASTM C91)	29
Physical Properties	29
CHARACTERISTICS OF PLASTIC (STUCCO) CEMENTS (ASTM C1328)	31
CONCLUSIONS.....	32
ACKNOWLEDGEMENTS	33
REFERENCES.....	33

LIST OF TABLES

Page

Table 1. Cement Types Produced in the US, as Reported in the 2022 Survey.....	5
Table 2. Oxide Composition and Other Chemical Characteristics of US Portland Cements Reported for 2022, % by mass.....	9
Table 3. Estimated (Bogue) Phase Composition of Portland Cements Reported for 2022, % by mass.....	10
Table 4. Equivalent Alkali ($\text{Na}_2\text{O}_{\text{eq}}$)* Content of Portland Cements Reported for 2022.....	11
Table 5. Tricalcium Aluminate (C_3A) Content of Type III Portland Cements Reported for 2022.....	11
Table 6. Sulfate Contents of Portland Cements Reported for 2022.....	11
Table 7. Miscellaneous Chemical Characteristics Reported for 2022, % by mass.....	12
Table 8a. Select Physical Properties of Portland Cements Reported for 2022.....	14
Table 9. Strength, Setting Time, and Fineness of Portland Cements Reported for 2022.....	16
Table 10. Nominal Amount of Constituents in Blended Cements Reported for 2022, % by mass....	18
Table 11. Select Chemical Characteristics Blended Cements Reported for 2022, % by mass.....	19
Table 12. Additional Characteristics Reported for Limestone used in Type IL Cements Reported for 2022.....	20
Table 13. Compressive Strength and Setting Time of Blended Cements Reported for 2022.....	22
Table 14. Other Physical Characteristics of Blended Cements Reported for 2022.....	23
Table 15. Physical Data for ASTM C91 Masonry Cements Reported for 2022.....	30
Table 16. Physical Data for ASTM C1328 Plastic (Stucco) Cements Reported for 2022.....	32

LIST OF FIGURES

Figure 1. ASTM C109 compressive strengths for portland cements as reported for 2022.....	17
Figure 2. ASTM C109 compressive strengths for blended cements as reported for 2022.....	21
Figure 3. ASTM C204 Air permeability (Blaine) fineness vs. limestone content for Type IL cements as reported for 2022..	24
Figure 4. Mean ASTM C191 setting times (Vicat method) for hydraulic cements reported for 2022.	25
Figure 5. Mean ASTM C204 Air permeability (Blaine) fineness of hydraulic cements reported for 2022 for general concrete construction.	25
Figure 6. Mean ASTM C109 compressive strengths of hydraulic cements for general concrete construction as reported for cements produced in 2022. In this figure, error bars represent the range of reported values for each cement type at each age.	27
Figure 7. Mean ASTM C109 compressive strength development of hydraulic cements for general concrete construction as reported for 2022.	27
Figure 8. ASTM C204 Air permeability (Blaine) fineness vs. ASTM C109 compressive strengths for Type II cements as reported for 2022.....	28
Figure 9. ASTM C204 Air permeability (Blaine) fineness vs. ASTM C109 compressive strengths for Type IL cements as reported for 2022.....	28
Figure 10. Mean ASTM C109 compressive strength of ASTM C91 masonry cements as reported for 2022. Error bars indicate the range of values reported in the survey.	29
Figure 11. Mean ASTM C266 Gillmore setting times of ASTM C91 masonry cements as reported for 2022. Error bars indicate the range of values reported in the survey.	31

Chemical and Physical Characteristics of US Cements: 2022

by James A. Farny*

INTRODUCTION

Overview

A survey was conducted in 2023 by the Portland Cement Association's Product Standards and Technology (PS&T) Committee to compile information on physical and chemical characteristics of cements commercially manufactured in the US in 2022, focusing on those characteristics referenced in specifications. The survey included questions for up to 30 chemical and about 20 physical properties for different cement types. In the survey, cement company staff were asked to provide chemical and physical properties of cements that were produced in 2022 including mean data for the year for each type of cement, as well as high and low values for the year, standard deviation, and number of analyses. This report focuses on the mean values of those characteristics.

Historical Surveys

Data summarized here represents properties of cements produced in the U.S. in 2022. The information follows the method used for the previous edition of this survey by Tennis (2016), that reported on cement characteristics data from 2014. Tennis (2016) also provides brief descriptions of earlier compilations of US cement properties by other authors that can offer some comparison with cements of earlier periods. These include Clifton and Mathey (1971) on results of chemical and physical analyses by the National Bureau of Standards on 193 portland cements produced in the 1950s; Gebhardt (1995) on data from a variety of sources for portland cements produced in 1994 for ASTM Committee C01 (see also PCA 1996 for a summary); Tennis (1999) on mill test report data from 1998; and Bhatti and Tennis (2008) on US and Canadian plants with yearly average data from 2004, including for blended cements and masonry cements.

Although quantities of cements produced for each cement type are not part of this survey, the US Geological Survey (USGS) does provide summary data on volumes of cements produced by type (USGS National Minerals Information Center) and has historical data available. Data for 2022 showed that Type I and II cements were estimated at a total of 59,400,000 metric tons, Type III cements at 2,820,000 metric tons, and Type V at 16,300,000 metric tons. Blended cements appear to be classified into Type IL (24,500,000 metric tons), Type IP (647,000 metric tons), and Type IS (1,150,000 metric tons), although

* Director, Environmental Measurement and Metrics Portland Cement Association, 200 Massachusetts Avenue NW, Suite 200, Washington, D.C., 20001 USA, jfarny@cement.org, www.cement.org.

those values appear to include C1157 cements in the totals. Data for Type IT cements were not collected by USGS in 2022. Masonry cements (including mortar and plastic (stucco) cements) accounted for 2,440,000 metric tons in 2022 (Hatfield 2024).

Methodology of Survey

Survey forms were sent via email on April 4, 2023, to PCA Product Standards and Technology Committee members as well as staff contacts (typically managers or chemists) at each cement plant. Yearly average chemical and physical data representing cements manufactured in 2022 under ASTM C150/AASHTO M 85 (portland cements), ASTM C595/AASHTO M 240 (blended hydraulic cements), and ASTM C1157 (hydraulic cements), ASTM C91 (masonry cements), ASTM C1328 (plastic (stucco) cements), and ASTM C1329 (mortar cements) were included. In addition, the survey asked for data for some optional tests that are not commonly reported, if such data was readily available. Electronic data forms were distributed as Microsoft® Excel files or Microsoft® Word files, and data was submitted using the Excel format, Word format, or PDF format. Data was collected by email and compiled and checked for data entry discrepancies and outliers and where problems were thought to exist, plants were contacted to verify or correct the data.

SURVEY RESPONSE

Of the 95 plants operating in 2022, 57 (60%) responded. Four of the plants were grinding-only facilities and 2 of those responded to the survey. At the time of the survey, eighteen companies were represented. Table 1 provides a summary of the 192 cements produced at the 57 plants responding to the survey.

Table 1. Cement Types Produced in the US, as Reported in the 2022 Survey.

ASTM C150/AASHTO M 85 ^a				Total ^a
Type I	Type II	Type III	Type V	
9 ^b	31 ^c	28	14 ^d	82
ASTM C595/AASHTO M 240 ^a				
Type IL	Type IP	Type IS		
47 ^e	5 ^f	1 ^g		53
ASTM C91				
Type N	Type S	Type M		
14	26 ^h	9 ⁱ		49
ASTM C1328				
Type S	Type M			
5	1 ^j			6
ASTM C1157 ^a				
Type HE	Type MS			
1 ^k	1 ^k			2

^a No data was received for C150 Type IV; C595 Type IT; C1157 Types GU, MH, LH, HS; or any C1329 cements. Total reflects survey data received, representing 60% of US cement plants.

^b Type I includes 2 Type IA cements and 1 white Type I cement, which are *excluded* from other data analysis.

^c Type II includes 14 Type I/II, 3 Type I/II(MH), and 2 Type II(MH) cements.

^d Type V includes 5 Type II/V and 4 Type I/II/V cements.

^e Type IL includes 7 Type IL(HS), 5 Type IL(MS), 3 Type IL(MS)(MH), 2 Type IL(HS)(MH) cements, and 1 Type IL(HE) cement.

^f Type IP includes Type 1 IP(HS) and 1 Type IP(HS)(MH) cement.

^g Only 1 Type IS was reported so it is *excluded* from other tables of this report.

^h Type S masonry cement includes 2 Type S/N and those were reported with the Type S masonry cements.

ⁱ Type M masonry cement includes 1 Type M/S and that is reported with the Type M masonry cements.

^j Plastic cement includes 1 Type M/S and that is reported with the Type S plastic cements.

^k Only 1 Type HE and 1 Type MS were reported so these are *excluded* from other tables of this report.

Portland Cements (ASTM C150/AASHTO M 85)

The 57 plants that responded to the survey produced 82 portland cements in 2022. Included in this total are Types I (general use), II (moderate sulfate resistance), II(MH)¹ (moderate sulfate resistance and moderate heat of hydration), III (high early strength), and V (high sulfate resistance). No data on any Type IV¹ (low heat of hydration) cements was received; Type IV cements have not been commonly produced for many years.

Seventeen of the 31 cements (about 55%) reported in the Type II category were marketed as Type I/II, indicating that those products meet requirements of both Type I and Type II. Twelve cements were marketed as solely Type II, and of those, all 12 also meet requirements for Type I.

Five cements are marketed as Type II(MH) (moderate heat of hydration and moderate sulfate resistance) and for consistency with previous surveys, these cements are summarized with Type II cements, representing about 16% of the entire Type II category. Of those five Type II(MH) cements, three are marketed as Type I/II(MH).

Of the 14 Type V cements, 5 (about 36%) are sold as Type II/V (indicating that they meet requirements for both Type II and Type V) and 4 (29%) as Type I/II/V (additionally meeting requirements for Type I).

Table 1 indicates that Type II cement, produced at 19 of the 57 plants responding, is the most common portland cement type produced in the US. The Type I/II designation is used by 11 of 57 (about 20%) of the plants responding to the survey.

