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USING CONFORMITY CONTROL OF CONCRETE COMPRESSIVE STRENGTH FOR CONSTRUCTION SITE CLASSIFICATION

BY

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Abstract. The accomplishment of the required strength class in concrete design is very important to avoid the development of pathologies into the concrete structures. This paper intends to evaluate the design required and the obtained strength classes of the concretes produced in ten different construction sites located in the north of Portugal. The strength classes were determined testing standard specimens. In order to know the *in-situ* compressive strength, cores were also extracted and tested. It was found that the *in-situ* compressive strength classes were higher than the obtained through the standard moulded specimens. These unexpected results can be explained due to a lack of knowledge and inspection on the manufacture of the specimens. The more extensive, fast and tight is the inspection, the better the control and the corrections in time, in order to maintain the quality of concrete used. It is important for a proper awareness, a training of the persons involved in this matter. Considering all the results obtained a construction site coefficient is proposed in order to classify the construction sites.

Key words: concrete technology & manufacture; quality control; compressive strength.

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1. Introduction

Concrete is legitimately considered a versatile construction material. It uses average plenty materials, the technology of manufacture is simple and it generally requests low energy consumptions. This appeared in substitution of great blocks of stones that formed the most ancient constructions, allowing works moulded to the builders' interests. In a very generic way concrete can be defined as the result of the mixture of cement, water and aggregates, obtaining a material more or less homogeneous and plastic (Illston, 1996; Jackson & Dhir, 1988). In order to obtain or improve some properties, it is common to include other substances into the mixture, namely mineral additions or chemical admixtures. The concrete mixture design assumes a lot of importance because its performance is intimately related with the optimization of the composition (Larrard , 1999; Neville, 1995).

A good concrete is obtained with a commitment between properties at fresh and at hardened states. Firstly, it is important to have a good workability, adapted to the conditions of the work, mainly placing and compacting methods available. Secondly, the hardened concrete must generally present high strength and durability. There are many factors that can affect the quality of concrete, like differences in the quality of constituent materials, variation in mix proportions, deviation in the quality of operating and mixing equipment, workmanship and supervision quality at the site (Arioz *et* al., 2007; EN 13670, 2009). Also, during transportation, placing, compacting and curing, variations may occur. These different factors causing variations in the quality should be taken into account (Arioz *et* al., 2007; Taylor, 1977), in order to avoid non quality and pathologies that can appear at short or long term.

The verification of the conformity of concrete properties with the applicable standards is a possible way to evaluate the quality of the work done. Usually the single property used for the conformity control is the compressive strength. For example, EN 206-18 and ACI 214R9 regulate the conformity control of compressive strength. Both documents (EN 13670, 2009; ACI 214R-02, 2002), take into account the test results obtained in specimens moulded from samples of the concrete before application. Therefore, the compressive strength obtained is a potential one and could be far from the *in-situ* one. This needs to be determined after casting and following the cure conditions of the structure. One good possibility is the extraction and subsequent testing of cores (EN 12504-1, 2009; EN 13791, 2007; ASTM C 42, 2004; ACI 318, 2002; Blab *et* al., 2010).

Indirect techniques could also be used to estimate the *in-situ* compressive strength (EN 13791, 2007; Chevva *et* al., 2008). The indirect tests, such as determination of rebound number, pull-out force or ultrasonic pulse velocity, provide alternatives to core tests for assessing the *in-situ* compressive strength of concrete in a structure. The indirect methods are semi-destructive or non-destructive in nature. Indirect methods may be used after calibration with core test results (EN 13791, 2007).

The construction sites classification is usually made using the standard deviation or the coefficient of variation of the compressive strength test results obtained at 28 days (ACI 214R-02, 2002). However, in order to decide about the quality of the work done into a construction site it is also important to take into account not only the dispersion of the results but also its average value. The compressive strength should be equal or higher than the required one and the confidence of the owner increased as the compressive strength obtained became higher.

