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Influence of Type of Concrete, of Size of the Body of Evidence Cylindrical and of Type of Laboratory in Determining the Compressive Strength of Concrete

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Abstract:- This paper presents a comparative analysis of the results obtained for testing the compressive strength by means of an interlaboratory test program in hardened concrete, developed in two different laboratories in the Goiânia, GO region, to identify and assess the influence of some factors affecting the results of compressive strength test. For this, we sought to determine the outcome of compressive strength, the influence of the concrete (Class C30 and CAR - High Strength Concrete), the size of the body of proof cylindrical (100 mm x 200 mm and 150 mm x 300 mm) and the type of laboratory. It was concluded that the type of concrete and type of lab results influenced the compressive strength. Moreover, it is noteworthy that the bodies of evidence dimension 100 mm x 200 mm of concrete Class C30 and of CAR (Class C60) presented the results with the highest dispersion.

Keyword:- Concrete; Basic Dimension; Compressive Strength; Interlaboratory; Dispersion.

[1]. INTRODUCTION

The resistance of a material is its ability to withstand tension without breaking. Sometimes, the break is identified by the appearance of cracks. However, the microstructural investigations indicate that in *ordinary* concrete, unlike the structural materials, concrete contains fine cracks before being subjected to external stresses. Given the above, the research aims to study and evaluate the influence of variables influence the type of concrete (C30 and Class CAR - High Strength Concrete), the size of the cylindrical specimen (100 mm x 200 mm and 150 x 300 mm) and the type of laboratory (Laboratory laboratory a and B) result in the compressive strength in hardened concrete and to check the variability of the experimental results.

[2]. EXPERIMENTAL PROGRAM

The experimental program was developed from an interlaboratory evaluation of compressive strength of concrete, developed in two different laboratories concrete located in the region of Goiânia, Goiás.
Considering the characteristics of interlaboratory program, where you can not fix all the independent variables, so we decided to study the following situation:

- Type of concrete (in two levels: class C30 and CAR);
- Dimensions of the test specimens at two levels: 100 mm x 200 mm and 150 mm x 300 mm;
- Type of Laboratory (in two levels: The lab and lab B).

As limitations of the study have been:

- They kept all specimens in the same moisture condition;
- Testing machine with load control with application rate of 0.6 MPa / s, the phase of the study;
- Materials used in the manufacture of concrete: CP V ARI Portland cement (high early strength), lithology and size of coarse aggregate (granite maximum dimension of 19 mm) and sand type (artificial sand);

- Compressive strength fc (28days) 30 MPa and 60 MPa;
- Finishing the top of the specimens (capping with sulfur).

The evaluation of the independent variable of basic dimension of the specimen is justified because the resistance specified for concrete are increasingly high and the capacity constraints of the testing machine did not follow this requirement, forcing laboratories to use the basic dimension (100 x 200) mm in the control tests technology. Therefore, it is important to assess the impact of this factor on the experimental results of the compressive strength.

To reduce the influence of the humidity of the specimens, they were demolded 24 hours after mixing, identified and stored in storage tanks for 28 days, with controlled humidity and temperature as specified by ABNT NBR 5738:2008. Once this term storage, the specimens were removed from the storage tank and stored in a dry environment at room temperature.

The levels defined for the concrete sample and concrete class C30 CAR (Class C60) were obtained by setting the concrete mix resistance (fc) of the order of 30 to 60 MPa.

Through the graphical behavior of concrete traces were obtained for concretes with strength estimated at 28 days at 30 MPa and 60 MPa. These traits are presented in TABLES 2.1 and 2.2.

TABLE 2.1 - Concrete mix for fc = 30 MPa
Material Proportioning by m³ of concrete
Mix design (1 : 3.78 : 4.23)
W/C ratio = 0.73

Materials	Conventionally Vibrated Concrete
	Quantity per m³
Cement CP V ARI	236 kg
Artificial sand	891 kg
Gravel size 1 (19 mm)	999 kg
Water	172 kg
Polyfuncitonal Additive	1.65 kg (0.7% of cement)
Superplasticizer	0.94 kg (0.4% of cement)
Silica Fume	18.9 kg (as replacement for 8% of cement in weight)
Fresh Concrete Properties:	
Consistency	130 mm
Air	2 %

