Third International
World of Construction
Project Management
Conference 2010

20th - 22nd October 2010

Coventry University

CIOB
THE CHARTERED INSTITUTE OF BUILDING

RYERSON UNIVERSITY

WORLD OF CONSTRUCTION
PROJECT MANAGEMENT

Proceedings of the Third International World of Construction Project Management Conference

20th – 22nd October 2010

ACT UK Simulation Centre, Coventry University Technology Park

Edited by:
Robby Soetanto and John W. Davies

Organising Committee

Dr. Robby Soetanto (Coventry University, UK) - Chair
Mr. Saleem Akram (CIOB, UK)
Prof. David Boyd (Birmingham City University, UK)
Prof. John Davies (Coventry University UK)
Dr. Chris Goodier (Loughborough University, UK)
Dr. Steve Martin (Coventry University, UK)
Prof. Alistair MacKenzie (Ryerson University, Canada)
Dr. Paul Poh (Ryerson University, Canada)
Dr. Kendra Schank-Smith (Ryerson University, Canada)
Mrs. Janet Wood (ACUA, UK)
Mrs. Pam Shoker-Texeira (Coventry University, UK)
Dr. Lorna Everall (Coventry University, UK)
Mrs. Natalie Johnson (Coventry University, UK)
Ms. Sharondeep Kaur (Coventry University, UK)

Scientific Committee

Dr. Robby Soetanto (Coventry University) - Chair
Mr. Steve Austin (Coventry University)
Dr. Geoff Briscoe (Coventry University)
Prof. David Boyd (Birmingham City University)
Prof. John Davies (Coventry University)
Prof. Hennes De Ridder (Delft University)
Prof. Andrew Dainty (Loughborough University)
Dr. Chris Goodier (Loughborough University)
Dr. Jane Hao (Ryerson University)
Dr. Constantine Katsanis (Ryerson University)
Dr. Steve Martin (Coventry University)
Prof. Alistair MacKenzie (Ryerson University)
Dr. Sarah Peace (CIOB)
Dr. Paul Poh (Ryerson University)
Prof. David Proverbs (Wolverhampton University)
Dr. Kendra Schank Smith (Ryerson University)
Prof. Hans Wamelink (Delft University)
Mr. Paul Yates (Coventry University)

Contents

Contents (continue):

QUALITY OF CONCRETE - ONE EXAMPLE IN THE NORTH OF PORTUGAL

P.J. Cunha*, J.B. Aguiar[†], P.N. Oliveira[‡], A.F. Camões[•]

*University of Minho, Department of Civil Engineering
Campus of Azurém, 4800-058 Guimarães, Portugal
e-mail: ***** paulojpdcunha@gmail.com, [†] aguiar@civil.uminho.pt, [‡] pno@dps.uminho.pt,
[°]aires@civil.uminho.pt

The non-quality and non-conformity of concrete, stimulates the development of pathologies into the structure and consequently in coatings and masonry. So an early degradation of the buildings could be reached.The objectives of this study were the characterization of the procedures adopted for the production of concrete in some works in the north of Portugal, determining the strength class of the concrete produced and the comparison with the strength class required in the project. At this point, we performed the evaluation of the compressive resistance of concrete in situ and the comparison with the strength class obtained in the works under study. It was found that the quality of concrete in situ is higher than the obtained with standard samples.We can say that when more extensive, fast and tight is the inspection, better you can control and make the corrections in time, in order to maintain the quality of concrete used. It is important for a proper awareness, a training and formation of the persons involved in this matter.

1 INTRODUCTION

Concrete is a material formed by cement, aggregates and water, resulting from the hydration of the cement, developing their properties. Besides these basic components, it can also contain admixtures and additions. It is still of considerable importance the choice of the concrete constituents, production and its application (transport, placement, compacting, cure and protection). The composition of the concrete, should be selected satisfying the criteria of behaviour for the fresh concrete and for the hardened concrete, including consistence, density, resistance, durability and protection of the armatures against the corrosion. The composition of the concrete should permit the achieving of a compatible workability with the construction method used. The aggregates maximum dimension has to be chosen so that the concrete can be put and compressed into the turn of the armatures without segregation.