In this study, the conformity of the compressive strength of concrete used in construction in Braga region is evaluated and one presents its subsequent statistical treatment of results. This work is focused on the range of years from 1998 to 2008 and only includes results of specimens tested at the Laboratory of Building Materials, University of Minho. The potential and the *in-situ* strength classes of the concretes produced were determined. It was evaluated the strength class of concrete produced as specified by European or American standards (EN 206-1 and ACI 214R-02) and compared to the strength class required by the designer. The concrete *in situ* compressive strength was also determined and compared with strength class obtained in the construction sites under study.

Analysing the obtained results one could also evaluate ten different construction sites.

2. Proposed Construction Site Classification

European standards are quite different from the American in the evaluation of the conformity control of the concrete. Both standards look for the conformity of the product. The American rules are more demanding than the European in the sampling plan. But in the criteria for verification, American rules verify sometimes more than the European ones. In the tests of identity, by the American rules, two cylindrical specimens are enough. In European standards are also needed at least 2 cubic or cylindrical specimens. If the analysis is done for a concrete production, whether initial or continuous, to obtain a result from a sample, simply a result of an individual specimen is enough. If the concrete has certification of production control, by European standards, the number of results can vary between 1 and 6, and may be sufficient a sample by mixing, per floor, or by week. While American rules require one sample per day, per class of concrete, for the European standard, if the concrete has no certification of production control, one sample per day may be enough. But if the concrete has certification of production control, the number of samples may be one per week. Despite the differences, the European and American standards are in agreement on the following point: if the specimen collected on the site, as a sample of the concrete class, does not check the criteria of the compressive strength of concrete, it should be put to consideration of the engineer a solution to the problem. If he decides to proceed with the coring and if it does not check, if the engineer agrees, it must pass to the load tests. In the end, in possession of all the data, the engineer must decide which solution will apply to the structure. That can pass through the demolition.

A total of 524 volumes of concrete, used in construction in Braga region, for the range of years from 1998 to 2008, tested at the Laboratory of Building Materials, University of Minho were analyzed. In this work, 82 volumes of concrete were of the concrete strength class C16/20, 369 of the class C20/25, 59 of the class C25/30, 2 are of the class C30/37 and 12 of the class C35/45. From Table 1, it can be observed that the percentage of lots in non-compliance is high, but it is lower for the types of concrete with higher class of concrete, except in the case of class C35/45. However, the low number of tests for the class C35/45 in addition to the fact that they are all from the same work does not allow a conclusion.

Table 1
Evaluation of Different Concrete Volumes with the EN 206-1

Concrete class	Total concrete volumes	EN 206-1: non conformity concrete volumes	
		Number	%
C16/20	82	34	41
C20/25	369	160	43
C25/30	59	20	34
C30/37	2	0	0
C35/45	12	8	67

The conformity control of the concrete should be followed by consequences. The evaluation of the quality of the work done is very important and may require subsequent action, taking measures, if necessary. If the strength class obtained is equal or higher the required one, the concrete should be considered with satisfactory quality and no measures are necessary to correct the work done. If the strength class obtained is lower than the required one, measures must be taken and options must be considered such as strengthening the concrete structure or demolishing it. The structural designer should be contacted to express his opinion.

Other important aspect is the classification of the site in order to express the confidence that the companies involved in production, transport and application of concrete transmit to the owner. The site classification could be made following ACI 214R9. For this, site classification is based on the standard deviation or the variation coefficient of the results obtained with standard specimens tested at 28 days of age. The CUSUM method presented in the same document, (ACI 214R-02, 2002), is a good way to monitor the quality of the concrete. However, the application of this method is complex. After the studies developed, a new site coefficient and a new construction site classification are proposed.

The site coefficient proposed is determined by the following expression:

$$SC = \frac{V}{10\,dS}, \tag{1}$$

where: *SC* is the site coefficient; *V* – variation coefficient of the compressive strength results, [%]; *dS* – difference between the concrete strength class obtained and required, [MPa].

Based on this coefficient, the classification of the construction site proposed is presented on Table 2.