TABLE 2.2 - Concrete mix for fc = 60 MPa
Material Proportioning by m³ of concrete
Mix design (1 : 1.928 : 2.58)
W/C ratio = 0.42

Materials	Conventionally Vibrated Concrete
	Quantity per m³
Cement CP V ARI	398 kg
Artificial sand	765 kg
Gravel size 1 (19 mm)	1028 kg
Water	167 kg
Polyfuncitonal Additive	2.79 kg (0.7% of cement)
Superplasticizer	1.59 kg (0.4% of cement)
Silica Fume	31.87 kg (as replacement for 8% of cement in weight)
Fresh Concrete Properties:	
Consistency	120 mm
Air	1.5 %

Were cast ten (10) specimens for compressive strength for each type of concrete, for each dimension of the specimen and for each type of laboratory (Lab A and Lab B), to meet the test methods ABNT NBR 5739:2007.

2.1 Technical Evaluation

Was applied to the statistical analysis technique of variance (ANOVA), contained in Statistica Statsoft Software 7 ® to the results found in individual laboratories for the A and B samples C30 and concrete class CAR (Class C60) separately and together. The test methodology consists of the application of the Fisher test (F).

[3]. PRESENTATION AND DISCUSSION OF RESULTS

As for the main analysis of this study, it is noteworthy that the specimens were tested in replicates (with 10 units per study situation) and randomized prior to testing of compressive strength. This randomization minimizes the effects of variables that were not or could not be considered in the experiment, such as: molding process of the specimen, the distribution of aggregates in concrete, installation of the measuring instrument, among others. In addition, if any dependency mechanism between the results of subsequent experiments, the randomization of the execution of experiments allows this dependency is diluted among all study situations and thus not favoring either situation.

In Table 3.1 presents the means, standard deviations and coefficients of variation of the results for all study situations obtained for samples molded concrete C30 and CAR, with a confidence interval of the mean (for 95% confidence) and a significance level of 5% for property compressive strength.

TABLE 3.1 - Statistical analysis of the results – Compressive Strength

Situation of Study			N°. of Specimen	Compressive Strength (MPa)		
Size (mm)	Type of Laboratory	Type of Concrete		Average (MPa)	Standard Deviation (MPa)	Coefficient of Variation (%)
———	———	CAR	38	65,8	5,5	8,3
———	———	C30	37	35,9	1,9	5,3
150X300	———	CAR	19	65,4	4,4	6,7
100X200	———	CAR	19	66,3	6,4	9,7
150X300	———	C30	19	36,2	0,76	2,1
100X200	———	C30	18	35,6	2,6	7,3
———	LABORATORY A	CAR	19	69,3	4,03	5,8
———	LABORATORY B	CAR	19	62,4	4,4	7,1
———	LABORATORY A	C30	19	34,6	1,6	4,6
———	LABORATORY B	C30	18	37,2	1,1	2,9
100X200	LABORATORY A	C30	9	33,2	1,2	3,5
	LABORATORY A	CAR	9	71,1	2,4	3,4
	LABORATORY B	C30	9	37,9	0,94	2,5
	LABORATORY B	CAR	10	61,9	5,8	9,4
150X300	LABORATORY A	C30	10	35,9	0,54	1,5
	LABORATORY A	CAR	10	67,7	4,6	6,8
	LABORATORY B	C30	9	36,6	0,804	2,2
	LABORATORY B	CAR	9	62,8	2,3	3,6
OBS.: - Type of concrete: concrete Classe C30 for dimensions 100 mm x 200 mm e 150 mm x 300 mm e CAR (High Strength Concrete) for dimensions 100 mm x 200 mm e 150 mm x 300 mm. - Five of the individual results were considered as spurious values.						

In TABLE 3.2, is the analysis of the significance of factors studied for the compression resistance property.

TABLE 3.2 - ANOVA - Analysis of the Global Experiment - Compressive Strength

Factors Studied	SQ	F	p	Result
Model Study	17409,46	273,49	0,000	significant
Error (residual)	609,29	———	———	———
Total	18018,75	———	———	———
Coefficient of Determination Model (R^2) = 0,96				
Dimension Body of Proof	———	0,17	0,682	not significant
Type of Laboratory	———	9,57	0,003	significant
Type of Concrete	———	1848,56	0,000	significant
Dimension Body of Proof x Type of Laboratory	———	0,02	0,893	not significant
Dimension Body of Proof x Type of Concrete	———	1,88	0,175	not significant
Type of Laboratory x Type of Concrete	———	48,47	0,000	significant
Dimension x Type of Laboratory x Type of Concrete	———	8,56	0,005	significant
Where: SQ = sum of squares; F = parameter of Fischer to the test of significance of the effects; p = probability of error involved in accepting the observed result as valid, this is, as representative of the sample; Result = result of the analysis, indicating that the effect is significant or not, $R^2 = (1 - SQerro/SQtotal)$.				