A durable concrete, should protect the armatures satisfactorily against the corrosion and should support the environmental conditions of exposition during the foreseen time of useful life. Some factors should be taken in consideration: choice of the constituents, choice of the composition, mechanical attacks, placement, compacting and the cure of the concrete. In Portugal, the control of the quality of the several factors actually is regulated through standard EN 206-1[1]. This standard replaced at short term the standard ENV 206[2].

This study has as an objective, the characterization of the procedures used to produce concrete in some construction sites in the north of Portugal. It was calculated the strength class of concrete produced in these construction sites and compared to the strength class

required in the project. It was study the evaluation of concrete strength in situ and it was made the comparison with strength class obtained in the construction sites under study. Here, we also proposed methodologies to improve the quality of concretes.

It was noted that the control of the conformity of the compressive strength of the concretes, reveals some negligence of the quality of this material. As consequence of no quality and no conformity of the concrete, pathologies can occur at the level of the structure or in the coverings and masonries, arriving to a precocious degradation of the constructions and possible fractures. This non execution of standard appears, frequently, due to the ignorance or relaxation, but also for times with the intention of saving material to improve the final profit.

2 CONCRETE

Concrete is legitimately considered the material for more versatile construction. It uses average plenty materials, the technology of manufacture is simple and it requests low energy consumptions. This appeared in substitution of the great blocks of stones that formed the most passing constructions, allowing more executions moulded to the builders' interests. In a very generic way we can define the concrete as the result of the mixture of cement, water and aggregates, being obtained a material more or less homogeneous and plastic[3,4].

The concrete with cement, water and aggregates presents certain general characteristics, but however, a lot of times it is convenient to valorise certain characteristics, as for instance, impermeability, fluidity, speed of obtaining the mechanical resistances, possible with addition of small amounts of admixtures that will be the responsible for the obtaining of these and other characteristics of the concrete.

A good concrete needs for one side a commitment between the strength and the permeability, and the workability for other side. It is necessary to know some elements related with the nature and the work type, placement means and compacting of the concrete, armatures and moulds, wanted class and type of the concrete, as well as the foreseen environmental conditions[5].

The concrete is an artificial stone resulting from the mixture with cement and aggregates achieving good characteristics of mechanical resistance. It is necessary the addition of water to promote the chemical reaction of hydration. With view to obtaining of improvements at the level of some of their properties, it is usual the inclusion of other chemical substances to the mixture, designated of admixtures. Being their dependent properties of several factors, they assume special relief the properties of the involved aggregate (geometric, mechanics and chemistries), the type of cement adopted and the several proportions among the elements, water/cement ratio (W/C) and amount of water[6].

3 DESCRIPTION OF THE EXPERIMENTAL WORK

3.1 Collect of specimens

Collect of several concrete specimens in ten sites of the North of Portugal, along the year of 2007, had as objective to accomplish a "enlarged" statistical study, not only of the minimum number of results demanded by EN 206-1[1], but, with a vast number of results, and with several combinations among them, respecting the minimum number of results demanded by the standard, to verify which possibilities exist of this to be respected or not.

Some companies were contacted, to collect in their sites concrete specimens, testing them in the Laboratory of Construction Materials of the University of Minho. For the

accomplishment of the tests existent equipments were used at the Laboratory (Figure 1). We compared that results with three core results token from that sites (Figure 2).

Figure 1: Vibrator, moulds and equipment for compression test

In the sites 1, 3, 7 and 9, it was used ready concrete of a strength class C20/25. In the site 2, the concrete used, done in site, with a compressive strength class C20/25. In the site 4 it was used ready concrete of a strength class C25/30. In the site 5 the compressive strength class intended was C12/15 and it was used concrete done in site. In the site 6 it was used ready concrete of a strength class C12/15. Finally, in the sites 8 and 10 it was used ready concrete of a strength class C30/37 and C16/20, respectively.

Inside of each site, ten specimens were accomplished. Individually for each combination, it was made the verification of the conformity criteria from the compressive strength as well as the determination of the class of the concrete obtained. The procedure adopted in the control of the conformity was done initially in agreement with standard EN 206-1[1]. The control of the conformity was verified also with the old standard ENV 206[2], comparing the two obtained results. It was made too, a piece with 40x20x20 cm[3], where were token three cylindrical cores, with a diameter of 10 cm each. In the end, we compare the results obtained with the specimens and with the cores.