Blended Cements (ASTM C595/AASHTO M 240)

Blended cements are commonly available in US cement plants: 48 plants reported producing blended cements. Although Type IL cements have been defined in US specifications since August 2012, it was in 2021 that more producers began offering Type IL cements to their customers; this survey reports 47 Type IL cements (produced by 43 plants), making it the most common type of cement manufactured in the US in 2022, though the volume of production was still lower than that for portland cement (Hatfield 2024). The next most common blended cement type is IP, with 5 portland-pozzolan cements being reported. Only one portland blast-furnace slag cement, Type IS, was reported. Data was not received for any ternary blended cements, Type IT. It should be noted that not all producers participated in this survey, so the lack of sufficient data for Type IS (one cement) and Type IT (zero cements) reflects an incomplete survey and not necessarily that these cement types were not produced in 2022.

ASTM C595 and AASHTO M 240 include options to designate cements as having special properties: A for air-entraining; MS and HS for moderate and high sulfate resistance, respectively; and MH and LH for moderate and low heat of hydration respectively.² Twenty plants indicated that the blended cements they produce met requirements for special designations: either (MS), (MS)(MH), (HS), (HS)(MH), or (HE).

¹ Type II(MH) and Type IV cement designations were removed from C150 and M 85 in 2024.

² MH and LH designations were removed from ASTM C595 and M 240 in 2024.

Masonry Cements (ASTM C91)

Nearly half (46%) of the cement plants that responded to the survey reported producing masonry cements: 26 plants provided data on 49 masonry cements. Type N and Type S cements are most common, at 14 (54%) and 26 (100%) of those plants, respectively, while only 9 plants (35%) reported producing Type M cements.

Hydraulic Cements (ASTM C1157)

One survey response was received for hydraulic cement Type GU and one for Type HE, so no physical or chemical characteristics for C1157 cements are included in this report because not enough data was supplied.

Plastic (Stucco) Cements (ASTM C1328)

Data was provided for 6 plastic cements; these included 5 Type S and 1 Type M/S cements.

Mortar Cements (ASTM C1329)

No responses were received in the ASTM C1329 mortar cement category.

SURVEY TOPICAL QUESTION

In addition to collecting data on cement characteristics, a question related to cement testing was included in the survey. When asked to note if they routinely use QXRD to measure C_3A or other clinker phase content of cements, 43% of respondents indicated yes for C150 and 39% indicated yes for C595 cements.

CHARACTERISTICS OF PORTLAND CEMENTS (ASTM C150/AASHTO M 85)

Chemical and Phase Composition

Chemical composition (as oxide analyses) and other chemical characteristics, such as loss on ignition, insoluble residue, free lime, and chloride content, are summarized in Table 2. Mean values are reported for each portland cement type, along with the standard deviation (SD) of those means, the maximum and minimum mean values reported, and the number of cements for which those values were reported (n). The survey also collected information about the limestone used in portland cements. For about 20 years (2004 for ASTM and 2007 for AASHTO), ground, uncalcined limestone has been permitted as an ingredient in portland cement. Of the 82 portland cements in the survey response, 62, or 75%, include limestone as an ingredient. The average limestone content of those portland cements is 3.6%, with a maximum of 4.9% and a minimum of 0.8%. In addition, 52 of the portland cements, or 63 %, reported an average calcium carbonate content of the limestone of 90% or greater for Types I, II, and III, and 87% for Type V. There were 20 cements in the survey that reported using an inorganic processing addition (IPA) as an ingredient in portland cement. Of those, the average IPA content was about 1.6%.

Mean Bogue phase composition, as determined using methods in ASTM C150/AASHTO M 85 are provided in Table 3.

Table 2. Oxide Composition and Other Chemical Characteristics of US Portland Cements Reported for 2022, % by mass.

Cement type ^A	Statistic	SiO ₂	Al ₂ O ₃	Fe ₂ O ₃	CaO	MgO	SO ₃	Loss on ignition	Na ₂ O	K ₂ O	Na ₂ O _{eq}	TiO ₂	P ₂ O ₅	Mn ₂ O ₃	Insoluble residue	Free lime	Acid-soluble chloride
I	Mean	19.62	5.07	2.82	63.27	2.20	3.34	2.42	0.16	0.77	0.51	0.26	0.19	0.09	0.38	1.07	0.012
	SD	0.80	0.41	0.54	1.84	0.97	0.52	0.37	0.10	0.29	0.16	0.03	0.08	0.07	0.16	0.21	0.003
	Maximum	20.76	5.72	3.47	66.04	3.31	3.91	2.85	0.34	1.07	0.73	0.30	0.27	0.15	0.69	1.41	0.014
	Minimum	18.67	4.67	1.93	60.78	0.92	2.68	1.75	0.06	0.37	0.35	0.23	0.06	0.02	0.26	0.89	0.009
	n	6	6	6	6	6	6	6	6	6	4	4	5	4	6	6	3
	Spec. limit	—	—	—	—	≤6.0	≤3.0, ≤3.5 ^C	≤3.0, ≤3.5 ^D	—	—	—	—	—	—	≤1.5	—	—
II	Mean	20.12	4.57	3.27	63.40	1.92	3.11	2.47	0.15	0.62	0.51	0.23	0.12	0.12	0.44	1.20	0.017
	SD	0.67	0.31	0.28	1.22	1.05	0.38	0.49	0.08	0.21	0.13	0.02	0.05	0.14	0.19	0.38	0.013
	Maximum	21.14	5.13	4.21	65.26	4.13	4.45	3.20	0.37	1.02	0.84	0.27	0.21	0.48	0.87	1.94	0.040
	Minimum	18.98	3.60	2.78	60.33	0.58	2.60	1.42	0.05	0.28	0.28	0.18	0.03	0.02	0.17	0.57	0.002
	n	31	31	31	31	31	31	31	31	31	27	20	20	11	27	30	16
	Spec. limit	—	≤6.0	≤6.0 ^B	—	≤6.0	≤3.0	≤3.0, ≤3.5 ^D	—	—	—	—	—	—	≤1.5	—	—
III	Mean	19.93	4.69	2.99	63.07	2.37	3.55	2.08	0.15	0.67	0.56	0.24	0.15	0.10	0.46	1.00	0.012
	SD	0.63	0.55	0.65	1.13	1.01	0.49	0.57	0.08	0.21	0.15	0.03	0.09	0.06	0.27	0.36	0.010
	Maximum	21.50	6.22	4.04	65.31	4.09	5.01	2.92	0.34	1.07	0.90	0.29	0.38	0.19	1.24	1.67	0.031
	Minimum	18.78	3.70	1.30	60.38	0.79	2.66	0.91	0.04	0.25	0.33	0.19	0.05	0.02	0.09	0.00	0.003
	n	28	28	28	28	28	28	28	28	28	26	14	16	10	26	27	14
	Spec. limit	—	—	—	—	≤6.0	≤3.5, ≤4.5 ^C	≤3.0, ≤3.5 ^D	—	—	—	—	—	—	≤1.5	—	—
V	Mean	20.66	4.08	3.80	63.32	2.27	2.80	2.32	0.14	0.50	0.47	0.20	0.10	—	0.67	0.97	0.004
	SD	0.53	0.24	0.39	0.75	1.13	0.44	0.54	0.07	0.15	0.12	0.02	0.05	—	0.31	0.37	0.003
	Maximum	21.53	4.44	4.29	64.83	4.69	3.75	2.98	0.27	0.76	0.74	0.23	0.18	—	1.24	1.46	0.006
	Minimum	19.85	3.69	2.87	61.89	0.90	2.11	1.29	0.07	0.25	0.30	0.18	0.05	—	0.23	0.15	0.001
	n	14	14	13	14	14	13	14	14	14	14	5	6	—	13	14	4
	Spec. limit	—	—	—	—	≤6.0	≤2.3	≤3.0, ≤3.5 ^D	—	—	—	—	—	—	≤1.5	—	—

Key: SD=Standard deviation; n= number of values; "Spec limit" is specification limit in ASTM C150-21/AASHTO M 85-21.

^A See Table 1 for groupings of cement types. Type I data excludes 2 Type IA cements and 1 Type I white cement.

^B These default limits can be exceeded if C1038 data demonstrate that 14-day expansions do not exceed 0.020%. See the specifications for complete details. See also Table 7.

^C The lower limit applies when C₃A is 8% or less and the higher limit applies when C₃A is more than 8%.

^D The lower limit applies when limestone is not an ingredient in cement and the upper limit applies when limestone is an ingredient in cement.

Table 3. Estimated (Bogue) Phase Composition of Portland Cements Reported for 2022, % by mass.

Cement type*	Statistic	C ₃ S	C ₂ S	C ₃ A	C ₄ AF
I	Mean	59.1	12.2	8.3	8.0
	SD	5.33	4.69	1.38	1.66
	Maximum	64	19	10	10
	Minimum	52	9	7	6
	n	4	4	3	4
	Spec. limit	—	—	—	—
II	Mean	58.7	13.3	6.5	9.9
	SD	3.86	3.56	0.71	0.86
	Maximum	68	20	8	13
	Minimum	50	3	4	8
	n	31	31	31	31
	Spec. limit	—	—	≤8	—
III	Mean	56.7	13.5	6.6	9.5
	SD	5.17	5.02	1.38	1.39
	Maximum	67	23	10	12
	Minimum	48	0	4	6
	n	27	27	24	24
	Spec. limit	—	—	≤15	—
V	Mean	56.3	14.9	4.6	11.2
	SD	4.68	6.21	0.50	1.25
	Maximum	65	23	5	13
	Minimum	48	0	4	9
	n	13	13	12	12
	Spec. limit	—	—	≤5	—

Key: SD=Standard deviation; n= number of values; "Spec limit" is specification limit in ASTM C150-21/AASHTO M 85-21; "—" = no limit.

* See Table 1 for groupings of cement types. Type I data excludes 2 Type IA cements and 1 Type I white cement.

A summary of the range of mean equivalent alkali contents of the portland cements surveyed is shown in Table 4. In ASTM C150 and AASHTO M 85, the alkali contents are reported on the manufacturer's certification. (Alkali contents of 0.60% or below were formerly defined as low-alkali.) Overall, 82% of portland cements in the survey have alkali contents less than or equal to 0.60% by mass. Cements with alkali contents at or below this limit were historically used to mitigate deleterious expansion with some alkali-silica reactive aggregates, although it is now understood that the alkali loading of the concrete is a more important parameter (see for example, ASTM C1778 or ACI 225.1T-20). Use of supplementary cementitious materials (SCM) is now a more common means of mitigating deleterious expansion due to ASR.