Table 2
Proposed Classification of the Construction Site

Classification	*SC*
Excellent	≥ 0.00 or < 0.05
Very good	≥ 0.05 or < 0.10
Good	≥ 0.10 or < 0.20
Fair	≥ 0.20 or < 0.40
Poor	≥ 0.40 or < 0

3. Experimental Work

During one year ten companies were contacted in order to obtain authorization for collecting several concrete specimens directly at different construction sites located on the North of Portugal. The specimen collection was done according to European standard EN 12390-216. The concrete specimens were tested in the Laboratory of Building Materials of University of Minho in order to obtain its compressive strength, as established into the European standard EN 12390-317. The compressive strengths of the concrete specimens were compared with the ones obtained on three cores taken from the construction sites (Fig. 1). To that end and for each construction site during concrete casting an additional concrete element about 40 × 20 × 20 cm^3 was produced. Its curing and conservation was maintained equal as the surrounding concrete structural elements of the building.

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

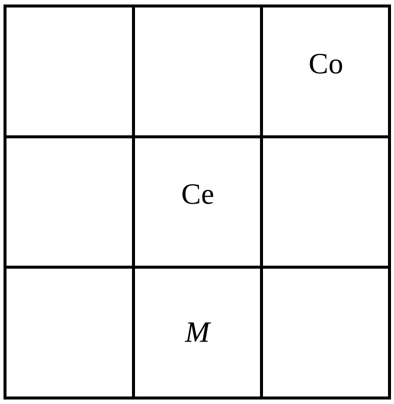

Fig. 1 – Localization of the cores extraction from the concrete element ($40 \times 20 \times 20$ cm^3).

Inside each site, ten specimens were moulded. The procedure adopted in the conformity control was done initially in agreement with standard EN 206-1, (2000). A concrete element with $40 \times 20 \times 20$ cm^3 was also made, where three cylindrical cores were extracted, with a diameter of 10 cm (Fig. 1). The localization of the cores extraction is one at the centre (Ce), one at the middle (*M*) and one at the corner (Co). Finally, the results obtained with the specimens and with the cores were compared. The cores results were analysed according to the European standard EN 13791, (2007).

4. Results

The main findings concerning the proposed classification of the studied construction sites using specimen’s results are presented on Table 3.

As one can observe through Table 3 six sites obtained the worst classification: “poor”. This happened because the strength class obtained was lower than the one specified (for 4 sites). The concrete of these 4 sites should be considered non conform with standard EN 206-1, (2000). For the 2 other sites classified as “poor” the difference between the strength class obtained and the strength class required is small, and the variation coefficient is relatively high.

The site classification “very good” was obtained by one construction site with a high difference between the strength class obtained and the strength class required, and with a relatively small variation coefficient.

Table 3
Classification of the sites Using Standard Cylindrical Specimens Results

Samples	*SS* MPa	*SO* MPa	10 *dS* MPa	S_m MPa	σ MPa	*V* %	*SC*	Site classification
Site *1*	25	16.7	–83.0	18.8	0.71	3.78	–0.05	Poor
Site *2*	25	26.2	12.0	28.6	1.10	3.85	0.32	Fair
Site *3*	25	22.6	–24.0	24.5	0.89	3.63	–0.15	Poor
Site *4*	30	30.9	9.0	33.3	1.52	4.56	0.51	Poor
Site *5*	15	18.7	37.0	20.9	1.13	5.41	0.15	Good
Site *6*	15	12.7	–23.0	14.8	0.35	2.36	–0.10	Poor
Site *7*	25	27.8	23.0	30.5	2.23	7.31	0.32	Fair
Site *8*	37	37.4	4.0	40.3	2.70	6.70	1.68	Poor
Site *9*	25	30.5	55.0	33.2	1.40	4.22	0.08	Very Good
Site *10*	20	18.8	–12.0	21.2	0.80	3.77	–0.31	Poor

Where: *SS* is the strength class specified; *SO* – strength class obtained; S_m – average; σ – standard deviation.

The problem of the classification presented at Table 3 is that the evaluation is made only concerning concrete production. The concrete strength used is the main indicated. To consider other aspects like transport and application of concrete, the *in-situ* compressive strength of concrete must be determined.