First, and in agreement with standard EN 206-1[1], for the sites 1, 3, 4, 6, 7, 8, 9 and 10 there are these combinations: 45 of 2 results; 120 of 3 results; 210 of 4 results; 252 of 5 results; 210 of 6 results. In the sites 2 and 5 there are 120 combinations of 3 results. With standard ENV 206[2], for the sites 1, 2, 3, 5, 6, 7, 9 and 10 there are these combinations: 120 of 3 results; 210 of 4 results; 252 of 5 results; 210 of 6 results. In the sites 4 and 8 there are 210 combinations of 6 results.

In the end, it was compared the results obtained according to the standards EN 206-1[1] and ENV 206[2]. For simplicity of understand a calculation leaf was used as tool to schematise the whole study described to the moment. For standard EN 206-1[1], for the determination of the class of the concrete obtained and control of the conformity of the compressive strength is necessary before everything to verify if each specimen tested to the 28 days accomplishes the criterion 2. The concrete in cause should be confirmed if accomplishes the criterion 3, in that case it belongs to the family, this in the case of the concretes with certification of the control of the production. Finally, it is necessary that the average of "n" transposed results accomplish to the criterion 1.
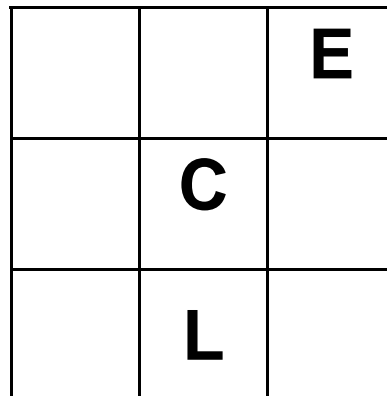
Figure 2: Cores extraction from the concrete piece

Type of calculations effectuated by standard ENV 206

3 to 5 results

a) Calculation of the failure's tensions average to the compression of 3 results:
$$X_n = \frac{23,5 + 27,6 + 24,2}{3} = 25,1 \text{MPa}$$

b) The smallest value of the obtained tensions:
$$X_{min} = 23,5 \text{MPa}$$

c) The specified characteristic value:
$$f_{ck} = 25 MPa$$

d) To verify if it accomplishes the following conditions:
$$X_n \geq f_{ck} + 5 \quad \Leftrightarrow \quad 25,1 \geq 25 + 5 \quad \rightarrow \quad \textit{(not verified)}$$
$$X_{min} \geq f_{ck} - 1 \quad \Leftrightarrow \quad 23,5 \geq 25 - 1 \quad \rightarrow \quad \textit{(not verified)}$$

e) To determine the class of the concrete:
$$25,1 \geq f_{ck} + 5 \quad \Rightarrow \quad f_{ck} \leq 20,1 \, MPa$$
$$23,5 \geq f_{ck} - 1 \quad \Rightarrow \quad f_{ck} \leq 24,5 \, MPa$$

- Being 20,1 MPa the smallest value $\Rightarrow$ Concrete's class obtained: C16/20 $\Rightarrow$ Not verified

6 or more results

a) Calculation of the failure's tensions average to the compression of 6 results:
$$X_n = \frac{39,0 + 41,1 + 41,1 + 38,7 + 37,4 + 39,7}{6} = 39,5 \text{MPa}$$

b) The smallest value of the obtained tensions:

$X_{min} = 37,4 MPa$

c) The specified characteristic value:
$f_{ck} = 30 MPa$

d) Calculation of the standard deviation:

$$S_n = \sqrt{\frac{\sum_{i=1}^{n}(X_i - X_n)^2}{n-1}} =$$

$$= \sqrt{\frac{(39,0-39,5)^2 + (41,1-39,5)^2 + (41,1-39,5)^2 + (38,7-39,5)^2 + (37,4-39,5)^2 + (39,7-39,5)^2}{6-1}} = 1,45$$

e) Remove the values λ and k from the table, in function of the number of samples:
λ=1,48 and k=3

f) To verify if it accomplishes the following conditions:
$X_n \geq f_{ck} + \lambda . S_n \quad \Leftrightarrow \quad 39,5 \geq 30 + 1,87 \times 1,45 \quad \rightarrow \quad$ *(verified)*
$X_{min} \geq f_{ck} - k \quad \Leftrightarrow \quad 37,4 \geq 30 - 3 \quad \rightarrow \quad$ *(verified)*

g) To determine the class of the concrete:
$39,5 \geq f_{ck} + 1,87 \times 1,45 \quad \Rightarrow \quad f_{ck} \leq 36,79 \, MPa$
$37,4 \geq f_{ck} - 3 \quad \Rightarrow \quad f_{ck} \leq 40,4 \, MPa$
- Being 36,79 MPa the smallest value $\Rightarrow$ Concrete's class obtained: C29/36 $\Rightarrow$ Verified

