Has the Adoption of the European Cement Specification (EN 197) Improved Cement Consistency in South Africa?

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1. Abstract.

In 1996, South Africa adopted the European Cement Specification (EN 197) and discontinued the specifications under which cement previously had been manufactured. These were based on British specifications (BS 12) which had a minimum requirement for strength at 3 and 7 days, using a water/cement ratio of 0.4. The European specification has early age strength hurdles with statistically-determined upper and lower control limits for standard (28-day) strength determinations. A water/cement ratio of 0.5 is used in the strength determination. An analysis was conducted on cements produced at specific factories, measuring the strength performance for the ten years prior to the change against the ten years after the adoption of the new standard. Assumptions were made on the strength classes in order to do the comparison. The results are inconclusive in that the performance and consistency of cements from some factories have improved, while in other cases it has deteriorated.

2. Introduction.

The four clinker manufacturers in South Africa are Pretoria Portland Cement Company Limited (PPC), Lafarge South Africa, Holcim South Africa and Natal Portland Cement (a wholly owned subsidiary of Cimpor).

Prior to 1996 South Africa manufactured cement under four specifications:

SABS 471-1971:	Portland cement (ordinary, rapid-hardening and sulphate-resisting) [1].
SABS 831-1971:	Portland cement 15 (ordinary and rapid-hardening) [2].
SABS 626-1971:	Portland blastfurnace cement [3].
SABS 1466-1988:	Portland fly ash cement [4].

The requirements of these specifications are summarized in Appendix 1.

After 1996, these four specifications were replaced with the European Specification ENV 197-1: Composition, specifications and conformity criteria for common cements, ENV 197-2: Conformity evaluation, and EN 413: Masonry Cement. These were replaced in 2000 with SANS 50197-1:2000 Cement Part 1 and SANS 50197-2:2000 Part 2; and SANS 50413-1:2004 Masonry Cement Part 1[5, 6, 7]. The cement composition specification for SANS 50197 is summarised in Appendix 2.

During the period 1985 to 2005, certain manufacturing facilities were decommissioned while others were commissioned by the various producers. Only data of products from plants which have been in operation over the 20 years under review was considered. The data sets for all the plants consisted of test results for the 42,5N strength class (OPC and the equivalent CEM I product).

3. Research method.

The Cement and Concrete Institute (C&CI), previously known as the Portland Cement Institute, is an organization funded by the cement industry to promote the use of concrete. C&CI had a fully equipped testing laboratory where concrete tests as well as cement mortar tests could be performed until recently.

Each of the cement manufacturing plants submitted representative samples of OPC (SABS 471 prior to 1996) and CEM I (EN 197-1 after 1996) to the C&CI on a monthly basis. During the period 1985 to 1996 OPC only was tested. After 1996 other cements types manufactured to EN 197-1specifications were also submitted for testing.

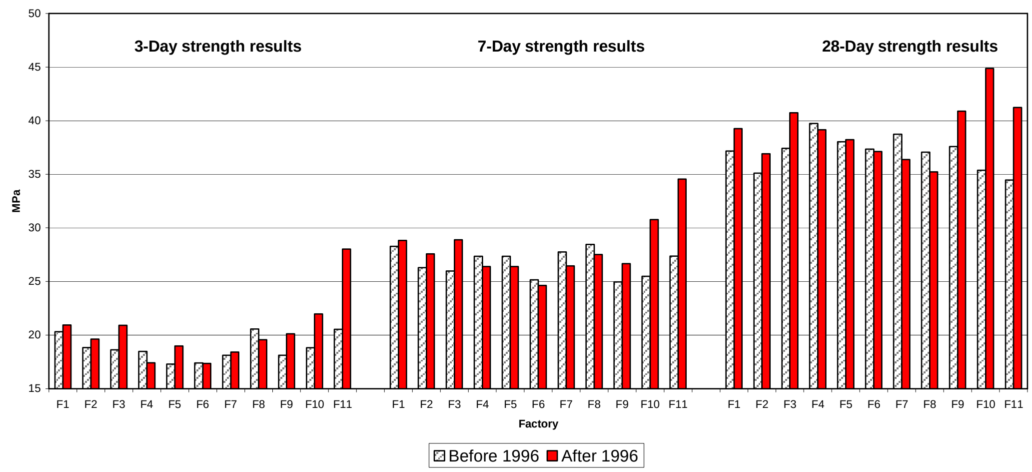
The cement was tested according to the mortar cube test prior to 1996, or the mortar prism test (EN 196-1 Methods of testing cement. Part 1: Determination of strength) after 1996, and a concrete cube test based on the British Standards BS 12 method. The mortar cube test used a water/cement ratio of 0.4 and the mortar prism test a water/cement ratio of 0.5. No comparison was thus possible using the mortar cube and prism test methods. The BS 12 concrete test uses a water/cement ratio of 0.6, and the comparative analysis was therefore done using these results.