Table 4 presents the results obtained on the tested cores. The comparison between Tables 3 and 4 shows higher compressive strength determined for cores results than for standard specimens. Considering the specimens results (Table 3) 4 sites should be considered non conform. With the results from the cores (Table 4) the situation of non conformity was maintained for only 2 sites (*1* and *6*). Concerning the site classification, it is now possible to have a better approach that includes aspects like production, transport, application and curing of concrete. However, only with the results of three cores the calculation of the variation coefficient can limit the statistical validity. In Table 4 other site classification is presented using the strength class obtained with the cores and maintaining the variation coefficient of the specimen tests.

The site classification obtained using the results of the cores (Table 4) shows that 2 sites decrease the level (sites *2* and *5*), 3 sites maintain the classification (sites *1*, *6* and *9*) and 5 sites increase the level (sites *3*, *4*, *7*, *8* and *10*). These changes show that there is a significant influence of transport, application and curing on the compressive strength of concrete. Other aspects that could be mentioned are the execution and curing of the specimens. During this study the European standard EN 12390-2, (2000), was followed. The making and curing conditions in the laboratory, specified for the specimens, are different from the *in-situ* conditions.

Table 4

Classification of the Sites Using Core Results

Samples	*SS* MPa	*SO* MPa	10 *dS* MPa	σ MPa	*V* %	*SC*	Site classification
Site *1*	25	23.9	–11.0	4.42	–0.40	–0.40	Poor
Site *2*	25	25.1	1.0	2.74	2.74	2.74	Poor
Site *3*	25	27.7	27.0	3.65	0.14	0.14	Good
Site *4*	30	40.2	102.0	0.17	0.00	0.00	Excellent
Site *5*	15	16.0	10.0	20.99	2.10	2.10	Poor
Site *6*	15	14.5	–5.0	2.02	–0.41	–0.41	Poor
Site *7*	25	34.9	99.0	4.07	0.04	0.04	Excellent
Site *8*	37	47.3	103.0	4.16	0.04	0.04	Excellent
Site *9*	25	32.7	77.0	13.05	0.17	0.17	Good
Site *10*	20	23.9	39.0	9.22	0.24	0.24	Fair

For site *1*, ready concrete, concrete with certification of the control of production, the concrete class intended was C20/25. With the standard EN 206-1, (2000), the class obtained was C12/16, the average 18.8 MPa, the standard deviation 0.71 MPa and the coefficient of variation 3.78%. Either on samples (Table 3) or cores (Table 4), the site classification was 'Poor'. The samples also had very bad appearance, with many voids, corresponding to a weak vibration. Even according the three cores extracted from the block cured *in-situ*, the class obtained, C18/23 was lowest then the class attempted. In this site, with the information of a questionnaire regarding sample preparation, it was found that the workers had no experience in making samples. The curing was made outdoor. The waiting time to begin the execution of the samples can broke the concrete links between the constituent particles that form immediately, causing a compressive strength lower than the real. The needle vibrator in the elements of the structure was fully introduced in the concrete. Moreover, specimens preserved in place, when extracted from the mold, must be send immediately to the laboratory. Here, the workers expected up to three days to do so. This is another factor contributing to the decrease of compressive strength test specimens.

For the site *2*, concrete manufactured at the place, concrete without certification of the control of production, the concrete class intended was C20/25. According to standard EN 206-1, (2000), the class obtained was C21/26, with 28.6 MPa of average strength, 1.10 MPa standard deviation and with a coefficient of variation of 3.85%. With samples (Table 3), the classification of the site was 'Fair' and with cores (Table 4) was 'Poor'. The samples had a reasonable appearance, with some voids. But according the three cores extracted from the block cured *in-situ*, the class obtained was C20/25, just like as it was pretended. Based on a questionnaire, it was found that the workers had no experience in making samples. However, they covered the samples after their conception. The workers waited until three days to send specimens to the laboratory. It was referred, during the investigation that the needle vibrator in the elements of the structure was never fully introduced into the concrete, reported as a vibration more or less uniform, as it can be seen by comparing the core results from the center (24.6 MPa), middle (24.2 MPa) and corner (23.3 MPa). It can be concluded that the concrete was not really a very good quality one.

