COMPARISON OF THE PROPERTIES OF PORTLAND CEMENT AND PORTLAND-LIMESTONE CEMENT

Alex Lyatonga Mrema
Department of Structural and Construction Engineering, College of Engineering and Technology, University of Dar es Salaam, P. O. Box 35131,Dar es Salaam, Tanzania. Tel. +255 754 285715, Email: mrema@ce.udsm.ac.tz

ABSTRACT

A study was made in a cement factory in Dar es Salaam, Tanzania, where Ordinary Portland Cement (CEM I 42.5N) and Portland-limestone cement (PLC) which has the brand name Twiga Cement Extra (CEM II/A-L/32.5R) are produced and conforming to the Tanzania Standard TZS 727 (Part1): 2002, which is equivalent to EN 197 published by the committee for European normalization (CEN). A comparison was made between the two types of cements in terms of physical, chemical and mechanical properties. It was found out that they all complied with the standards, that there was no significant difference in their setting times and that the Portland cement had higher strengths than the PLC. It was also observed that there was a slightly lower water demand for the same consistency when compared to OPC and hence there is an improvement of the cohesiveness of a concrete mix when PLC is used. It was concluded, however, that the two cements are different and that using the two cements interchangeably as is done in Tanzania is wrong because they do not have equivalent strengths and therefore equivalent performance since the PLC is not optimized. Portland-limestone cement (PLC) is known to offer significant energy savings and green house gas (GHG) reduction (up to 10% GHG savings) over conventional Portland cement while at the same time providing comparable performance if optimized.

Keywords: *Portland cement, Portland-limestone cement, properties, optimization*

INTRODUCTION

What are Portland-limestone cements?

Portland-limestone cements are a type of common cement specified by BS EN 197-1: 2000. There are two types containing 6-20% and 21-35% limestone fines respectively. Portland-limestone cements containing up to 20% limestone fines were previously specified in the UK by BS 7583: 1996. The cement designations for factory made Portland-limestone cements are CEM II /A-L (or A-LL) and CEM II /B-L (or B-LL) where:

- CEM II /A-L (or A-LL) may contain 6-20% limestone.
- CEM II /B-L (or B-LL) may contain 21-35% limestone.

The suffix –LL, rather than –L signifies a source of high purity limestone with a particularly low content of organic material. The limestone is generally interground (rather than blended) with Portland cement clinker and the cements are available at standard strength class 42.5/52.5 and when air-entrained 32.5R. Portland-limestone cement should not be confused with Portland cement (CEM I) which is permitted to contain up to 5% of a minor additional constituents (m.a.c.) (Hawkins et al. 2003). The m.a.c. often used is limestone fines with a particle size similar to cement. A CEM I that includes a limestone m.a.c. is indistinguishable in properties from any other CEM I and can be used whenever and wherever CEM I is specified.

DETERMINATION OF PROPERTIES OF PORTLAND CEMENT AND PORTLAND-LIMESTONE CEMENT

The cements compared were Portland cement (CEM I 42.5N) and Portland-limestone cement (CEM II/A-L/32.5R) and were tested according to the European Standard EN 196 and checked for conformity with Tanzania Standard TZS 727-2002 which is equivalent to EN 197. The tests carried out were physical, mechanical and chemical tests.

Physical tests

The physical tests carried out were determination of setting times and soundness according to EN 196: Part 3, and fineness according to EN 196: Part 6.

Mechanical tests

The mechanical tests done were determination of compressive strengths according to EN 196: Part 1. Mortar cubes of size 7.01x7.01x7.01cm were used and the test equipment was a compression machine type MFL 300 MPF.

Chemical tests

The chemical tests done were loss on ignition, insoluble residue, chemical composition of the cement and its raw materials by XRF analysis according to EN 196: Part 2 and determination of the chloride, carbon dioxide and alkali content of the cements according to EN 196: Part 21.

