Cement and Concrete Research 78 (2015) 165–177

Contents lists available at ScienceDirect

Cement and Concrete Research

journal homepage: http://ees.elsevier.com/CEMCON/default.asp

Current developments and future needs in standards for cementitious materials

R. Douglas Hooton

University of Toronto, Dept. of Civil Engineering, Toronto, ON M5S1A4, Canada

ARTICLE INFO

Article history:
Received 9 March 2015
Accepted 18 May 2015
Available online 29 July 2015

Keywords:
Portland cement (D)
Fly ash (D)
Slag
Alkali-activated cement (D)
Admixtures (D)

ABSTRACT

Globally, test methods and requirements in portland cement specifications are very similar and, while suitable as manufacturing standards, in many respects they do not address the needs of the concrete producer. Cement is only one ingredient in the cement paste matrix that binds concrete, and all paste matrix components (such as pozzolans, slags, ground limestone and chemical admixtures), influence concrete performance. Recent developments in standards for cementitious materials are reviewed. In addition, new types of binders are being developed and used for making concrete, and current test methods cited in specifications are not often directly suitable for use in their evaluation. Thus, modified or completely new test methods may be needed. Due to limited experience with field performance, new specifications for novel materials also need to address more than the limits on setting time and strength development found in current cement standards. Issues related to developing new standards are discussed.

Contents

E-mail address: hooton@civ.utoronto.ca.

http://dx.doi.org/10.1016/j.cemconres.2015.05.022
0008-8846/

Table 1A
Chemical limits for portland cement in various specifications.

Chemical limits	Version	Cement type	MgO	LOI	Insol. res.	SO_3	Chloride	CO_2	Eq. alkali	MAC
Standard			max. %	max. %	max. %	max. %	max. %	max. %	max. %	max. %
ASTM C150	2012	Type I	6.0	3.0	0.75	3.0 if $C_3A \le 8\%$[a] 3.5 if $C_3A > 8\%$[a]				5
Canada CSA A3001	2013	Type GU	5.0	3.0[b]	1.5	3.0 if $C_3A \le 8\%$[a] 3.5 if $C_3A > 8\%$[a]				5
Europe EN197	2011	CEM I 42.5 N		5.0	5.0	3.50%	0.10			5
Australia AS3972	2010	Type GP	4.5			3.5	0.10			7.5
New Zealand NZS1322	2009	Type GP	4.5	(Report only)		3.5	(Report only)			10
China GB 175-2007	2007	PO 42.5	5.0[c]	5.0	0.75	3.5	0.06			
Japan JIS R 5210	2009	N	5.0	5.0		3.5	0.035		0.75	
Brazil NPR5732		CP I-40	6.5	2.0	1.0	4.0		1.0		
Russia GOST 30515-97		M500	5.0			4.0	0.10			

[a] Limit can be exceeded if ASTM C1038 (or CSA A3004-C6) mortar bars in water ≤ 0.020% at 14 days.
[b] Limit is raised to 3.5% if LOI at 550 °C is <3.0%.
[c] MgO allowed up to 6.0% if passes autoclave test.

1. Introduction

As stated in a previous review [1], cement standards have evolved from relatively simple requirements in the early 20th century, typically based on measurements of setting time, strengths at different ages, volume stability as well as prescriptive limits on chemical components. Minimum specifications are set for materials such as portland and blended hydraulic cements, and standard test methods are used to determine compliance with specification limits. While test methods and test limits have changed during this evolution, the basic properties are still the same, namely that setting time, strength development and heat evolution are reasonably uniform and that there is good volume stability. With the development of different types of binders for concretes, the current specifications are likely not sufficient. At the very least, many of the test methods used in these specifications either need to be modified or replacements sought in order to adequately assess novel binder materials.

This contribution is not meant to be a comprehensive review of standards, but attempts to explain the need for alternative standards and to identify future needs. While much of the discussion is from a North American perspective, most of the issues are relevant in the global context.

2. Current standards

2.1. Current standards for portland cement

Most of the global standard requirements for portland cement are very similar and are primarily manufacturing standards. While details of test methods and test limits differ between standards, similar properties are being measured. This is shown in Tables 1A, 1B, and 1C for several major standards (note that these values were obtained from various sources and some may not be up to date). For this comparison, ordinary portland cement with a mid-strength range was selected from the different types available in a given standard (e.g. EN197 CEM I 42.5). It should be noted that ASTM C150 is currently considering changing its insoluble residue and LOI limits to match those in the Canadian standard, CSA A3001 [2], as shown in Table 1A. This change is required to allow for maximizing the 5% MAC. In 2015, the ASTM C150 *Specification for Portland Cement* [3] approved the addition of a 0.10% chloride limit, matching the value in EN197 [4].

As a method of reducing the clinker content of cement, and hence the greenhouse gas emissions associated with clinker production, almost all portland cement standards allow 5% interground limestone or other minor additional components (MAC) in addition to calcium sulfate. In addition, many countries, led by Europe, have adopted portland–limestone cements, with higher contents of interground limestone. EN197 [4] has CEM II/A-L cements with 6–20% limestone and CEM II/B-L cements with 21–35% limestone, in addition to composite cements (CEM II/A-M and II/B-M) with combinations of limestone and fly ash or slag of the same replacement levels. Since 2008, the Canadian standard CSA A3001 [2] adopted a new class of portland–limestone cements with 6–15% limestone, and ASTM C595 and AASHTO M240 blended cement specifications adopted similar Type IL cements in 2012. In these North American standards, the limestone cements have to meet the same time-of-set and strength development as portland cement. The Australian standard AS3972 adopted Type GL cements with 8–20% limestone in 2010. In New Zealand, NZS 3125 includes portland–limestone filler cements with up to 15% limestone. In China, GB 175-2007 allows ordinary portland cement to contain up to 15% filler with 5% of that filler allowed to be cement kiln dust. South Africa adopted EN197 cement standards in 2002 [5].

Table 1B
Physical limits for portland cement in various specifications.

Physical limits	Version	Cement type	Mortar air content	Blaine	Retained on 45 μm	Autoclave exp'n.	Pat test over boiling water[a]	Le Chatelier soundness	Time of set (Vicat)	
Standard			max. %	min. m^2/kg	max. %	max. %		max. mm	min. (min)	max. (min)
ASTM C150	2012	Type I	12	260	NA	0.8		NA	45	375
Canada CSA A3001	2013	Type GU			28	1.0		NA	45	375
Europe EN197	2011	CEM I 42.5N						10	>60	NA
Australia AS3972	2010	GP						5	45	360
New Zealand NZS1322	2009	Type GP						5	45	360
China GB 175-2007	2007	PO. 42.5					No cracks or bending	5	45	600
Japan JIS R 5210	2009	N		250			No cracks or bending	10	60	600
Brazil NPR5732		CP I-40						5	60	600
Russia GOST 30515-97		M500							45	120

[a] ASTM C189-49 Method of test for soundness of hydraulic cement over boiling water (pat test) of portland cement (withdrawn 1956).