Type of calculations effectuated for standard EN 206-1

Initial production - 3 results

a) The value of the obtained tensions:
$f_{c1} = 29,65 MPa$
$f_{c2} = 28,93 MPa$
$f_{c3} = 29,08 MPa$

b) Calculation of the average's tensions average to the compression of 3 results:
$f_{cm} = \frac{29,65 + 28,93 + 29,08}{3} = 29,22 MPa$

c) The specified characteristic value:
$f_{ck} = 20 MPa$

d) To verify if it accomplishes the following criteria:
Criterion 2 $\rightarrow f_{ci} \geq f_{ck} - 4 \quad \Leftrightarrow \quad 20 \geq 20 - 4 = 16 \quad \rightarrow \quad$ *(Verified)*
Criterion 1 $\rightarrow f_{cm} \geq f_{ck} + 4 \quad \Leftrightarrow \quad 29,22 \geq 20 + 4 = 24 \rightarrow$ *(Verified)*

e) To determine the class of the concrete:

$28,93 \geq f_{ck} - 4 \Rightarrow f_{ck} \leq 32,93\, MPa$

$29,22 \geq f_{ck} + 4 \Rightarrow f_{ck} \leq 25,22 MPa$

- Being 25,22 MPa the smallest value $\Rightarrow$ Concrete's class obtained: C20/25 $\Rightarrow$ Verified

Identity test - 3 results

a) The value of the obtained tensions:

$f_{c1} = 29,65 MPa$

$f_{c2} = 28,93 MPa$

$f_{c3} = 29,08 MPa$

b) Calculation of the average's tensions average to the compression of 3 results:

$f_{cm} = \dfrac{29,65 + 28,93 + 29,08}{3} = 29,22 MPa$

c) The specified characteristic value:

$f_{ck} = 20 MPa$

d) To verify if it accomplishes the following criteria:

$\text{Criterion } 2 \rightarrow f_{ci} \geq f_{ck} - 4 \Leftrightarrow 20 \geq 20 - 4 = 16 \rightarrow (Verified)$

$\text{Criterion } 1 \rightarrow f_{cm} \geq f_{ck} + 1 \Leftrightarrow 29,22 \geq 20 + 1 = 21 \rightarrow (Verified)$

e) To determine the class of the concrete:

$28,93 \geq f_{ck} - 4 \Rightarrow f_{ck} \leq 32,93\, MPa$

$29,22 \geq f_{ck} + 1 \Rightarrow f_{ck} \leq 28,22 MPa$

- Being 28,22 MPa the smallest value $\Rightarrow$ Concrete's class obtained: C23/28 $\Rightarrow$ Verified

4 RESULTS

The procedure adopted in control of the conformity for the compressive strength, it was initially in agreement with standard ENV 206[1], using the same type of calculations effectuated before. It was verified later also with standard EN 206-1[2], comparing the obtained results. They were used for such the several possible combinations with the 20 results of each site (Table 1).

For the Site 1, ready concrete, concrete with certification of the control of production, the concrete class intended was C20/25. With the 10 results, making the combinations showed in Table 2, none verified the conformity criteria of the compressive strength to the shelter of the two standards. For standard EN 206-1[1], the class obtained was C12/16, the average 18,75 MPa, the standard deviation 0,71 MPa, the median 18,80 MPa and the coefficient of variation 3,79%. The classification of the site was 'Good'. This classification was obtained by using the ACI 214R-02[7], with the tables 3.2 and 3.3, 'standards of concrete control'. Even according the three cores extracted from the piece cured in situ, the class obtained, C18/23 was lowest then the class attempted (Table 3).