The analysis of variance showed compression strength of the resulting value of the coefficient of determination adopted (R^2) was 0.96, which means that 96% of the total variance of the data compression strength can be explained by variable adopted. Therefore, uncontrolled factors accounted for approximately 4% of the variations observed in the study.

With respect to the influence of intensity, taking as a basis the magnitude of F values, it can be seen the great influence of the type of the laboratory and the results of concrete compressive strength.

The interaction effects were also statistically significant, that is, for each type of laboratory used depending on the size of the specimen and the type of concrete, the compression strength of concrete presents difference result (different behavior).

In column F values of Table 3.2, the interactions involving the effect of the size of the specimen x type laboratory showed the lowest values, indicating less influence of this variable on the results of compressive strength. Stands out even the individual effect of variable dimension of the specimen is not significant, ie, the dimensions of the specimens studied (100 mm x 200 mm and 150 mm x 300 mm), alone and interacted with type laboratory or type of concrete does not significantly influence the results of compressive strength.

As a result of ANOVA - Compressive Strength (Table 3.2) have revealed the significant effects of the variables type of laboratory and type of concrete, there was the grouping of homogeneous medium by the method of Duncan, in order to observe the similarities and differences the obtained results.

In this method, it was shown that laboratories A and B show similar results, as the average overall compressive strength of the laboratory was 52.0 MPa and average overall compressive strength of laboratory B was 50.1 MPa, this is the lab a had only 4% higher overall average compressive strength compared to laboratory B. Therefore, depending on the laboratory used for the test, the values of resistance to compression approach.

After taking the average of the grouping factor type of concrete by the method of Duncan, it was shown, as expected, that the specific type of influence values of compressive strength as the overall average compressive strength of the concrete was Class C30 35.9 MPa and average overall resistance to compression (CAR high strength concrete) was 65.8 MPa, that is, the CAR was more than 83% overall mean compressive strength compared with concrete class C30 .

FIGURE 3.1 shows the graphical analysis of the study, showing the results for each variable.