TEST RESULTS

Table1: Physical properties of the cements tested

Physical Test	Portland cement (CEM I 42.5N)	Portland-limestone cement (CEM II/A-L/32.5R)	Requirements according to EN 197-1
Standard Consistence test (%)	26	25.5	None
Initial setting time (min)	179	169	$\geq 60, \geq 75$ respectively
Soundness (mm)	1.5	1.0	≤ 10
Fineness (cm^2/g)	3669	3776	≥ 2250

Both cements passed the physical properties tests.

Table 2: Mechanical Properties of the cements tested

Cement Type	Early strength (2 days)	Standard strength (28 days)	Requirements according to EN 197-1
Portland cement (CEM I 42.5N)	16.95 MPa	47.13 MPa	> 10 MPa at 2days and between 42.5 and 62.5 MPa at 28 days
Portland-limestone cement (CEM II/A-L/32.5R	13.14 MPa	41.98 MPa	> 10 MPa at 2days and between 32.5 and 52.5 MPa at 28 days

Both cements passed the mechanical properties tests.

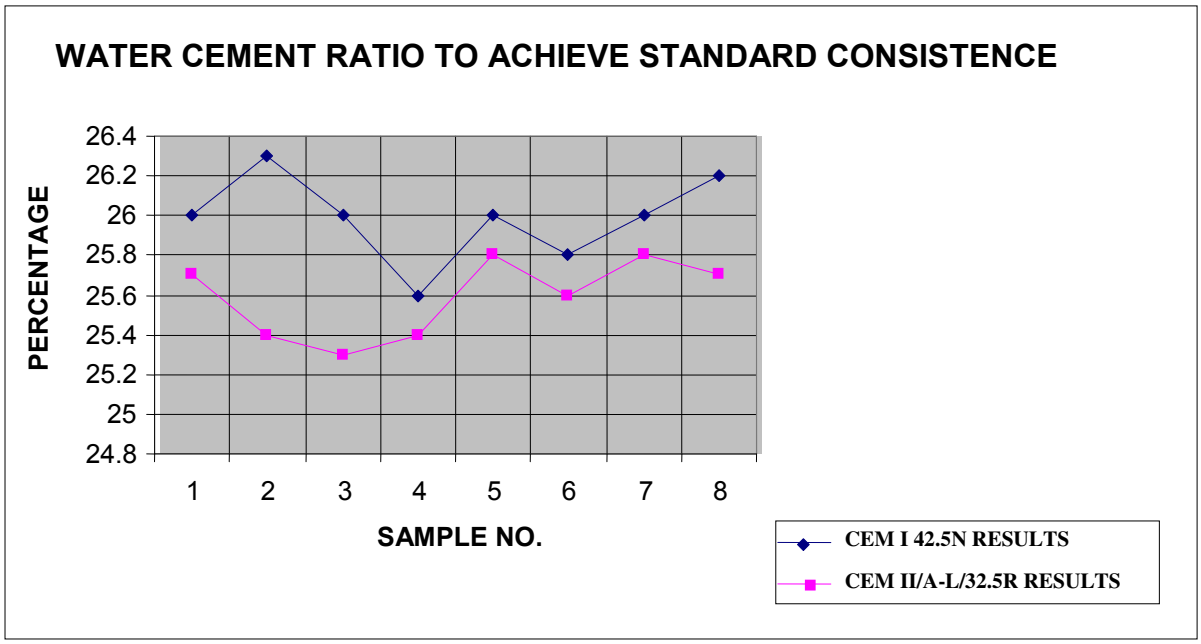

Figure 1: Water cement ratio to achieve standard consistence

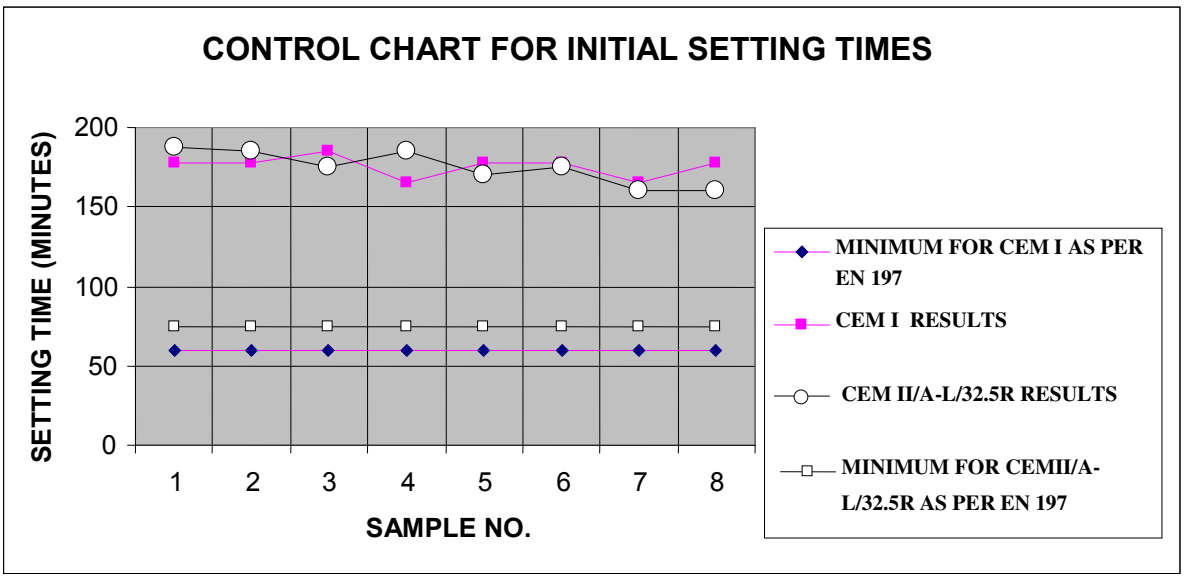

Figure 2: Control Chart for Initial Setting times

DISCUSSION OF RESULTS

The two cements investigated i.e. the Portland cement (CEM I 42.5N) and the Portland-limestone cement (CEM II/A-L/32.5R) passed the physical, mechanical and chemical properties as required by the Tanzania Standard: TZS 727 (Part 1):2002 which is equivalent to the European Standard EN 197-1:2000.

The tests have shown that to achieve the same consistency PLC requires less water than Portland cement (Figure 1) which confirms earlier observations by other people that the tendency to bleeding is significantly reduced in concrete made of PLC.

From the tests conducted there was no significant difference in the initial setting times for both cements (Figure 2).