Table 4. Equivalent Alkali (Na₂O_{eq})* Content of Portland Cements Reported for 2022.

Cement type**	≤ 0.60, % by mass	> 0.60, % by mass	Percent with alkali ≤ 0.60, % by mass
I	3	1	75
II	24	3	89
III	18	8	69
V	13	1	93
Total	58	13	82

* %Na₂O_{eq} = %Na₂O + 0.658 %K₂O.

**See Table 1 for cement type groupings. Data for some cements did not include equivalent alkali content.

Table 2 of ASTM C150/AASHTO M 85 provides optional requirements for Type III cements for C₃A content, as an indicator of sulfate resistance. Table 5 (below) lists the number of cements in the survey meeting those requirements.

Table 5. Tricalcium Aluminate (C₃A) Content of Type III Portland Cements Reported for 2022.

C ₃ A content range	Number	Percentage
Less than or equal to 5%	2	8.3%
More than 5% and less than or equal to 8%	20	83.3%
More than 8%	2	8.3%

Inorganic processing additions (IPAs) are permitted ingredients in portland cements, and 19 of the 79 cements (24%) in the survey included IPA as an ingredient. There were IPAs utilized in 14 Type II cements, 2 Type III cements, and 3 Type V cements. The mean amount of IPA used in those cements was 1.4% by mass, with a range of 0.1% to 5.0%. Materials used as IPAs included cement kiln dust (CKD)/baghouse dust/fines and granulated blast furnace slag. Default limits on sulfate content are included in portland cement specifications ASTM C150 and AASHTO M 85. However, it is recognized that cement or concrete properties can sometimes be improved by exceeding those limits, and provisions to exceed the default limits are included in the specifications: the cement, when tested via ASTM C1038, shall not exceed expansion of 0.020% at 14 days. Table 6 summarizes data on sulfate contents above or below the default table limits in C150/M 85.

Table 6. Sulfate Contents of Portland Cements Reported for 2022.

Cement type*	C ₃ A content	Default maximum SO ₃ content limit**	Number		Mean ASTM C1038 expansion at 14 days, for cements exceeding table SO ₃ limit, %
			Below default limit	Above default limit	
I	8% or less	3.0	1	0	—
	More than 8%	3.5	1	1	0.010
II	All	3.0	0	31	0.007
III	8% or less	3.5	14	8	0.007
	More than 8%	4.5	2	0	—
V	All	2.3	0	12	0.007

*See Table 1 for cement Type groupings.

**See ASTM C150/AASHTO M 85 for complete details.

In ASTM C150, there is an optional physical requirement for Type V of 0.040 % at 14 days for sulfate resistance by ASTM C452, but there is no optional requirement for Type II cement. However, for five Type II cements, ASTM C452 expansion data was reported, with an average of 0.025%. Similarly, ASTM C563 provides another option for cement manufacturers to evaluate the effect of sulfate content on cement characteristics.

If the SO₃ content of a cement exceeds the default table limit shown in ASTM C150 (shown in Table 2 of this report), ASTM C1038 can be used to show that excessive expansion does not occur at this higher sulfate content. Of the cements included in the 2022 survey, ASTM C563 data was reported for 13 Type II cements and 4 Type V cements. In both cases, the ASTM C563 average optimum sulfate content was 3.2%.

Two other requirements in ASTM C150 and AASHTO M 85 are the sum of C₃S and 4.75 times the C₃A content for Type II(MH) cements (the so-called “heat index”)³, and a maximum 25% limit on the sum of the C₄AF content and twice the C₃A content for Type V cements. Table 7 provides simple statistics on those characteristics based on the survey.

Table 7. Miscellaneous Chemical Characteristics Reported for 2022, % by mass.

Cement type and limit	Statistic	Value
Type II(MH) C ₃ S+4.75 C ₃ A	Mean	88.7
	SD	2.8
	Maximum	92
	Minimum	84
	n	5
	Spec. limit	≤100
Type V C ₄ AF + 2 C ₃ A	Mean	19.8
	SD	0.5
	Maximum	21
	Minimum	19
	n	4
	Spec. limit	≤25

Key: SD=Standard deviation; n= number of values; “Spec limit” is specification limit in ASTM C150/AASHTO M 85.

Physical Properties

Table 8a shows data on several physical properties, including autoclave expansion (ASTM C151), air content (ASTM C185), normal consistency (ASTM C187), paste early stiffening (ASTM C451), and mortar expansion (ASTM C1038). Although heat of hydration (ASTM C1702) is an optional physical requirement only for Type II(MH) and II(MH)A, many producers provided results for Types II, III, and V cements.

Table 8b shows the heat of hydration results only for Type II(MH) cements. If Type II(MH) or II(MH)A cements can meet the optional limit for a maximum heat of hydration of 335 kJ/kg at 3 days, the standard composition limit for a maximum C₃S + 4.75 C₃A of 8% (as shown in Table 8) does not apply.

³ This requirement was removed from C150 and M 85 in 2024.

Table 10 shows summary statistics for various physical properties listed in ASTM C150/AASHTO M 85, including the mortar cube compressive strengths (ASTM C109), Vicat setting times (ASTM C191), and fineness values by air permeability (Blaine, ASTM C204) and No. 325 (45- μm) sieve (ASTM C430 or ASTM C1891). As with Tables 2 and 3, mean values are reported for each portland cement type, along with the standard deviation (*SD*) of those means, the maximum and minimum mean values, and the number of cements for which those values were reported (*n*).

The mean and range of mean values of ASTM C109 mortar cube compressive strengths reported in the 2022 survey are shown in Fig. 1. As expected, Type III cements have the highest strength development over the first 28 days. Type I and II have comparable strength development. Type V cements lag slightly behind Type I and II on average at 1 day but have comparable strengths by 28 days.

Table 8a. Select Physical Properties of Portland Cements Reported for 2022.

Cement type*	Statistic	Autoclave expansion, %	Air content of mortar, %	Normal consistency, %	Early stiffening, %	Mortar expansion, %	Heat of hydration, kJ/kg	
							3 days	7 days
I	Mean	0.120	7.8	26.4	73.8	0.006	—	—
	SD	0.075	1.4	0.5	11.4	0.006	—	—
	Maximum	0.209	10.0	26.9	84.7	0.011	—	—
	Minimum	0.009	5.8	25.6	62.0	-0.003	—	—
	n	5	6	6	3	5	—	—
	Spec. limit	≤0.80	≤12	—	Optional, ≥50	≤0.020**	—	—
II	Mean	0.04	7.30	25.8	79.5	0.007	303	355
	SD	0.05	1.10	0.9	8.0	0.003	18	22
	Maximum	0.18	10	27.7	91.9	0.014	349	405
	Minimum	-0.05	5	23.4	66.0	0.00	270	332
	n	29	31	31	17	15	18	10
	Spec. limit	≤0.80	≤12	—	Optional, ≥50	≤0.020**	—	—
III	Mean	0.04	7.47	28.8	69.0	0.007	354	419
	SD	0.06	1.14	1.2	9.9	0.004	25	13
	Maximum	0.20	9.50	30.6	85.0	0.012	376	427
	Minimum	-0.05	5	25.7	55.0	0.002	326	404
	n	27	28	27	12	17	3	3
	Spec. limit	≤0.80	≤12	—	Optional, ≥50	≤0.020**	—	—
V	Mean	0.02	7.06	26.1	82.7	0.007	289	339
	SD	0.04	0.79	0.5	6.7	0.004	13	7
	Maximum	0.11	8.40	26.9	91.0	0.013	300	343
	Minimum	-0.03	6.1	25.4	76.4	0.001	274	330
	n	12	13	12	4	10	3	3
	Spec. limit	≤0.80	≤12	—	Optional, ≥50	≤0.020**	—	—

Key: SD=Standard deviation; n= number of values; "—" = no limit; "

Spec limit" is the specification limit in ASTM C150/AASHTO M 85.

*See Table 1 for groupings of cement types.

**Mortar expansion limit at 14 days only applies if sulfate content exceeds default table limits.

Table 8b. ASTM C1702 heat of hydration data for Type II(MH) cements.

Cement type*	Statistic	Heat of hydration, kJ/kg	
		3 days	7 days
II(MH)**	Mean	313	359
	SD	27	32
	Maximum	349	405
	Minimum	278	338
	n	5	4
	Optional spec. limit	335	—

*See Table 1 for groupings of cement types.

**As of 2024, Type II(MH) and Type II(MH)A cements are no longer defined in C150/M 85.

Table 9. Strength, Setting Time, and Fineness of Portland Cements Reported for 2022.

Cement type*	Statistic	Compressive strength, MPa (psi)				Setting time (Vicat), minutes		Fineness (Blaine), m ² /kg	Fineness 45-µm (No. 325) sieve, % passing
		1 day	3 days	7 days	28 days	Initial	Final		
I	Mean	16.8 (2440)	27.9 (4050)	34.6 (5010)	43.2 (6270)	102	218	408	96.8
	SD	1.6 (235)	0.6 (91)	1.8 (265)	3.9 (567)	11	19	15	1.9
	Maximum	18.6 (2700)	28.8 (4180)	37.3 (5420)	48.1 (6980)	121	247	428	99.3
	Minimum	14.3 (2080)	27.3 (3950)	32.0 (4650)	38.1 (5530)	91	200	393	94.4
	n	6	6	6	6	6	6	6	6
	Spec. limit	—	≥12.0 (1740)	≥19.0 (2760)	—	≥45, ≤375	—	≥260	—
II	Mean	15.7 (2280)	26.7 (3870)	33.5 (4860)	43.3 (6280)	110	215	402	95.2
	SD	1.6 (235)	1.7 (243)	1.7 (252)	2.5 (365)	18	31	24	3.0
	Maximum	19.2 (2790)	31.1 (4500)	36.7 (5320)	47.9 (6950)	157	276	439	99.6
	Minimum	12.4 (1800)	23.6 (3420)	28.1 (4080)	35.0 (5080)	77	162	346	88.1
	n	31	31	31	31	31	28	31	31
	Spec. limit	—	≥10.0 (1450)	≥17.0 (2470)	—	≥45, ≤375	—	≥260	—
III	Mean	25.4 (3680)	35.6 (5170)	41.8 (6060)	49.4 (7160)	86	182	571	99.0
	SD	2.7 (388)	2.8 (411)	3.3 (477)	3.9 (572)	20	41	41	0.9
	Maximum	30.4 (4410)	40.5 (5870)	47.4 (6880)	55.3 (8020)	143	245	674	99.9
	Minimum	20.4 (2950)	29.7 (4300)	35.7 (5180)	41.4 (6000)	50	90	506	95.5
	n	28	28	28	28	28	23	28	28
	Spec. limit	≥12.0 (1740)	≥24.0 (3480)	—	—	≥45, ≤375	—	—	—
V	Mean	15.0 (2180)	26.8 (3890)	33.9 (4910)	43.7 (6330)	119	223	397	98.3
	SD	1.7 (253)	2.0 (284)	1.8 (255)	2.3 (333)	16	30	44	0.9
	Maximum	17.9 (2600)	30.4 (4410)	36.7 (5330)	48.4 (7020)	146	271	423	99.2
	Minimum	12.2 (1770)	24.2 (3520)	29.9 (4340)	39.5 (5730)	93	173	250	96.3
	n	13	13	13	13	13	10	14	13
	Spec. limit	—	≥8.0 (1160)	≥15.0 (2180)	≥21.0 (3050)	≥45, ≤375	—	≥260	—

Key: SD=Standard deviation; n= number of values; "Spec limit" is specification limit in ASTM C150/AASHTO M 85; "—" = no limit.