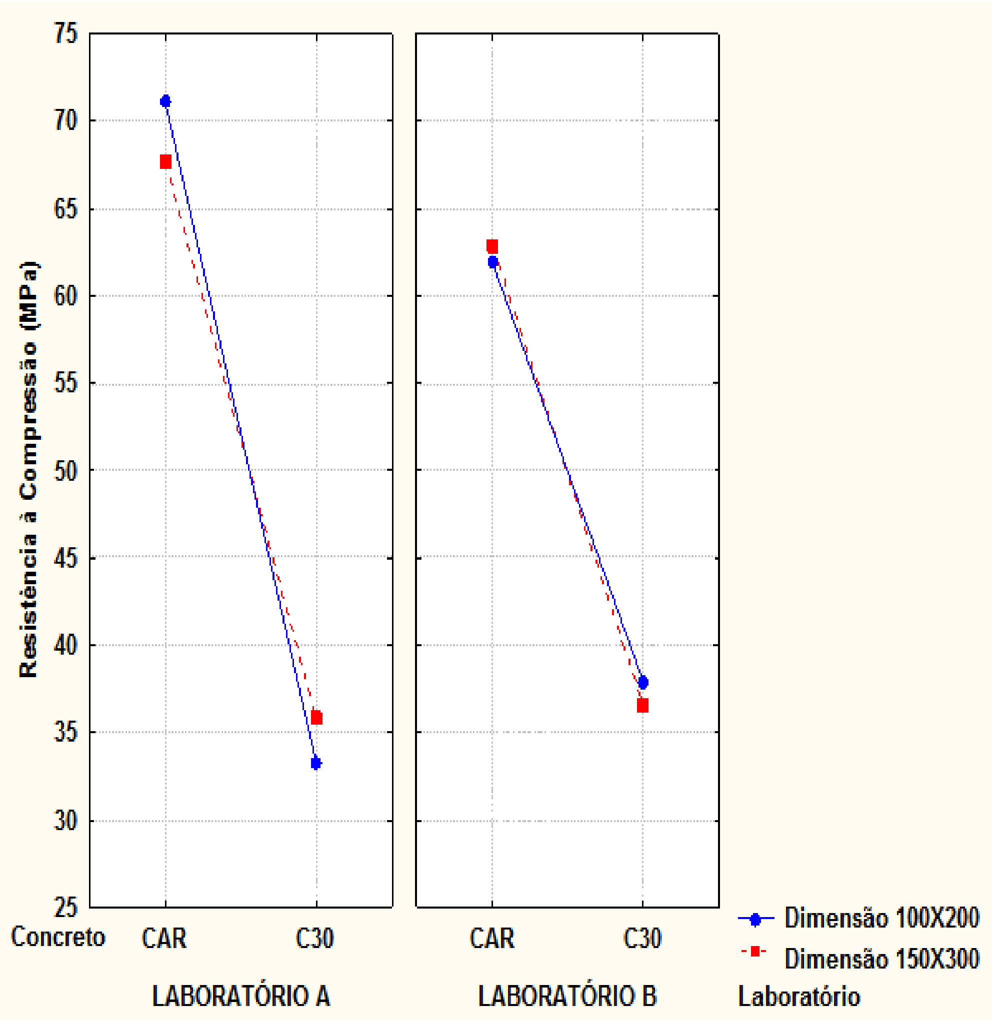

Figure 3.1 - Average resistance to compression by body size-de-race, class and type of concrete lab

Figure 3.1 shows the values of compressive strength are shown next to two dimensions of the specimens. As for specimens with dimensions 100 mm x 200 mm, the results of the compressive strength of the concrete class C30 and CAR (High Strength Concrete) in the laboratory, shown in Figure 3.1, showed averages of 33.2 and 71 MPa, 1 MPa, and their coefficients of variation were 3.5% and 3.4%. In contrast, in laboratory B the results showed average compressive strength of 37.9 MPa and 61.9 MPa, and their coefficients of variation were 2.5% and 9.4%. As regards the size 100 mm x 200 mm, it was found that the concrete class C30 showed greater dispersion in the laboratory, ie the concrete class C30, 1% more than the coefficient of variation in the laboratory with the laboratory B. Already, CAR showed greater dispersion B in the laboratory, or CAR was more than 6% coefficient of variation B in the laboratory compared with the laboratory A.

As for the test specimens with dimensions 150 mm x 300 mm, the results of the compressive strength of the concrete class C30 in the laboratory and CAR, shown in Figure 3.1, show averages of 35.9 MPa and 67.7 MPa, and its coefficients of variation were 1.5% and 6.8%. In contrast, in laboratory B the results showed average compressive strength of 36.6 MPa and 62.8 MPa, and their coefficients of variation were 2.2% and 3.6%. As regards the size 150 mm x 300 mm, it was found that the concrete class C30 in the laboratory showed greater dispersion B, ie, concrete class C30 had more than 0.7% coefficient of variation in lab lab B in relation to A. Already, CAR showed greater dispersion in the laboratory, or CAR was more than 3.2% coefficient of variation in the laboratory compared with the laboratory B.

Because of the samples with dimension 100 mm x 200 mm had the highest dispersion of results, the variable dimension of the specimen was highlighted in subsequent analyzes presented by FIGURES 3.2 and 3.3.