From the control charts for 2 days strength (Figure 3) and the 28 days strength (Figure 4) it shows that the Portland cement has higher strengths than PLC at both ages and therefore the use of both cements interchangeably as the case is in Tanzania is uneconomical. It has been noted in the literature review that performance of concrete produced with PLC was affected by the quality and particle size distribution of the limestone and that if the proper particle size and distribution is not achieved in PLC, a process called 'optimization', then the PLC will not produce equivalent results to a comparable Portland cement.

The use of the PLC and Portland cement (discussed here) interchangeably as the case is in Tanzania assumes that the two cements have equivalent strengths and therefore equivalent durability and performance which has been shown here not to be the case.

CONCLUSIONS

Portland-limestone cement (PLC) is known to offer significant energy savings and green house gas (GHG) reduction (up to 10% GHG savings) over conventional Portland cement while at the same time providing comparable performance if optimized.

While the use of PLC has been known in Europe for 25 years now, it is very new in developing countries and even in some developed ones. For example the National Building Code of Canada (NBCC) will reference (allow the use of) PLC in 2010 (Townson, 2009).

It has been observed that while we use PLC in developing countries, (Tanzania in particular), the characteristics of such cements remain largely unknown to builders and even to some practicing engineers because of lack of technical information on such cements. Portland-limestone cements and Portland cements have very often been used interchangeably even in situations where the PLCs had not been optimized. It is time to disseminate the knowledge on PLCs and the other similar cements to the technical community. The manufacturing industry/producer should always optimize the PLC and publicize the benefits of using it.

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