*See Table 1 for groupings of cement types.

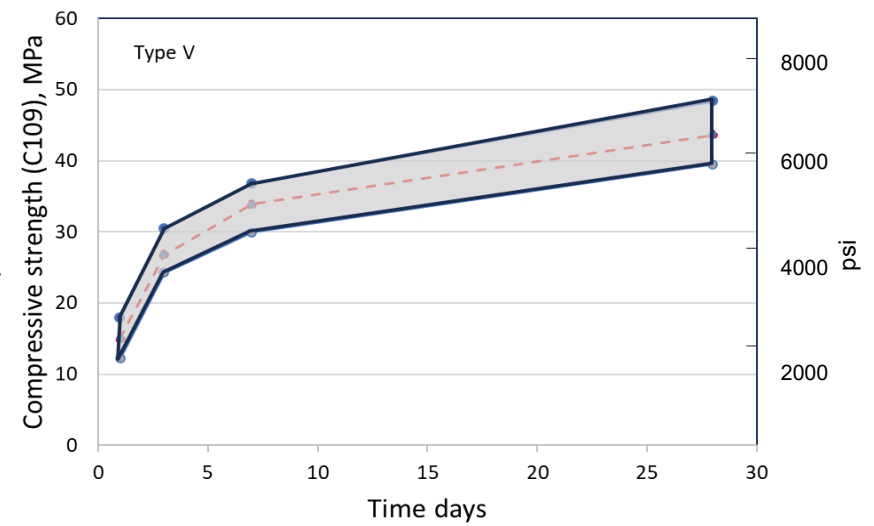
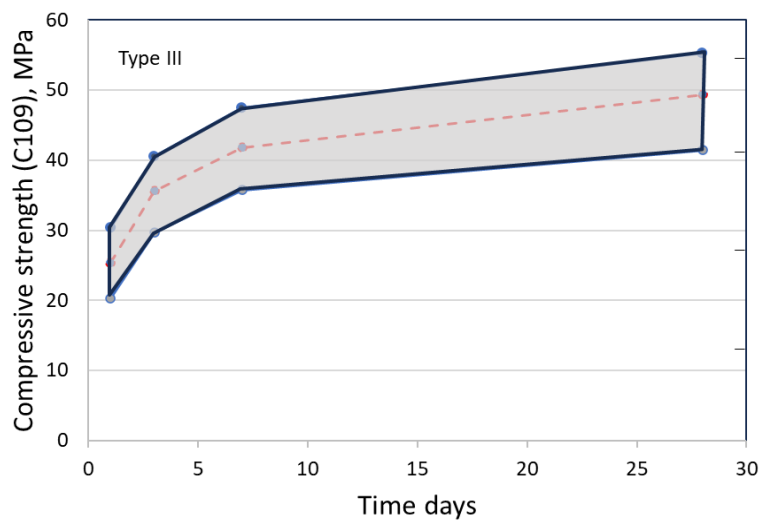
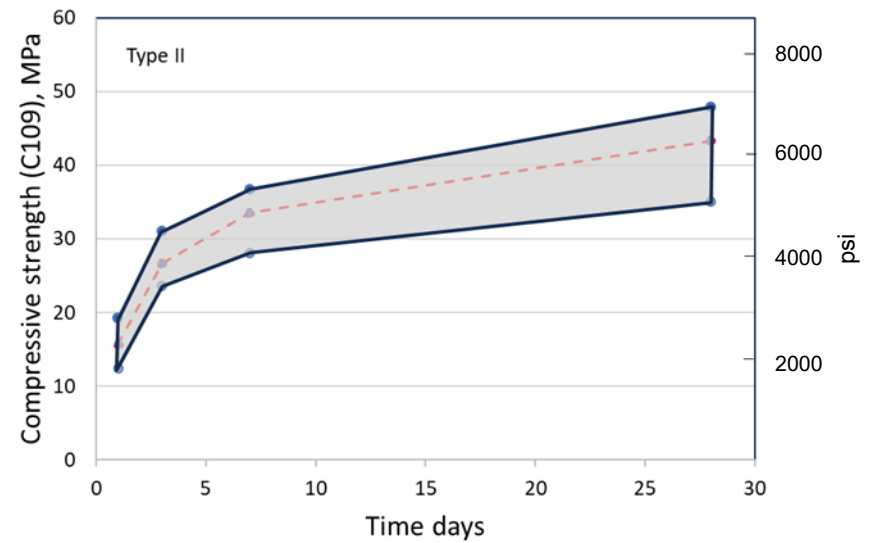
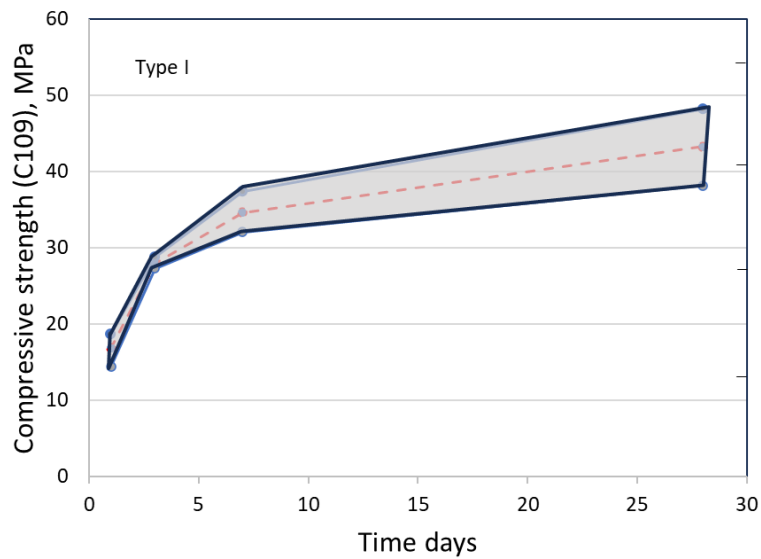


Figure 1. ASTM C109 compressive strengths for portland cements as reported for 2022. Mean values are connected by dashed lines and shaded areas represent ranges of values reported in the survey.

CHARACTERISTICS OF BLENDED CEMENTS (ASTM C595/AASHTO M 240)

Constituent Content and Chemical Characteristics

ASTM C595 and AASHTO M 240 include naming conventions that identify the nominal amount of limestone, slag cement, or pozzolan in the cement. Mean values for cements produced in 2022 according to the survey are: limestone content of Type IL cements, nearly 11%; inorganic processing additions of Type IL cements, 1.4%; and pozzolan content of Type IP cements, about 25%. Table 10 provides summary statistics.

Table 10. Nominal Amount of Constituents in Blended Cements Reported for 2022, % by mass.

Constituent/Cement type	Statistic	Content, % by mass	IPA content, % by mass
Limestone/Type IL	Mean	10.5	1.4
	SD	1.38	0.97
	Maximum	13.5	3.3
	Minimum	8.0	0.0
	n	44	10
	Spec limit	>5 and ≤15	—
Pozzolan/Type IP	Mean	25.1	—
	SD	2.81	—
	Maximum	29.5	—
	Minimum	22.8	—
	n	5	—
	Spec limit	≤40	—

Key: SD = Standard deviation; n = number of values; “Spec limit” = specification limit in ASTM C595/AASHTO M 240.

Table 11 shows chemical characteristics of ASTM C595/AASHTO M 240 blended cements reported for 2022. Data on mean, standard deviation, maximum, minimum, and number of cements represented are reported on the following cement properties (ASTM C114): MgO content, SO₃ content, and loss on ignition (LOI) and insoluble residue (IR).

Table 11. Select Chemical Characteristics Blended Cements Reported for 2022, % by mass.

Cement type*	Statistic	MgO	SO ₃ **	Loss on ignition	Insoluble residue
IL	Mean	2.07	3.12	5.44	0.67
	SD	1.06	0.42	0.73	0.32
	Maximum	4.37	4.38	7.33	1.38
	Minimum	0.55	2.20	4.07	0.06
	n	45	45	45	30
	Spec limit	—	≤3.0*	≤10.0	—
IP	Mean	1.42	2.79	2.47	—
	SD	0.38	0.36	0.48	—
	Maximum	1.98	3.26	3.05	—
	Minimum	1.08	2.39	1.92	—
	n	5	5	4	—
	Spec limit	≤6.0	≤4.0	≤5.0	—

Key: SD = Standard deviation; n= number of values; — = not enough data reported or no limit; “Spec limit” = specification limit in ASTM C595/AASHTO M 240.

*See Table 1 for groupings of cement types.

**Table limit for SO₃ content may be exceeded if C1038 expansion does not exceed 0.020% at 14 days. See ASTM C595-21/AASHTO M 240-21 for complete details.