4. Results and Discussion.

Prior to 1996 the cement industry operated as an acknowledged cartel with defined market share. Strength performance aims of cements based on the mortar cube test, were agreed upon centrally by the producers. The South African Cement Producers Association (SACPA) was dissolved in 1994 after price collusion was banned in South Africa [8].

The introduction of the new specification led to the production of a number of different cement types. Producers competed for market share and modified product performance in response to market demands. The difference in mean values for the strength performance is shown for the different periods (Figure 1).

Figure 1. Concrete compressive strength performance (BS12) before and after the adoption of the EN 197 standard in 1996 (Strength Class 42,4N –OPC/CEM I).



The number of observations in most data sets exceeded 30, and was normally distributed. Different factories were denoted F1 to F11. Statistical t-tests were done to compare data sets for significant differences in the mean values before and after the adoption of the standard. The means were compared at 3, 7 and 28-day compressive strength. The results are summarized in Table 1.

Table 1: Summary of t-test results:

(H_o hypothesis – There is no significant difference between the means of the “before” and “after” data sets)

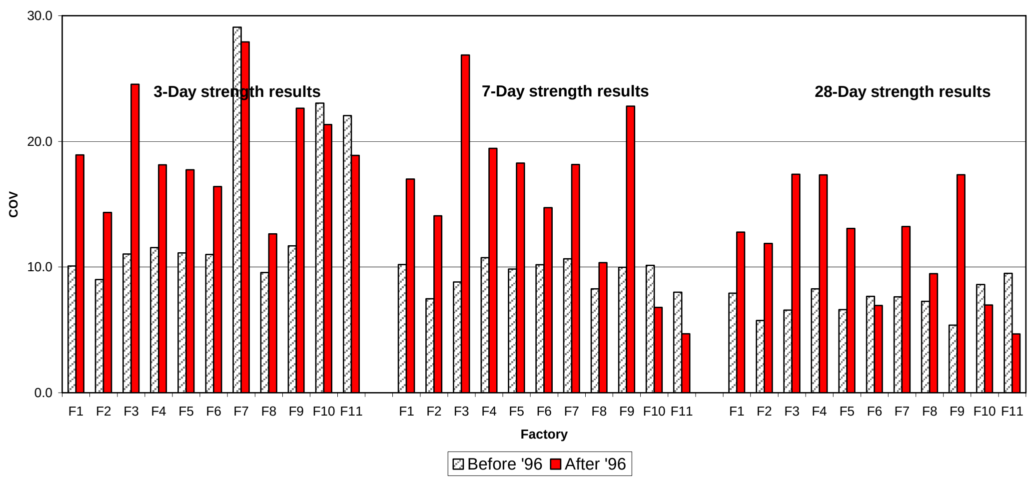
Factory	3 day	7 day	28 day
F1	Not rejected	Not rejected	Rejected
F2	Rejected	Rejected	Rejected
F3	Rejected	Rejected	Rejected
F4	Rejected	Not rejected	Not rejected
F5	Rejected	Not rejected	Not rejected
F6	Not rejected	Not rejected	Not rejected
F7	Not rejected	Rejected	Rejected
F8	Rejected	Rejected	Rejected
F9	Rejected	Rejected	Rejected
F10	Rejected	Rejected	Rejected
F11	Rejected	Rejected	Rejected

At 3-days, eight plants have significantly different means, at 7-days, seven plants have significantly different means and at 28-days, eight plants have significantly different means. This indicates that the performance of the products changed after the EN 197-1 specification was introduced, with the introduction of cement types and accompanying changes in composition. The changes were driven by different marketing strategies and production cost reduction.

The analysis of variance was done using the Coefficient of Variation (COV), for the “before” and “after” periods. The COV will be influenced by changes in the mean values over the period under investigation. The COV was calculated assuming random variation and are shown in Figure 2.

What is immediately apparent is the significant increase in COV after 1996. The assumption that there was no change in performance targets in the “after” period was tested by evaluating individual factory results. The apparent changes in mean values could be explained by a change in the classification of the CEM I product strength class. Initially the OPC or CEM I replacement was classified as a CEM I 32,5N and then changed to a CEM I 42,5N. This introduced a deliberate change in mean values and increased the COV.

Figure 2. Concrete (BS12 compressive strength) COV before and after the adoption of the EN 197 standard in 1996 (Strength Class 42,4N –OPC/CEM I)



5. Conclusion

The adoption of the new specifications allowed the South African cement producers to increase the number of products to allow optimization of product composition and production processes. In the period following the adoption of the new standard, a number of changes were introduced to most products, which are noticeable as distinct sub-sets of data in the "after" period. When the data for the period after 1996 is treated as a single data set there was an apparent increase in variance. Because of the number of variables that influenced the strength performance and consistency, it is not possible to conclude that the new standard had a positive influence on the strength performance and consistency of the cement products in concrete.

6. References

[1] South African Bureau of Standards. SABS 471–1971: Portland cement (ordinary, rapid hardening, and sulphate resisting), Pretoria, South Africa.

[2] South African Bureau of Standards. SABS 831–1971: Portland cement 15 (ordinary and rapid-hardening), Pretoria, South Africa.