For site *3*, ready mixed concrete was used with certification of the control of production and the concrete class intended was C20/25. According to standard EN 206-1, (2000), the class obtained was C17/22, with an average compressive strength of 24.5 MPa, a standard deviation of 0.89 MPa and a coefficient of variation of 3.63%. With samples (Table 3), the classification of the site was 'Poor' and with cores (Table 4) was 'Good'. The samples also had very bad appearance, with many voids, corresponding to a weak vibration. The difference with the classification between the samples and the cores resulted, in large part, because the cores were made by the foreman of the site and the samples were made by a servant. However for the three cores extracted from the piece cured *in-situ*, the strength class obtained was C22/27, even higher then it was pretended. In this site, and after answering the questionnaire, it was founded that the workers had experience in making samples. However, they didn't start to make the samples as the concrete arrived at the site. Also, they keep them outdoors. The workers waited until three days to send specimens to the laboratory. This is another factor contributing to the decrease of the compressive strength of the specimens. The needle vibrator in the elements of the structure was never fully introduced into the concrete, reported as more or less uniform vibration, as can be seen by comparing results of the cores: from the center (27.4 MPa), from the middle (25.8 MPa) and from the corner (25.7 MPa).

For site *4*, ready mixed concrete with certification of the control of production, the concrete class intended was C25/30. According to standard EN 206-1, (2000), the class obtained was C25/30, with an average strength of 33.3 MPa, a standard deviation of 1.52 MPa and a coefficient of variation of 4.56%. With samples (Table 3), the classification of the site was 'Good' and with cores (Table 4) was 'Excellent'. The samples had a reasonable appearance, with voids, corresponding to a reasonable vibration. The difference with the classification between the samples and the cores is due in large part because the cores were made by the foreman of the site and the samples were made by a servant. But according to the three cores extracted from the block cured *in-situ*, the class obtained was C32/40, much higher then it was pretended. In this site, and based on the questionnaire, it was founded that the workers had some experience in making samples. However, they did not start to make the samples as the concrete arrived at the site. They never kept them covered. The workers waited until three days to send specimens to the laboratory. It was referred, during the investigation that the needle vibrator was never fully introduced into the concrete, taking part in the final presented a very uniform vibration, as can be seen by comparing the results of the cores: center (34.3 MPa), middle (34.5 MPa) and corner (34.4 MPa).

For site *5*, ready mixed concrete with certification of the control of production was used. The concrete class intended was C12/15 but the class obtained was C14/18 according to standard EN 206-1, (2000). The average compressive strength was 20.9 MPa, the standard deviation 1.13 MPa and the coefficient of variation 5.41%. Site 5 showed a much better classification with samples (Table 3), 'Good', than with cores (Table 4), 'Poor'. The samples had very good appearance, corresponding to an optimal vibration. According on the three cores extracted from the block cured *in-situ*, the class obtained was C12/16, as it was aimed. In this site, it was found that the workers had no experience in making samples. However, they started to make the samples as the concrete arrived at the site and they kept them covered. The workers waited until three days to send specimens to the laboratory. The needle vibrator in was wrongly used in all the concrete element, leading to a lower compressive strength, as can be observed by the atypical dispersion of results from the center core (20.4 MPa), the middle (17.9 MPa) and the corner (13.3 MPa).

For site *6*, concrete manufactured at the place and without certification of the control of production, the concrete class intended was C12/15. According to standard EN 206-18, the class obtained was C9/12, with an average compressive strength of 14.8 MPa, a standard deviation of 0.35 MPa and a coefficient of variation of 2.36%. With samples (Table 3) and cores (Table 4), the classification of the site was 'Poor'. The samples had also bad appearance, with voids, corresponding to a weak vibration. With the three cores extracted from the block cured *in-situ*, the class obtained, C11/14 was lowest then the class attempted. In this site, it was found that the workers had no experience in making samples. However, they started to make the samples as the concrete arrived at the site and they kept them covered. The workers waited until three days to send specimens to the laboratory. It was referred during the investigation that the needle vibrator in elements of the structure was wrongly introduced in all the concrete, leading to a lesser compressive strength.