For the Site 2, concrete manufactured at the place, concrete without certification of the control of production, the concrete class intended was C20/25. With the 10 results, making the combinations showed in Table 2, almost none verified the conformity criteria of the compressive strength to the shelter of the two standards. For standard EN 206-1[1], the class

obtained was C19/24, the average 28,64 MPa, the standard deviation 1,10 MPa, the median 28,50 MPa and the coefficient of variation 3,84%. The classification of the site was 'Good'. But according the three cores extracted from the piece cured in situ, the class obtained was C20/25, just like as we pretended (Table 3).

For the Site 3, ready concrete, concrete with certification of the control of production, the concrete class intended was C20/25. With the 10 results, making the combinations showed in Table 2, none verified the conformity criteria of the compressive strength to the shelter of the two standards. For standard EN 206-1[1], the class obtained was C17/22, the average 24,50 MPa, the standard deviation 0,89 MPa, the median 24,50 MPa and the coefficient of variation 3,63%. The classification of the site was 'Good'. But according the three cores extracted from the piece cured in situ, the class obtained was C22/27, even higher then we pretended (Table 3).

For the Site 4, ready concrete, concrete with certification of the control of production, the concrete class intended was C25/30. With the 10 results, making the combinations showed in Table 2, always verified the conformity criteria of the compressive strength to the shelter of the two standards. For standard EN 206-1[1], the class obtained was C26/31, the average 33,32 MPa, the standard deviation 1,51 MPa, the median 33,32 MPa and the coefficient of variation 4,53%. The classification of the site was 'Fair'. But according the three cores extracted from the piece cured in situ, the class obtained was C32/40, much higher then we pretended (Table 3).

For the Site 5, ready concrete, concrete with certification of the control of production, the concrete class intended was C12/15. With the 10 results, making the combinations showed in Table 2, almost always verified the conformity criteria of the compressive strength to the shelter of the two standards. For standard EN 206-1[1], the class obtained was C12/16, the average 20,88 MPa, the standard deviation 1,13 MPa, the median 20,88 MPa and the coefficient of variation 5,41%. The classification of the site was 'Poor'. According the three cores extracted from the piece cured in situ, the class obtained was C12/16, as we pretended (Table 3).

For the Site 6, concrete manufactured at the place, concrete without certification of the control of production, the concrete class intended was C12/15. With the 10 results, making the combinations showed in Table 2, almost none verified the conformity criteria of the compressive strength to the shelter of the two standards. For standard EN 206-1[1], the class obtained was C9/12, the average 14,77 MPa, the standard deviation 0,33 MPa, the median 14,77 MPa and the coefficient of variation 2,23%. The classification of the site was 'Very Good'. Even according the three cores extracted from the piece cured in situ, the class obtained, C11/14 was lowest then the class attempted (Table 3).

	Class Pretended	Class Obtained	Average	Standard Desviation	Median	Coeficient Variation	Site Classification
Site 1	C20/25	C12/16	18,75 MPa	0,71 MPa	18,80 MPa	3,79 %	Good
Site 2	C20/25	C19/24	28,64 MPa	1,10 MPa	28,50 MPa	3,84 %	Good
Site 3	C20/25	C17/22	24,50 MPa	0,89 MPa	24,50 MPa	3,63 %	Good
Site 4	C25/30	C26/31	33,32 MPa	1,51 MPa	33,32 MPa	4,53 %	Fair
Site 5	C12/15	C12/16	20,88 MPa	1,13 MPa	20,88 MPa	5,41 %	Poor
Site 6	C12/15	C9/12	14,77 MPa	0,33 MPa	14,77 MPa	2,23 %	Very Good
Site 7	C20/25	C23/28	30,52 MPa	2,24 MPa	30,52 MPa	7,34 %	Poor
Site 8	C30/37	C30/38	40,32 MPa	2,70 MPa	40,32 MPa	6,70 %	Poor
Site 9	C20/25	C26/31	33,18 MPa	1,41 MPa	33,18 MPa	4,25 %	Fair
Site 10	C16/20	C15/19	21,23 MPa	0,81 MPa	21,23 MPa	3,82 %	Good