In 2022, when limestone was used as an ingredient in portland-limestone cements, ASTM C595/AASHTO M 240 required that the limestone have a minimum calcium carbonate (CaCO₃) content of 70% by mass, which was based on the CaO content of the limestone,⁴ multiplied by a stoichiometric factor. Values reported for CaO and MgO content of the limestones used in cement were requested in the survey, and those values are reported in Table 12.

⁴ Although there were no limits involving MgCO₃ in ASTM C595/AASHTO M 240 in 2022, requirements for limestone used in blended cements in 2025 are for a total CaCO₃ and MgCO₃ content of 70% by mass, with a minimum CaCO₃ content of 40% by mass. These limits are based on CaO and MgO contents of the limestone, multiplied by factors of 1.785 and 2.092 respectively.

Table 12. Additional Characteristics Reported for Limestone used in Type IL Cements Reported for 2022.

	CaO content, % by mass	MgO content, % by mass
Mean	50.3	1.6
SD	3.05	1.44
Maximum	54.9	5.3
Minimum	43.1	0.2
n	34	36

Key: SD = Standard deviation; n= number of values.

Physical Properties

Tables 13 and 14 provide physical data of ASTM C595/AASHTO M 240 blended cements received in the 2022 survey. The data on mean, standard deviation, maximum, minimum and number of cements represented are reported for the following cement properties:

- Compressive strength (ASTM C109)
- Setting time (Vicat, ASTM C191)
- Fineness (Blaine, ASTM C204, and No. 325 sieve, ASTM C430)
- Air content (ASTM C185)
- Normal consistency (ASTM C187)
- Autoclave expansion (ASTM C151), and
- Mortar expansion (ASTM C1038).

Figure 2 provides plots of mean C109 compressive strength data for the two blended cement types at 3, 7 and 28 days, as well as the range of values received at those ages. These figures are plotted at the same scale as Fig. 1 to facilitate comparison. In broad terms, these cements show comparable strength development to Type I portland cements. Figure 3 shows air permeability (Blaine) fineness vs. limestone content for Type IL cements. As limestone content increases, there appears to be no statistically significant trend with fineness across cements from multiple plants.

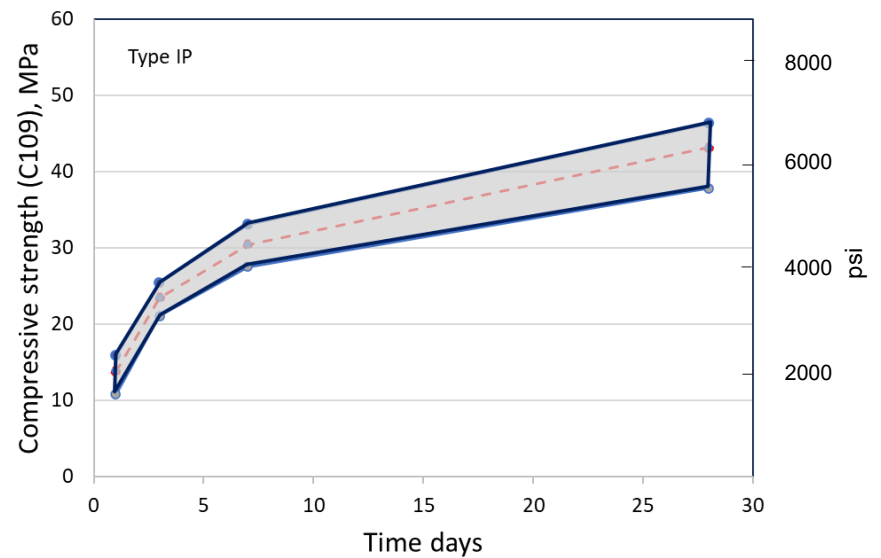
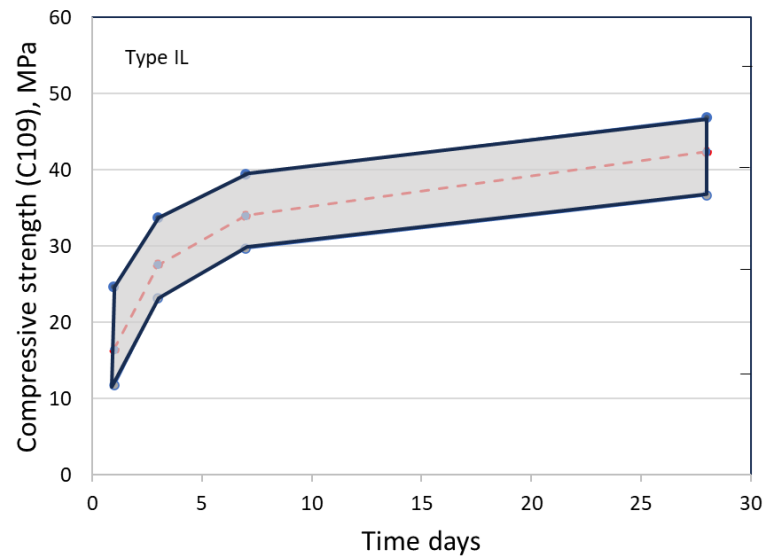


Figure 2. ASTM C109 compressive strengths for blended cements as reported for 2022.
Mean values are connected by dashed lines and shaded areas represent ranges of values reported in the survey.

Table 13. Compressive Strength and Setting Time of Blended Cements Reported for 2022.

Cement type*	Statistic	Compressive strength, MPa (psi)				Setting time (Vicat), minutes	
		1 day	3 days	7 days	28 days	Initial	Final
IL	Mean	16.3 (2370)	27.5 (3990)	34.0 (4920)	42.3 (6140)	113	221
	SD	2.35 (341)	2.24 (325)	2.07 (301)	2.23 (324)	20.0	28.0
	Maximum	24.6 (3570)	33.7 (4890)	39.4 (5710)	46.3 (6710)	165	276
	Minimum	11.7 (1700)	23.2 (3370)	29.7 (4310)	36.7 (5320)	83	160
	n	45	45	45	45	45	39
	Spec limit	—	≥13.0 (1890)	≥20.0 (2900)	≥25.0 (3620)	≥45, ≤420	—
IP	Mean	13.8 (2000)	23.4 (3400)	30.4 (4410)	43.2 (6260)	126	277
	SD	2.20 (319)	2.04 (296)	2.17 (315)	3.53 (512)	16.8	24.4
	Maximum	15.9 (2300)	25.4 (3680)	33.0 (4790)	46.3 (6720)	137	305
	Minimum	10.8 (1560)	21.0 (3050)	27.5 (3990)	37.8 (5480)	101	246
	n	5	5	5	5	4	4
	Spec limit	—	≥13.0 (1890)	≥20.0 (2900)	≥25.0 (3620)	≥45, ≤420	—

Key: SD = Standard deviation; n= number of values; — = no limit; “Spec limit” = specification limit in ASTM C595/AASHTO M 240.

*See Table 1 for groupings of cement types.

Table 14. Other Physical Characteristics of Blended Cements Reported for 2022.

Cement type*	Statistic	Blaine fineness, m ² /kg	Fineness, 45 µm (No. 325) sieve, % passing	Air content, %	Normal consistency, %	Autoclave expansion, %	Mortar expansion, %
IL	Mean	465	96.6	7.4	26.4	0.041	0.006
	SD	39.1	2.54	1.19	1.0	0.050	0.003
	Maximum	546	99.8	9.7	29.2	0.204	0.010
	Minimum	393	89.9	4.4	23.8	-0.025	-0.001
	n	45	45	44	44	38	20
	Spec limit	—	—	≤12	—	≥-0.02, ≤0.80	≤0.020**
IP	Mean	510	98.6	7.2	29.4	-0.021	—
	SD	82.3	0.84	1.99	1.4	0.018	—
	Maximum	577	99.8	8.9	31.1	0.006	—
	Minimum	392	97.5	3.9	28.2	-0.030	—
	n	4	5	5	4	4	—
	Spec limit	—	—	≤12	—	≥-0.02, ≤0.80	≤0.020**

Key: SD = Standard deviation; n= number of values; — = not enough data reported or no limit; “Spec limit” = specification limit in ASTM C595/AASHTO M 240.

*See Table 1 for cement type groupings.

**ASTM C1038 mortar expansion limits only apply if sulfate content exceeds default table limits.

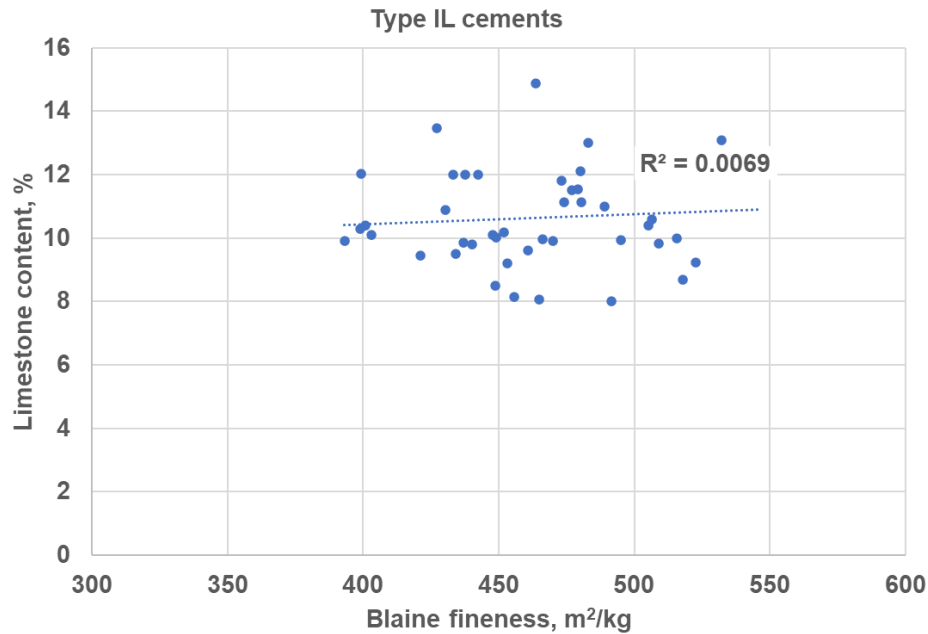


Figure 3. Limestone content vs. ASTM C204 air-permeability (Blaine) fineness for Type IL cements as reported for 2022.