For site *7*, ready mixed concrete concrete with certification of the control of production was used. The concrete class intended was C20/25 and the obtained one was C22/27, with an average strength of 30.5 MPa, a standard deviation of 2.23 MPa and a coefficient of variation of 7.31%. With samples (Table 3), the classification of the site was ‘Fair’ and with cores (Table 4) was ‘Excellent’. The samples had also bad appearance, with voids, corresponding to a weak vibration. According to the three cores extracted from the concrete element cured *in-situ*, the class obtained was C29/34, higher then it was aimed. In this site, it was found that the workers had some experience in making samples. However, they started to make the samples as the concrete arrived at the site and they kept them covered. The workers waited more than three days to send the specimens to the laboratory. It was referred during the investigation that the needle vibrator was never fully introduced in the concrete structural elements, leading to an uniform vibration, as can be seen by comparing the results of the cores: in the center (33.6 MPa), in the middle (32.6 MPa) and in the corner (31.0 MPa).

For site *8*, ready mixed concrete with certification of the control of production was used and the concrete class intended was C30/37. According to standard EN 206-1, (2000), the class obtained was C30/37, with an average compressive strength of 40.3 MPa, a standard deviation of 2.70 MPa and a coefficient of variation of 6.70%. With samples (Table 3), the classification of the site was ‘Poor’ and with cores (Table 4) was ‘Excellent’. The samples had also very bad appearance, with voids, corresponding to a weak vibration. The different classification from the samples and the cores resulted in large part because the cores were made by the foreman of the site and the samples were made by a servant. According on the three cores extracted from the concrete block cured *in-situ*, the class obtained was C37/47, much higher then it was aimed. In this site, it was found that the workers had some experience in making samples. However, they started to make the samples as the concrete arrived at the site and they kept them covered. The workers waited more than three days to send them to the laboratory. It was referred during the investigation that the needle vibrator was never fully introduced in the concrete structural elements, leading to an uniform vibration, as can be seen by comparing the results of the cores: in the center (40.5 MPa), in the middle (38.3 MPa) and in the corner (37.3 MPa).

For site *9*, where ready mixed concrete with certification of the control of production were used, the concrete class intended was C20/25 and the obtained one was C25/30. The average compressive strength reaches 33.2 MPa, the standard deviation 1.40 MPa and the coefficient of variation 4.22%. The site *9* showed better classification with the samples (Table 3), ‘Very Good’, than with cores (Table 4), ‘Good’. The samples had a reasonable appearance, corresponding to a reasonable vibration. The different classification from the samples and the cores resulted in large part because the cores were made by the foreman of the site and the samples were made by a servant. According to the three cores extracted from the block cured *in-situ*, the class obtained was

C27/32, higher then it was pretended. In this site, it was found that the workers had no experience in making samples. However, they started to make the samples as the concrete arrived at the site and they kept them covered. The workers waited until three days to send the specimens to the laboratory. It was referred during the investigation that the needle vibrator in implementing elements of the structure was wrongly introduced in all the concrete, leading to a very low vibration and to a lesser compressive strength, as can be observed analysing the dispersion of the results of the cores: at the center 33.4 MPa, at the middle 32.1 MPa and at the corner 26.0 MPa.

For site *10*, ready concrete with certification of the control of production was used and the concrete class intended was C16/20. The compressive strength class obtained was C14/18, with an average strength of 21.2 MPa, a standard deviation of 0.80 MPa and a coefficient of variation of 3.77%. With samples (Table 3), the classification was ‘Poor’ and with cores (Table 4) was ‘Fair’. The samples had a bad appearance, with voids, corresponding to a bad vibration. According on the three cores extracted from the block cured *in-situ*, the class obtained was C18/23, higher then it was aimed. In this site, it was found that the workers had no experience in making samples. However, they started to make the samples as the concrete arrived at the site and they kept them covered. The workers waited until three days to send specimens to the laboratory. It was referred during the investigation that the needle vibrator in implementing elements of the structure was wrongly introduced into all the concrete, leading to a very low vibration and to a lesser compressive strength.