Table 1 : Results of ten sites obtained with the standard EN 206-1

	Cubic sample results (R_i)										Percentage of combinations of results that verify the NP EN 206-1 (%)					Percentage of combinations of results that verify the NP ENV 206 (%)				
	R1	R2	R3	R4	R5	R6	R7	R8	R9	R10	C2	C3	C4	C5	C6	C2	C3	C4	C5	C6
Site 1 (C20/25)	18,4	18,6	18,9	18,0	18,9	19,2	19,7	17,4	18,7	19,7	0,0	0,0	0,0	0,0	0,0		0,0	0,0	0,0	0,0
Site 2 (C20/25)	27,3	28,0	30,5	27,2	27,9	28,5	29,3	30,0	29,2	28,5		29,17					0,0	0,0	0,0	100,0
Site 3 (C20/25)	24,6	23,5	24,9	23,9	25,3	25,3	24,4	25,7	22,8	24,6	0,0	0,0	0,0	0,0	0,0		0,0	0,0	0,0	0,0
Site 4 (C25/30)	34,5	34,4	32,0	34,9	35,3	34,3	31,1	31,7	32,3	32,7	100,0	100,0	100,0	100,0	100,0					100,0
Site 5 (C12/15)	20,3	21,1	22,5	20,4	21,3	21,6	19,6	22,1	18,8	21,0		100,0					95,0	98,6	100,0	100,0
Site 6 (C12/15)	14,4	14,8	14,9	15,5	15,1	14,4	14,9	14,6	14,5	14,6	0,0	0,0	0,0	0,0	0,0		0,0	0,0	0,0	0,0
Site 7 (C20/25)	28,1	33,2	34,4	30,4	28,1	29,9	31,7	32,0	28,2	29,3	100,0	100,0	100,0	100,0	100,0		100,0	100,0	100,0	100,0
Site 8 (C30/37)	41,9	38,9	43,3	42,4	40,0	42,7	34,3	38,0	41,0	40,7	88,89	95,0	99,0	94,0	99,0					14,8
Site 9 (C20/25)	30,9	33,6	33,2	34,1	31,2	31,7	34,9	34,1	34,2	33,8	100,0	100,0	100,0	100,0	100,0		100,0	100,0	100,0	100,0
Site 10 (C16/20)	20,9	20,2	20,7	20,8	20,6	21,6	20,9	21,7	22,4	22,6	62,22	83,33	85,70	0,0	0,0		0,0	0,0	0,0	100,0

Table 2 : Results of the combinations with the samples

For the Site 7, ready concrete, concrete with certification of the control of production, the concrete class intended was C20/25. With the 10 results, making the combinations showed in Table 2, always verified the conformity criteria of the compressive strength to the shelter of the two standards. For standard EN 206-1[1], the class obtained was C23/28, the average 30,52 MPa, the standard deviation 2,24 MPa, the median 30,52 MPa and the coefficient of variation

7,34%. The classification of the site was 'Poor'. According the three cores extracted from the piece cured in situ, the class obtained was C29/34, higher then we pretended (Table 3).

	Cylindrical core results (f_{cbi}) (MPa)			f_{ck}	k	$f_{m(n),is}$	$f_{is,men}$	Resistance characteristic of the in situ concrete, is the smallest value of:		Which class of the compressive strength of concrete obtained?
	Center	Corner	Middle	(MPa)		(MPa)	(MPa)	$f_{ck,is}=f_{m(n),is}-k$ (MPa)	$f_{ck,is}=f_{is,menor}+4$ (MPa)	
Site 1 (C20/25)	24,17	22,14	23,00	17	7	23,10	22,14	16,10	26,14	C18/23
Site 2 (C20/25)	24,60	23,31	24,23	17	7	24,05	23,31	17,05	27,31	C20/25
Site 3 (C20/25)	27,43	25,71	25,85	17	7	26,33	25,71	19,33	29,71	C22/27
Site 4 (C25/30)	34,34	34,37	34,46	21	7	34,39	34,34	27,39	38,34	C32/40
Site 5 (C12/15)	20,44	13,32	17,95	10	7	17,24	13,32	10,24	17,32	C12/16
Site 6 (C12/15)	17,15	16,55	16,59	10	7	16,76	16,55	9,76	20,55	C11/14
Site 7 (C20/25)	33,65	31,03	32,60	17	7	32,43	31,03	25,43	35,03	C29/34
Site 8 (C30/37)	40,49	37,35	38,27	26	7	38,70	37,35	31,70	41,35	C37/47
Site 9 (C20/25)	33,46	26,00	32,12	17	7	30,53	26,00	23,53	30,00	C27/32
Site 10 (C16/20)	25,58	21,94	21,83	14	7	23,12	21,83	16,12	25,83	C18/23