COMPARISON OF HYDRAULIC CEMENTS FOR GENERAL CONCRETE CONSTRUCTION

Physical Properties

Figures 4 through 9 compare properties of hydraulic cements for general concrete construction in the US, as reported in the survey. Respectively, these are setting time (Vicat), air permeability (Blaine) fineness, and compressive strength.

In Figure 4, initial and final Vicat (ASTM C191) setting times for most cements are comparable; initial and final setting times for Type III cements are somewhat shorter than for other hydraulic cement types and the final setting time for Type IP cements is noticeably slower on average. Generally, average initial setting times fall between 100 minutes and 125 minutes and final setting times fall between 215 minutes and 225 minutes.

Figure 5 provides a comparison of ASTM C204 Blaine fineness for the portland and blended cements reported in the survey. ASTM C204 notes that the values determined from the Blaine air-permeability apparatus represent relative rather than absolute fineness values and recommends that users exercise judgment when measuring fineness of cements with different densities or porosities than the standard portland cement reference materials. Blaine fineness values for Type I, II, and V cements are very close to each other, around 400 m²/kg. Both blended cement types reported in the survey, Type IL and Type IP, have higher average fineness of 465 m²/kg and 510 m²/kg, respectively. As expected, Type III cements have the highest

average fineness at 570 m²/kg. As shown by the error bars, Type V portland cements may run slightly coarser than Types I and II, and the blended cements are most often finer than Types I, II, and V portland cements but generally not as fine as Type III portland cements.

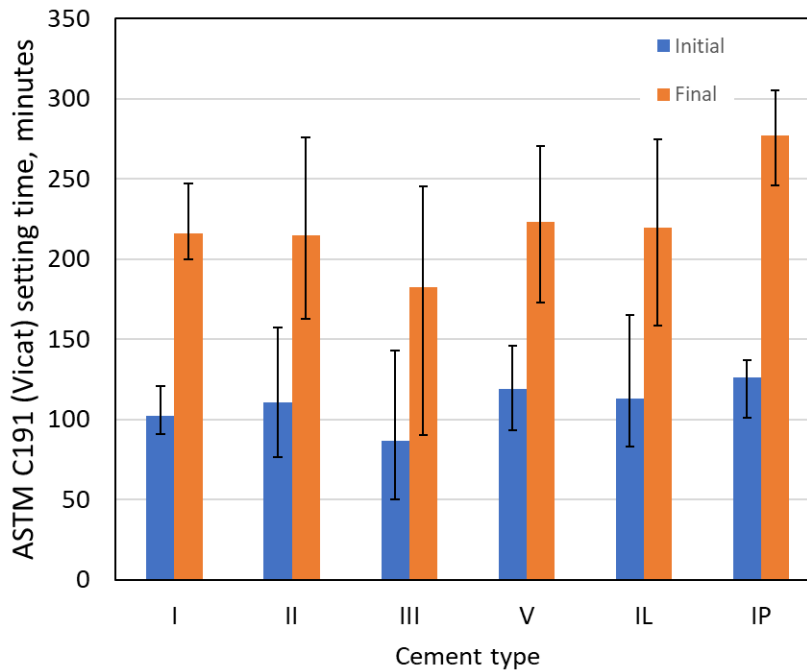


Figure 4. Mean ASTM C191 setting times (Vicat method) for hydraulic cements reported for 2022. Error bars indicate the range of reported values.

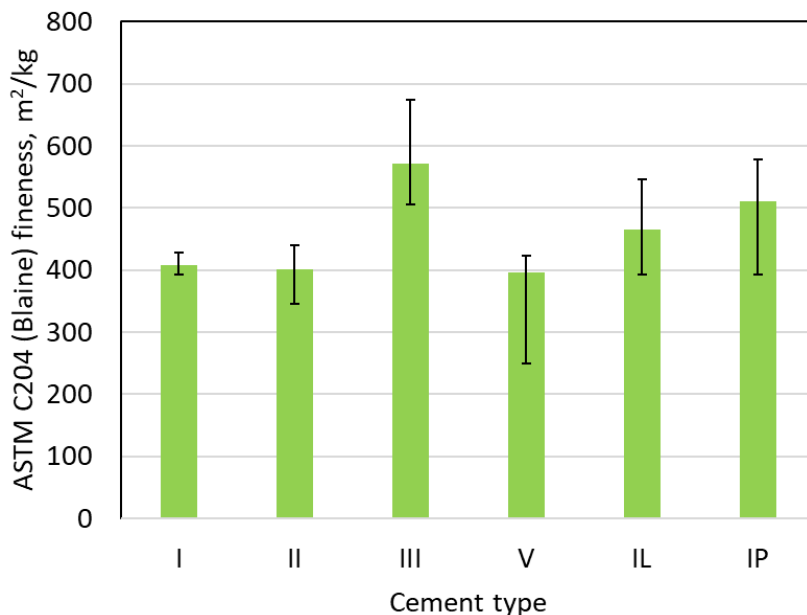


Figure 5. Mean ASTM C204 air-permeability (Blaine) fineness of hydraulic cements reported for 2022 for general concrete construction. Error bars indicate the range of reported values.

As shown in Figure 6, compressive strength levels for portland and blended cements are generally comparable at 1, 3, 7, and 28 days, except those for Type III cement, which are higher than other cements at each age through 28 days. All cement types average over 40 MPa (5800 psi) at 28 days. Figure 7 illustrates that Types I, II, V, and IL all have nearly equivalent strength development at each age. Type III follows a similar strength development curve, though shifted higher than the others by about 6 to 8 MPa (about 800 to 1200 psi). Type IP cements gain strength more slowly, with strength about 3 to 4 MPa (about 400 to 600 psi) less than Types I/II/V/IL cements at ages of 1, 3, and 7 days, but by 28 days, have similar strength to all but Type III cements. The slightly steeper slope for the strength of Type IP cements vs. time between 7 days and 28 days implies that their ultimate strengths will continue to increase to be close to or higher than that of Type III with continued curing.

Comparable early strength development properties for the various cement types are somewhat expected because these cements are all used for similar concrete applications. One factor that may complicate direct strength comparisons between portland and blended cements is that ASTM C109 specifies a mortar with a water:cement ratio 0.485 for portland and portland-limestone cements, whereas mortars made with other blended cements are proportioned with a water content to produce a flow of 110 ± 5 (via ASTM C1457).

Figures 8 and 9 show air-permeability (Blaine) fineness vs. 1-day, 3-day, 7-day, and 28-day strengths for Type II and Type IL cements. For both types of cements, increased fineness has very little effect on strength and the trend is relatively flat. For Type II cements, there is a slight decrease in strength with increased fineness at 28 days. For Type IL cements, as the fineness increases, strength only slightly increases, and at 28 days, there is almost no difference in strength based on fineness.

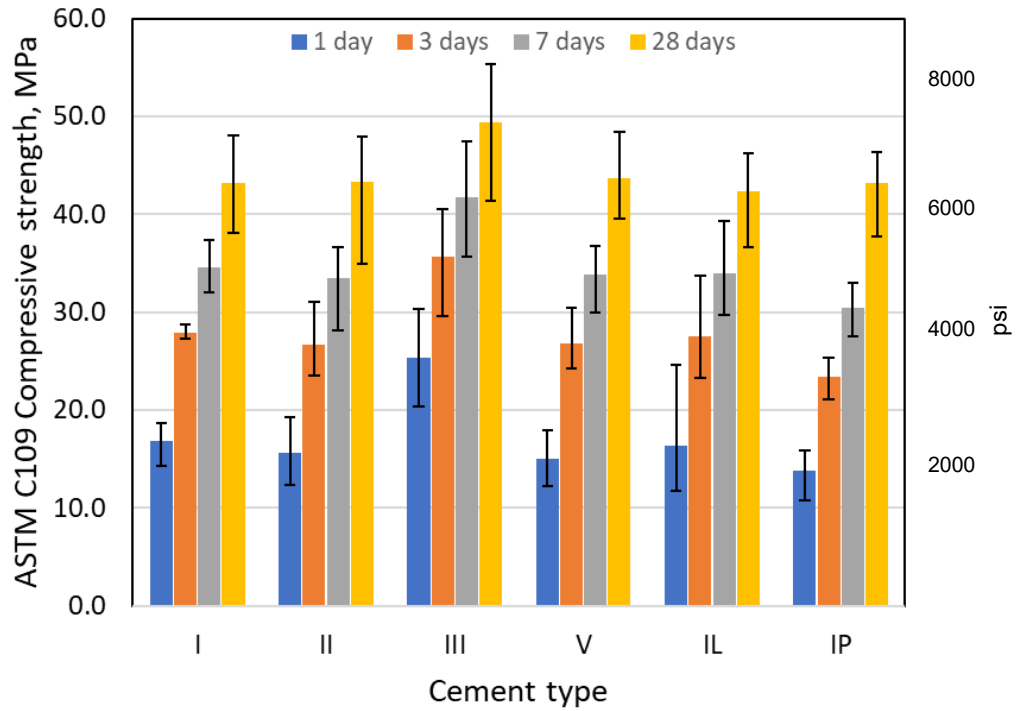


Figure 6. Mean ASTM C109 compressive strengths of hydraulic cements for general concrete construction as reported for cements produced in 2022. In this figure, error bars represent the range of reported values for each cement type at each age. Type IP cements are tested at a fixed flow rather than a fixed water-cement ratio, which complicates direct strength comparisons with other cements.