[3] South African Bureau of Standards. SABS 626–1971: Portland Blastfurnace cement, Pretoria, South Africa.

[4] SABS 1466 – 1988: Portland fly ash cement, Pretoria, South Africa.

[5] South African Bureau of Standards (2000) SANS 50197-1:2000/ EN 197-1:2000: Cement Part 1: Composition, specifications and conformity criteria for common cements. Pretoria, South Africa.
[6] South African Bureau of Standards (2000) SANS 197-1:2000 /EN 197-2:2000. Cement Part 2: Conformity Evaluation. Pretoria, South Africa.
[7] South African Bureau of Standards (2004) SANS 50413-1:2004/EN 413-1:2004. Masonry cement Part 1: Composition, specifications and conformity criteria. Pretoria, South Africa.
[8] De Wet, H.F. (2003) A Note on Cartel Pricing in the South African Cement Industry: New Evidence. The South African Journal of Economics. Vol. 71:3

Appendix 1

Compositional requirements.

Specification	Clinker + Gypsum	Slag	Fly Ash	NDM
SABS 471	95-100%			0-5%
SABS 831	80-95%	5-15%		0-5%
SABS 831	80-95%		5-15%	0-5%
SABS 626	25-85%	15-70%		0-5%
SABS 1466	60-75%		25-35%	0-5%

Minimum strength requirements – MPa

Specification	**3 days**	**7 days**	**28 days**[1]
SABS 471 OPC	16,0	24,0	
SABS 471 Rapid Hardening	21,0	28,0	
SABS 831 OPC	16,0	24,0	
SABS 831 Rapid Hardening	21,0	28,0	
SABS 626	14,0	23,0	35,0
SABS 1466	14,0	23,0	35,0

1) Only if required by customer.

Appendix 2.

THE 27 PRODUCTS IN THE FAMILY OF COMMON CEMENTS										
Main types	Notation of the 27 products (types of common cement)		Composition (percentage							Minor additional constituents
			Main Constituents							
			Clinker	Blastfurnace slag	Silica fume	Fly Ash		Limestone		
						siliceous	calcareous			
			K	S	D^b	V	W	L	LL	
CEM I	**Portland Cement**	**CEM 1**	95-100	-	-	-	-	-	-	0-5
CEM II	**Portland -slag cement**	**CEM II/A-S**	80-94	6-20	-	-	-	-	-	0-5
		CEM II/B-S	65-79	21-35						0-5
	Portland-silica fume cement	**CEM II/A-D**	**90-94**		**6-10**					**0-5**
	Portland-pozzolana cement	**CEM II/B-P**	80-94	-	-	-	-	-	-	0-5
		CEM II/B-P	65-79	-	-	-	-	-	-	0-5
		CEM II/A-Q	80-94	-	-	-	-	-	-	0-5
		CEM II/B-Q	65-79	-	-	-	-	-	-	0-5
	Portland-fly ash cement	**CEM II/A-V**	80-94	-	-	6-20	-	-	-	0-5
		CEM II/B-V	65-79	-	-	21-35	-	-	-	0-5
		CEM II/A-W	80-94	-	-	-	6-20	-	-	0-5
		CEM II/B-W	65-79	-	-	-	21-35	-	-	0-5
	Portland-burnt shale cement	**CEM II/A-T**	80-94	-	-	-	-	-	-	0-5
		CEM II/B-T	65-79	-	-	-	-	-	-	0-5
	Portland-limestone cement	**CEM II/A-L**	80-94	-	-	-	-	6-20	-	0-5
		CEM II/B-L	65-79	-	-	-	-	21-35	-	0-5
		CEM II/A-LL	80-94	-	-	-	-	-	6-20	0-5
		CEM II /B-LL	65-79	-	-	-	-	-	21-35	0-5
	Portland-composite cement [c]	**CEM II/A-M**	80-94	< ------------------------ 6-20 ----------------------						0-5
		CEM II/B-M	65-79	< ---------------------- 21-35 --------------------						0-5
CEM III	**Blastfurnace cement**	**CEM III/A**	35-64	36-65	-	-	-	-	-	0-5
		CEM III/B	20-34	66-80	-	-	-	-	-	0-5
		CEM III/C	5-19	81-95	-	-	-	-	-	0-5
CEM IV	**Pozzolanic cement [c]**	**CEM IV/A**	65-89	-	< -------------- 11-35 -------------			-	-	0-5
		CEM IV/B	45-64	-	--------------- >			-	-	0-5
CEM V	**Composite cement [c]**	**CEM V/A**	40-64	18-30	-	-- 18-30 --	-	-	-	0-5
		CEM V/B	20-38	31-50	-	-- 31-50 -	-	-	-	0-5

a. The values in the table refer to the sum of the main and minor additional constituents.

b. The proportion of silica fume is limited to 10%

c. In Portland-composite cements CEM II/A-M and CEM II/B-M, in pozzolanic cements CEM IV/A and CEM IV/B and in composite cements CEM V/A and CEM V/B the main constituents other than clinker shall be declared by designation of the cement (for example see clause 8).