Table 3 : Results of cores

For the Site 8, ready concrete, concrete with certification of the control of production, the concrete class intended was C30/37. With the 10 results, making the combinations showed in Table 2, almost always verified the conformity criteria of the compressive strength to the shelter of the two standards. For standard EN 206-1[1], the class obtained was C30/38, the average 40,32 MPa, the standard deviation 2,70 MPa, the median 40,32 MPa and the coefficient of variation 6,70%. The classification of the site was 'Poor'. According the three cores extracted from the piece cured in situ, the class obtained was C37/47, much higher then we pretended (Table 3).

For the Site 9, ready concrete, concrete with certification of the control of production, the concrete class intended was C20/25. With the 10 results, making the combinations showed in Table 2, always verified the conformity criteria of the compressive strength to the shelter of the two standards. For standard EN 206-1[1], the class obtained was C26/31, the average 33,18 MPa, the standard deviation 1,41 MPa, the median 33,18 MPa and the coefficient of variation 4,25%. The classification of the site was 'Fair'. According the three cores extracted from the piece cured in situ, the class obtained was C27/32, higher then we pretended (Table 3).

For the Site 10, ready concrete, concrete with certification of the control of production, the concrete class intended was C16/20. With the 10 results, making the combinations showed in Table 2, almost never verified the conformity criteria of the compressive strength to the shelter of the two standards. For standard EN 206-1[1], the class obtained was C15/19, the average 21,23 MPa, the standard deviation 0,81 MPa, the median 21,23 MPa and the

coefficient of variation 3,82%. The classification of the site was 'Good'. According the three cores extracted from the piece cured in situ, the class obtained was C18/23, higher then we pretended (Table 3).

In relation to this study, so much with standard ENV 206[2] as with EN 206-1[1], complemented with core tests, in the universe of the five analysed sites, in which took place a week of tests, with twenty results each, was verified that the number of tests in that the class of the concrete obtained is superior to the demanded class is very high. Only in the Sites 1 and 6 they were observed some problems with the verification of the criteria for compressive strength conformity.

5 CONCLUSIONS

The analyse of the results for the ten sites of 2007, in relation to the verification of the conformity criteria in the two standards, complemented with core tests, showed that the concrete class obtained is superior to demanded. The percentage is very high, having had only some problems of results with the sites 1 and 6.

The construction sector is increasing the competitiveness. The bet on quality, it's a way to win the bet in the sector. To buy concrete made at a central production with certification at their control of production, is almost a guarantee of conformity with the criteria of resistance to compression. This new standards are more stringent to the producers. The competition between producers of concrete, leads to an improvement in concrete quality and low prices. It is cheaper to buy concrete to a central production than doing it at the work site.

When the real value of the compressive strength is less than the resistance pretended, we should contact the engineer and ask for opinion, if it is verified the safety of the structure for this new reality of values. If the workability of a concrete is very low, never should simply add water, because it will interfere with other properties of concrete. This addition should be made by the producer, together with other constituents properly dosed. In these cases, it is always preferable to the user rejects the concrete. There are a total ignorance on the part of workers, in the correct way of implementation and cure of the concrete, in the elements of reinforced concrete structure, and in the samples. It is necessary to invest in training and instruct them

REFERENCES

[1] European Committee for Standardisation, *EN 206-1, Concrete. Part 1: Specification, performance, production and conformity*, Brussels, Belgium (2007).

[2] European Committee for Standardisation, *ENV 206, Concrete. Performance, production, placing and compliance criteria*, Brussels, Belgium (1990).

[3] J. M. Illston, *Construction materials, their nature and behaviour*, E & FN Spon, London (1996).

[4] N. Jackson and R. Dhir, *Civil engineering materials*, MacMillan Education, London (1988).

[5] F. Larrard, *Concrete mixture proportioning: a scientific approach*, E & FN Spon, London (1999).

[6] A.M. Neville, "*Properties of concrete*", Longman, London (1995).

[7] American Concrete Institute Committee (ACI), *Evaluation of strength test results of concrete*, Farmington Hills, USA (2002).