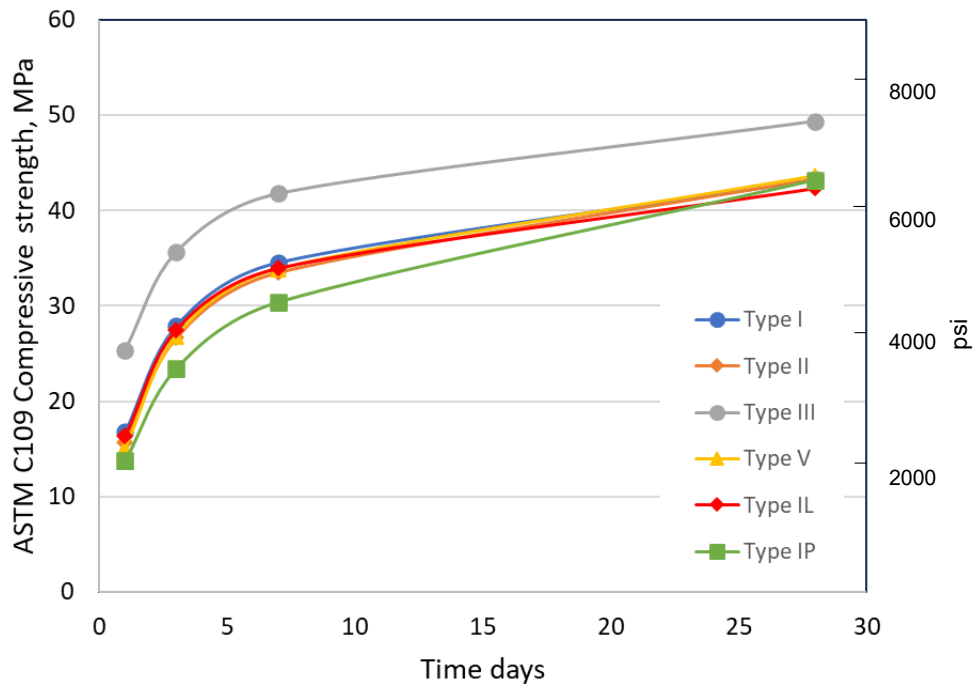


Figure 7. Mean ASTM C109 compressive strength development of hydraulic cements for general concrete construction as reported for 2022.

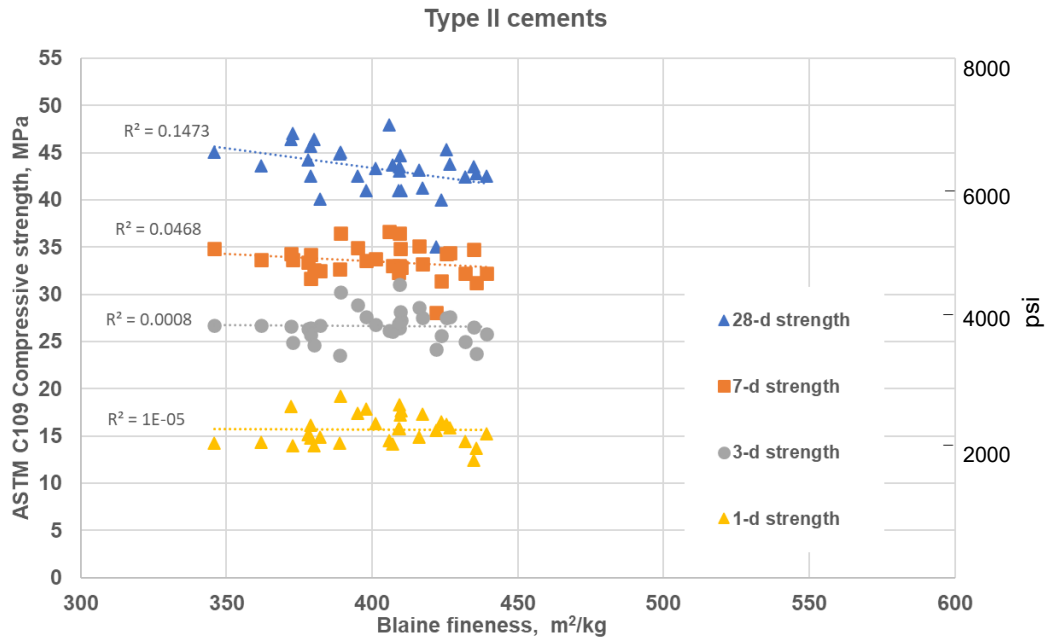


Figure 8. ASTM C109 compressive strengths vs. ASTM C204 air-permeability (Blaine) fineness for Type II cements as reported for 2022.

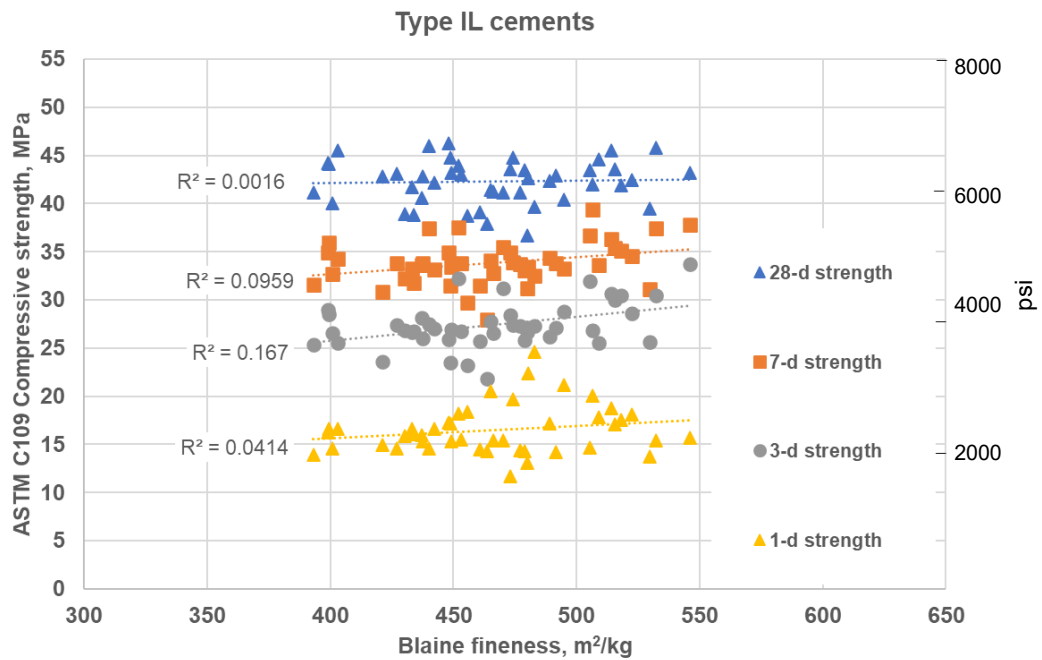


Figure 9. ASTM C109 compressive strengths vs. ASTM C204 air-permeability (Blaine) fineness for Type IL cements as reported for 2022.

CHARACTERISTICS OF MASONRY CEMENTS (ASTM C91)

Physical Properties

Table 15 is a summary of physical data for ASTM C91 cements reported in the 2023 survey. The data are reported on the following properties of cements:

- Compressive strength (ASTM C109, using mortars defined in C91)
- Setting time (Gillmore, ASTM C266)
- Air content (ASTM C185)
- Water retention (ASTM C1506)
- Autoclave expansion (soundness) (ASTM C151), and Fineness by 45- μ m (No. 325) sieve (ASTM C430).

Strengths for masonry cements, on average, follow the following progression: $N < S < M$, which follows the order of increasing strength requirements in ASTM C91. Mean 7-day strengths are approximately 80% of their 28-d values for all 3 cement types. Setting times show Type N setting slightly faster on average, followed by Type S and Type M. However, it should be noted that there is a range of setting times for each cement type that overlaps the other types somewhat. Figures 10 and 11 provide a graphical summary of the strengths and setting times, respectively.

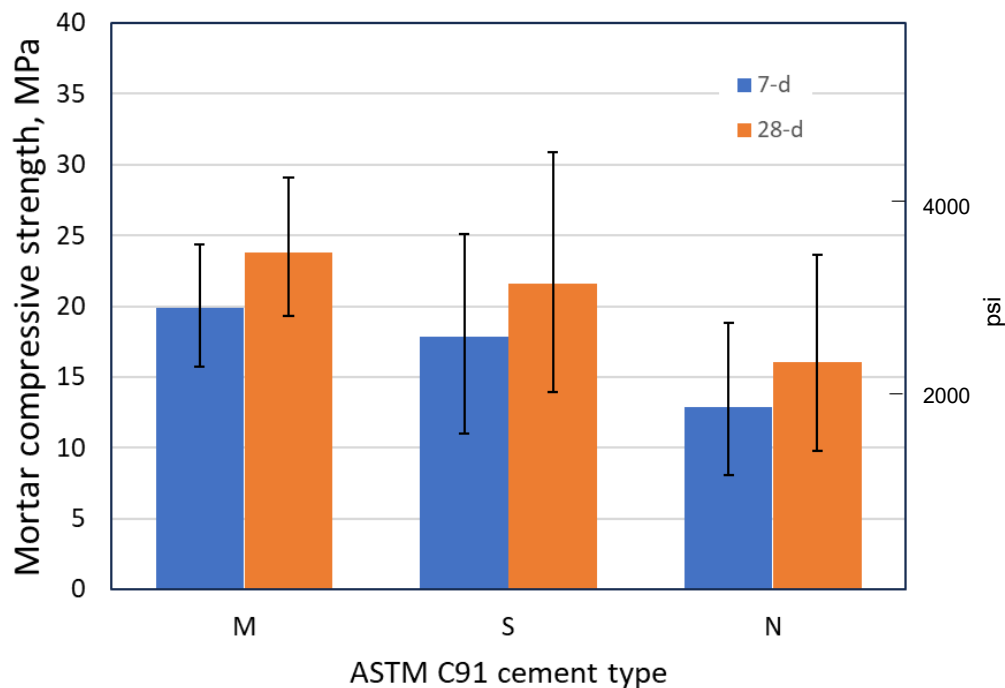


Figure 10. Mean ASTM C109 compressive strengths of ASTM C91 masonry cements as reported for 2022. Error bars indicate the range of values reported in the survey.

Table 15. Physical Data for ASTM C91 Masonry Cements Reported for 2022.