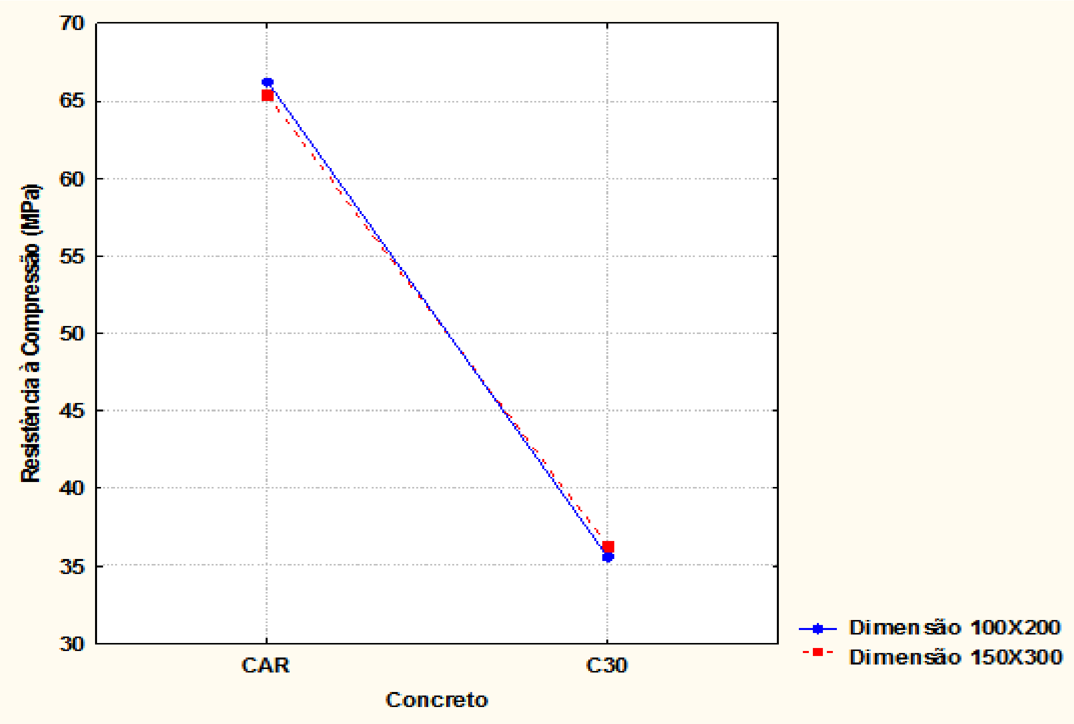

FIGURE 3.2 - Average resistance to compression: effect of concrete type and size of the body-of-evidence, encompassing the values obtained by all laboratories

Figure 3.2 shows the effect of the type of concrete, having CAR (high strength concrete) presented the results of compressive strength higher than average. As for the test specimens with dimensions 100 mm x 200 mm, the results of the compressive strength of the concrete class C30, and CAR, shown in Figure 3.2, show averages of 35.6 MPa and 66.3 MPa, and the coefficients of variation were 7.3% and 9.7%. Now, as the specimens with dimensions 150 mm x 300 mm, the results showed average compressive strength of 36.2 MPa and 65.4 MPa, and the coefficients of variation were 2.1% and 6.7 %.

As for the concrete class C30, it was found that the samples with dimension 100 mm x 200 mm higher dispersion (coefficient of variation 5.2% higher) compared to specimens with dimensions 150 mm x 300 mm. As for the CAR, it was found that the samples with dimension 100 mm x 200 mm higher dispersion (coefficient of variation 3% higher) compared to specimens with dimensions 150 mm x 300 mm.

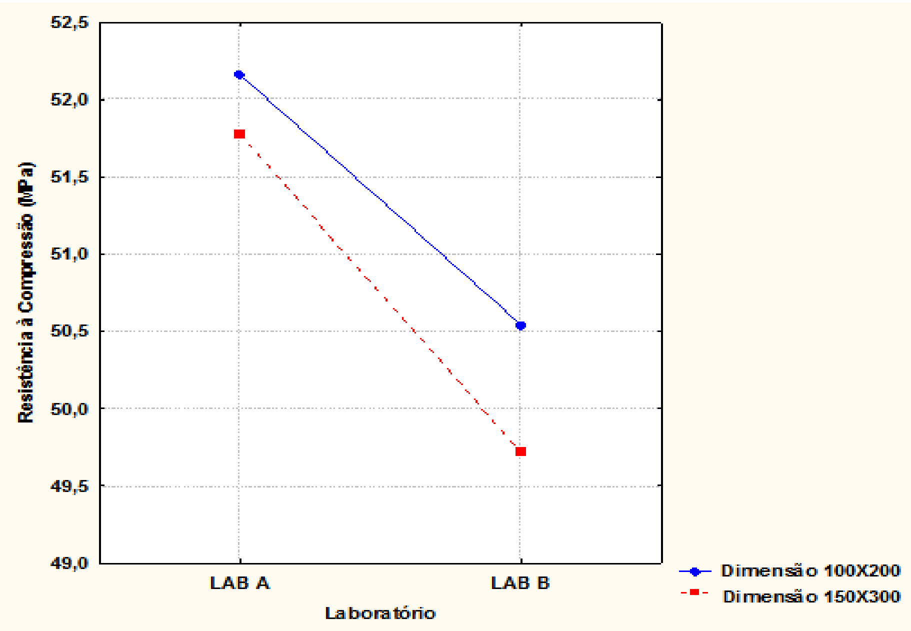

FIGURE 3.3 - Average resistance to compression: effect of the type of laboratory (LAB = LAB) and the effect of the size of the body of the test piece, involving the values obtained on specific types of concrete.