In relation to this study according to EN 206-1, (2000), and complemented with core tests, in the universe of the ten analysed sites, where in each took place a week of tests, with ten results each, it 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* there were some problems with the verification of the criteria for compressive strength conformity. Analyzing all the sites, by the classifications obtained with samples and comparing then with the cores, it can be concluded that, technically, the execution of the samples failed. Moreover, with the classification of the sites from the cores, there are two sites with a classification of ‘Poor’, confirming the classification obtained in the samples, which corresponds a bad result for the concrete analysis.

In 8 of 10 works, the highest result was found in the centre part of concrete block, followed by the middle and finally, the lowest result was found in the corners, where generally the concrete element was worse vibrated. Only in one site, site *4*, the one that had the lowest standard deviation, the centre of the block had the worst result, and the middle part obtained the best result. This proves that the vibration of the concrete in the sites is not perfect. In another block, at site *10,* the second best result was obtained at the corner and the worst result was obtained in the middle of the piece. However, in the centre of the block, the result was 4 MPa higher than in the others. This shows that this is a block badly vibrated. Examples of sites with more bad vibrated blocks are sites *5* and *9,* because the difference between the corner and the middle is approximately 7 MPa. Sites *5* and *9* were the only ones that shows a higher site classification with samples than with cores. It can be concluded that there is a big deficiency in the production and execution of samples. The reason of the failure in some results seems to be related to the rent of poor workmanship in the application of concrete, than from the quality of the concrete itself. On the other hand, the good result in the classification of site is due largely to the good quality of concrete, overcoming the bad practices of implementation. The best example is site *7* where, despite the samples present many voids due to poor vibration, the results of the compressive strength are quite satisfactory. It can also be concluded that, the fact that most of the concrete producers have provided the certification for its production control, is a strong guarantee of quality of concrete.

5. Conclusions

The compressive strength conformity control of the studied concretes reveals some negligence about the quality control of this material. There is a great ignorance on workers related to the correct way of placing and curing concrete, either in structural reinforced concrete elements or in making the samples needed for quality control. It is necessary to invest in training and instruction. As a consequence of deficient quality and no conformity of concrete, pathologies can occur in the structure or in the coverings and masonries, leading to a precocious degradation of the constructions.

The analysis of the results for ten construction sites concerning the verification of the conformity criteria, complemented with core tests, showed that the concrete strength class obtained is usually higher than the specified. The percentage is very high, having had only some problems of results with sites *1* and *6*.

The conformity control of concrete should be followed by some decisions concerning the work done. The proposed site classification is based into a site coefficient that takes into account the coefficient of variation of the compressive strength results at 28 days and the difference between the obtained strength class and the specified strength class of the concrete.

The use of core tests that can estimate the *in-situ* compressive strength of concrete makes possible the site classification with more accuracy because it is possible to take into account the production, the transport, the application and the curing.

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FOLOSIREA CONTROLULUI DE CONFORMITATE A REZISTENŢEI LA COMPRESIUNE A BETONULUI ÎN VEDEREA CLASIFICĂRII ŞANTIERELOR DE CONSTRUCŢII

(Rezumat)

Realizarea clasei de rezistenţă, necesare la proiectarea betonului, este foarte importantă pentru evitarea patologiei structurilor din beton. Lucrarea îşi propune să evalueye clasele de beton pe baza rezistenţelor proiectate şi a celor obţinute în zece şantiere de construcţii diferite, localizate în nordul Portugaliei. Clasele de rezistenţă s-au determinat prin testarea unor epruvete standard. Pentru determinarea rezistenţelor la compresiune *in situ*, au fost extrase carote din structurile reale şi încercate la compresiune. S-a constatat că toate clasele de rezistenţă *in situ*, au fost mai ridicate decâtcele obţinute pe epruvete turante în tipare. Aceste rezultate neaşteptate se pot explica prin lipsa inspecţiei la fabricarea epruvetelor. Cu cât inspecţia este mai cuprinzătoare, mai rapidă şi mai exigentă cu atât este mai bun controlul şi corecţia în timp pentru menţinerea calităţii betonului folosit. Această acţiune este importantă pentru o conştientizare corespunzătoare şi pentru o pregătire adecvată a persoanelor implicate în acest proces. Prin luarea în considerare a rezultatelor obţinute, se propune un coeficient de evaluare a şantierului în scopul clasificării şantierelor de construcţie.