Cement type*	Statistic	Compressive strength, MPa (psi)		Setting time (Gillmore), min		Air content, %	Water retention, %	Autoclave expansion, %	Fineness, 45 µm (No. 325) sieve, % retained
		7-day	28-day	Initial	Final				
M	Mean	19.9 (2880)	23.8 (3450)	224	339	15.6	85.4	0.051	2.8
	SD	2.90 (421)	2.52 (365)	70	104	1.4	6.2	0.054	1.68
	Maximum	24.4 (3530)	29.0 (4210)	342	534	17.7	94.6	0.119	5.1
	Minimum	15.7 (2280)	19.3 (2800)	138	202	13.3	78.0	-0.011	0.2
	n	9	9	8	7	9	9	7	9
	Spec limit**	≥12.4 (1800)	≥20.0 (2900)	≥90, ≤1000	—	≥8, ≤19	≥70	≤1.0	≤24
S	Mean	17.9 (2590)	21.6 (3240)	215	318	15.7	84.1	0.043	3.2
	SD	3.36 (488)	3.73 (542)	70	76	1.2	5.1	0.052	2.27
	Maximum	25.1 (3650)	30.9 (4480)	398	543	18.8	95.1	0.172	8.4
	Minimum	11.0 (1590)	14.0 (2030)	130	205	13.5	76.2	-0.050	0.2
	n	26	26	23	19	26	21	18	25
	Spec limit**	≥9.0 (1300)	≥14.5 (2100)	≥90, ≤1000	—	≥8, ≤19	≥70	≤1.0	≤24
N	Mean	12.9 (1870)	16.1 (2330)	203	323	17.2	85.0	0.031	4.0
	SD	3.81 (553)	4.60 (668)	67	89	1.6	4.6	0.041	2.49
	Maximum	18.8 (2730)	23.7 (3430)	357	542	19.1	95.0	0.104	9.7
	Minimum	8.1 (1170)	9.8 (1420)	140	205	14.2	76.8	-0.011	0.2
	n	14	14	14	13	14	13	10	14
	Spec limit**	≥3.4 (500)	≥6.2 (900)	≥120, ≤1000	—	≥8, ≤21	≥70	≤1.0	≤24

Key: SD = Standard deviation; n= number of values; — = no limit; "Spec limit" = specification limit.

*See Table 1 for cement type groupings.

**See ASTM C91/C91M-18 for complete details.

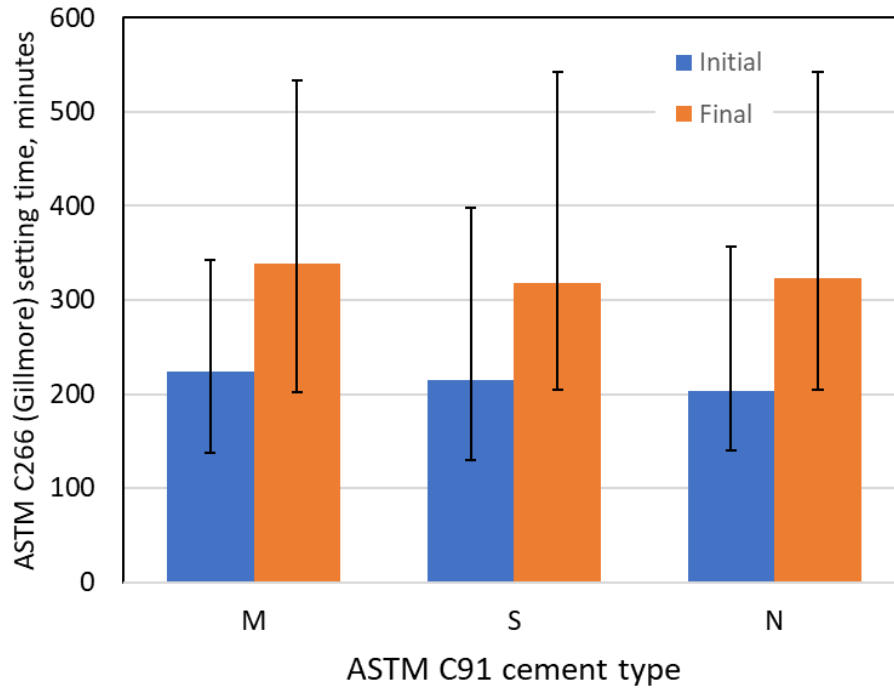


Figure 11. Mean ASTM C266 Gillmore setting times of ASTM C91 masonry cements as reported for 2022. Error bars indicate the range of values reported in the survey.

CHARACTERISTICS OF PLASTIC (STUCCO) CEMENTS (ASTM C1328)

Although data is available for only a limited number of plastic (stucco) cements, physical data for these ASTM C1328 cements reported for 2022 are given in Table 16. Summary data are reported as mean, standard deviation, maximum, minimum, and number of cements for the following properties:

- Compressive strength (ASTM C109)
- Setting times (Gillmore, ASTM C266)
- Autoclave expansion (ASTM C151)
- Water retention (C1506)
- Air content (ASTM C185), and
- Fineness (ASTM C430)

Table 16. Physical Data for ASTM C1328 Plastic (Stucco) Cements Reported for 2022.

Cement type*	Statistic	Compressive strength, MPa (psi)		Setting time (Gillmore), minutes		Autoclave expansion, %	Water retention, %	Air content, %	Fineness, 45 µm (No. 325) sieve, % retained
		7-day	28-day	Initial	Final				
S	Mean	19.8 (2870)	24.4 (3540)	179	286	0.118	83.2	16.3	2.2
	SD	4.8 (702)	5.2 (760)	38	58	0.256	4.75	1.95	0.61
	Maximum	25.7 (3730)	30.3 (4390)	229	342	0.576	89.9	18.8	2.9
	Minimum	15.0 (2170)	18.5 (2690)	131	198	-0.006	76.1	13.4	1.4
	n	0	6	5	5	5	6	6	6
	Spec limit	≥9.0 (1300)	≥14.5 (2100)	≥90, ≤1000	—	≤1.0	≥70	≥8, ≤20	≤24

Key: SD = Standard deviation; n= number of values; — = no limit or not enough data; “Spec limit” = specification limit.

*See Table 1 for cement type groupings.

CONCLUSIONS

This report summarizes mean values for cement characteristics obtained in a 2023 survey of hydraulic cements in the US, which requested yearly average data for cements produced in 2022 under ASTM C150/AASHTO M 85 (portland cements), ASTM C595/AASHTO M 240 (blended hydraulic cements), ASTM C1157 (hydraulic cements), ASTM C91 (masonry cements), ASTM C1328 (plastic (stucco) cements), and ASTM C1329 (mortar cements). Data for 192 cements were provided by 57 plants, representing about 60% of active U.S. plants in 2022. No data was received for ASTM C1329 cements.

As seen in Table 1, while the four types of portland cement represent 82 products and the blended cement category has 53 products, the single most common type of cement produced in the U.S. in 2022 was Type IL blended cement with 47 products reported by survey respondents. The next most common cement type was Type II portland cement, with 31 of those products made in 2022. Of the 57 plants reporting data for this survey, 53 made at least one portland cement product, and 48 made at least one blended cement product. Data reported by the USGS (Hatfield 2024) indicate that, by production volume, portland cement was still the most common type of cement in 2022 at about 69% of production, blended cements were the next most common types of cement at about 28% of production, and masonry cements represented the next most common types of cement at about 3% of production.

The data on blended cements produced to meet ASTM C595/AASHTO M 240 indicate broadly similar setting times and strength development characteristics as Types I, II, and V portland cements. Type III cements set slightly faster and generate higher strengths through 28

days, while Type IP cements set slightly slower and lag strength development compared to Types I, II, and V until about 28 days.

Data on cements for masonry are provided for 49 cements produced to meet ASTM C91, with C1328 cements being less commonly produced. In 2022, the average strength of Type S masonry cement reported was similar to the average strength of Type S reported for 2014, whereas the average strength of Type M masonry cement was slightly lower and the average strength of Type N masonry cement was slightly higher, meaning that the three types of cement had more similar strength development than the masonry cements of 2014. Similarly, both initial and final setting times for all three types of masonry cements in 2022 were also closer together than they were in 2014.

ACKNOWLEDGEMENTS

This research report (PCA R&D SN3354) reflects the views of the author, who is responsible for the facts and accuracy of the data presented. The contents do not necessarily reflect the views of the Portland Cement Association. The author would like to thank Emily McCarthy of PCA's Market Intelligence group for assistance in conducting the survey.

REFERENCES

ASTM International standards referenced in this text can be found at www.astm.org and AASHTO standards can be located at www.bookstore.transportation.org.

ACI Committee 225, "Removal of Optional Alkali Limit in Standard Specifications for Portland Cement," ACI 225.1T-20 TechNote, American Concrete Institute, Farmington Hills, Michigan, 2020, 3 pages.

Bhatty, J. I. and Tennis, P. D., *US and Canadian Cement Characteristics: 2004*, R&D SN2879, Portland Cement Association, Skokie, Illinois, USA, 2008, 67 pages, http://www2.cement.org/pdf_files/SN2879.pdf.

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, <https://ia600307.us.archive.org/22/items/interrelationsbe36clif/interrelationsbe36clif.pdf>.

Gebhardt, R. F., "Survey of North American Portland Cements: 1994," *Cement, Concrete, and Aggregates*, December 1995, pages 145 to 189. <https://doi.org/10.1520/CCA10140J>

Hatfield, Ashley K. "Cement," Tables 12 & 15 in 2022 Minerals Yearbook Tables-Only Advance Release, U.S. Geological Survey, June 2024, 22 Tables, <https://view.officeapps.live.com/op/view.aspx?src=https%3A%2F%2Fd9-wret.s3.us-west-2.amazonaws.com%2Fassets%2Fpalladium%2Fproduction%2Fs3fs->

[public%2Fmedia%2Ffiles%2Fmyb1-2022-cemen-ert.xlsx&wdOrigin=BROWSELINK](#).

Additional data and updates available at:

<http://minerals.usgs.gov/minerals/pubs/commodity/cement/>.

Tennis, P. D., “Portland Cement Characteristics —1998,” *Concrete Technology Today*, Vol. 2, No. 2, PL992, Portland Cement Association (PCA), Skokie, Illinois, USA, August 1999, pages 1 to 4, http://www2.cement.org/pdf_files/PL992.pdf.

Tennis, P. D. and Bhatti, J. I., “Portland Cement Characteristics — 2004,” *Concrete Technology Today*, Vol. 26, No. 3, CT053, Portland Cement Association (PCA), Skokie, Illinois, USA, December 2005, pages 1 to 3,
<https://1121.sydneyplus.com/PCA/Portal/Default.aspx?component=AAAAIY&record=96eb1107-33cd-42f9-91a2-560f2d9d63f9>

Tennis, P. D., *Chemical and Physical Characteristics of US Cements: 2014*, R&D SN3284, Portland Cement Association, Skokie, Illinois, USA, 2016, 32 pages,
http://www.cement.org/pdf_files/SN3284.pdf.