Figure 3.3 shows the effect of the type and size laboratory test body, and the laboratory results presented compressive strength greater.

As for the test specimens with dimensions 100 mm x 200 mm, the results of compressive strength in laboratories A and B shown in Figure 3.3, show averages of 52.2 MPa and 50.5 MPa, and their coefficients of variation were 37.5% and 25.8%. Now, as the specimens with dimensions 150 mm x 300 mm, the results of compressive strength in laboratories A and B showed averages of 51.8 MPa and 49.7 MPa, and the coefficients of variation were 32.1 % and 27.3%.

As for the laboratory, it was found that the specimens with dimensions 100 mm x 200 mm higher dispersion (coefficient of variation 5.4% higher) compared to specimens with dimensions 150 mm x 300 mm. Regarding lab B, it was found that the specimens with dimensions 150 mm x 300 mm higher dispersion (coefficient of variation 1.5% higher) compared to specimens with dimensions 100 mm x 200 mm.

[4]. CONCLUSION

The true scope of a search is to provide data capable of supporting answers and solutions for the unknowns in the different fields of human knowledge. Thus, the final considerations aimed at compiling the most important information, cast off the results and settle the practical aspects of the study, facilitating access through technical scientific discoveries.

The final considerations drawn from the presentation and analysis of results presented earlier considered: the influence of the concrete class, the size of the specimen, the type of laboratory test, and the comparison between these variables obtained in the study and their applicability in the analysis and inspection of concrete structures.

The knowledge of the compressive strength of concrete is a matter of fundamental importance, both in the design and implementation stages as in the case of assessments of the quality of the structures in use. It is necessary to understand the concepts of the test requirements and the variables that influence, to interpret the results and to rule out possible discrepancies caused by deficiencies of the test equipment or operator.

1. As for the concrete class C30, it was found that the samples with dimension 100 mm x 200 mm higher dispersion (coefficient of variation 5.2% higher) compared to specimens with dimensions 150 mm x 300 mm. As for the concrete class C60, it was found that the samples with dimension 100 mm x 200 mm higher dispersion (coefficient of variation 3% higher) compared to specimens with dimensions 150 mm x 300 mm (Figure 3.2). Therefore, specimens with dimensions 100 mm x 200 mm higher dispersion. This behavior was also obtained by the research of Martins (2008).
2. As for the laboratory, it was found that the specimens with dimensions 100 mm x 200 mm higher dispersion (coefficient of variation 5.4% higher) compared to specimens with dimensions 150 mm x 300 mm. Regarding lab B, it was found that the specimens with dimensions 150 mm x 300 mm higher dispersion (coefficient of variation 1.5% higher) compared to specimens with dimensions 100 mm x 200 mm (Figure 3.3).
3. Although the results obtained from specimens 100 mm x 200 mm have a higher dispersion (higher coefficient of variation), the difference is not significant with respect to these results obtained from specimens 150 mm x 300 mm (evidenced in table 3.2).
4. The participating laboratories test showed wide divergence of results, although they were following the standard guidelines. This serves as a warning of the need for further investigations, especially in regard to the influence of the concrete types, dimensions of test specimens and the different processes used by the laboratories involved in the study.
5. Although the results obtained from specimens 100 mm x 200 mm have a higher dispersion (higher coefficient of variation), the difference is not significant with respect to these results obtained from specimens 150 mm x 300 mm (evidenced in table 3.2).

In general, the steps inspection of concrete structures involve a series of activities ranging from the collection and analysis of designs and specifications to the planning and development of research methodology. Furthermore, the effectiveness of the evaluation depends on the knowledge and experience on the part of the researcher. The successful application of the correlations obtained in this study is deeply associated with the professional expertise and prior knowledge about the method of determining the compressive strength of concrete.

It is noted that the results obtained here are valid for materials and test conditions adopted, therefore, should consider this limit research.

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