ANALYSIS OF CONCRETE COMPRESSION RESISTANCE DUE TO THE INCORPORATION OF SYNTHETIC DETERGENT AS A PLASTICIZING ADDITIVE

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ABSTRACT

The aim of this study was to compare the strengths of 30 specimens cast from Portland cement concrete with different concentrations of detergent. Six reference Portland cement concrete specimens and six Portland cement concrete specimens with plasticizer additives were used. The trace used was the same for the samples of the 6 dosages studied. The Portland cement reference concrete was molded with concrete without the additive mixture, the 01 to 05 dosages of specimens received the addition of different synthetic detergents and, finally, the last dosage was concrete with a plasticizing additive. For all the specimens, the slump test was carried out to analyze the concrete slump of each dosage. Procedure for molding and curing test specimens and NBR NM 67 (1996): Concrete: The molding of the specimens and the slump test were carried out in accordance with NBR 5738(2015): Concrete: The consistency of the cone trunk,respectively, with the help of equipment from the civil construction laboratory at Unesc - Colatina (ES). After molding, the specimens were stored in water tanks until they had cured for 28 days and were then broken using an EMIC model automated press: PC200c. Analyzing the results of the strengths of the test specimens, it can be seen that the strength of dosage 4 obtained an average of 10.79 MPa, compared to the dosage of the reference concrete with an average of 21.44 MPa, but the plasticity of these dosages (1 to 5) was directly proportional to the amount of detergent applied to the concrete.

Keywords: *Concrete; plasticizing additive; strength.*

1 INTRODUCTION

Analysis of the compressive strength of concrete is a fundamental aspect of civil engineering, as it directly influences the durability and safety of reinforced concrete structures. The search for methods to improve the mechanical properties of this material has been the focus of intense research. However, the incorporation of additives has been highlighted as a promising strategy for improving concrete performance. One of the additives under study is synthetic detergent, a substance with

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properties capable of altering the mechanical characteristics of concrete, especially with regard to its resistance to compression.

The primary function of a plasticizing additive, such as synthetic detergent, is to modify the mechanical properties of concrete, promoting significant improvements in the workability of the material. The ability to reduce the amount of water needed to mix the concrete, maintaining its plasticity and facilitating the molding process, is one of the advantages sought with the use of these additives. However, understanding the specific negative impact of the synthetic detergent on compressive strength is crucial to validating its viability as a plasticizing additive.

The main objective of this study is to investigate the feasibility of using additives in concrete without technical criteria, which are regulated by NBR 11768 (Associação Brasileira de Normas Técnicas [ABNT], 2011), which specifies the requirements for chemical additives for the preparation of Portland cement concrete.

The research involves adding 5 different dosages of synthetic detergent to concrete and checking its compressive strength and determining the consistency of the concrete by the cone trunk slump according to the requirements of NM 67/1996 *(Slump test),* providing a possible low-cost solution for use in construction.

The general objective of the chosen research is to study the feasibility of using synthetic detergent in concrete and the possible problems caused by the inappropriate use of this additive in construction. The detergent used in the kitchen costs around R$1.50 for a 500 ml bottle.

Therefore, this article proposes an analysis of the influence of incorporating synthetic detergent as a plasticizing additive on the compressive strength of concrete. The effects of this additive in different proportions and curing conditions will be examined, with the aim of providing valuable results for professionals in the field and contributing to the advancement of scientific knowledge in the development of more efficient and sustainable technologies in the construction industry.

2 PORTLAND CEMENT

Portland cement is a product obtained by pulverizing clinker made up essentially of hydraulic calcium silicates, with a certain proportion of calcium sulphate (Bauer, 2013).

According to Lopes (2017), cement is considered a hydraulic binder and hardens in the presence of water, resulting from a homogeneous mixture of clinker, gypsum and additions of other substances that modify its properties or facilitate its use.

Portland cement is obtained by grinding a product called clinker, which is obtained by cooking 30% of the liquid phase of a mixture of limestone and clay until it melts. Let’s take a look at the main components that make up cement, which are determined by chemical analysis: Lime (CaO), Silica (SiO2), Alumina (Al2O3), Iron oxide (Fe2O3), Magnesia (MgO) (Petrucci, 1998).

According to Bauer (2013), the chemical properties of Portland cement are directly linked to the process of hardening by hydration, and it is currently assumed that a process takes place comprising dissolution in water, precipitation of crystals and gel with hydrolysis and hydration of the cement components.

Cement stability is a characteristic linked to the possible occurrence of undesirable volumetric expansions when the concrete hardens and results from the hydration of lime and free magnesia present in it, the heat of hydration, during the cement hardening process. The thermal energy produced is of great interest due to the rise in temperature resulting from bulky works, which leads to the appearance of shrinkage cracks at the end of the cooling process. The heat of hydration of ordinary Portland cement varies between 85 and 100 cal/g, reducing to 60 to 80 cal/g in cements with a low heat of hydration (Bauer, 2013).

These are the classic theories that try to explain hydration, such as Le Chatelier’s and Michaelis’. In Le Chatelier’s theory, hardening is explained by the engulfment of crystals formed by the crystallization of a supersaturated solution of hydrated compounds that are less soluble than anhydrous ones. According to the Michaelis theory, the hydration of cement gives rise to a supersaturated solution and crystals form in hexagonal needles and vanes.

The physical properties of Portland cement should be analyzed in three aspects: the natural condition of the powder, its mixture with water and its mixture with aggregates (Petrucci, 1998).

According to NBR 5732 (ABNT, 1991), common Portland cements are designated by the acronym CP - Portland Cements, which corresponds to the additions present, or not, and their strength classes.

Several types of cement are produced, officially standardized. There are type 1,2,3,4,5 cements, which are produced in Brazil.

> **Type 1 Portland cement** is commonly used in general construction work. It is a natural development of cement manufactured before 1936.
>
> **Type 2 Portland cement,** known as a modifier, is a cement with a moderate development of heat of hydration. It was widely used for paving and recommended for large, moderate-sized buildings.
>
> **Type 3 Portland cement** is the cement with the highest initial strength, differing from type 1 by the higher proportion of C3S and greater fineness.
>
> **Type 4 Portland cement** is a cement with a very low heat of hydration, intended for use in large-scale voluminous constructions.
>
> **Type 5 Portland cement** is intended for use in works where resistance to attack by sulphated water is important (Bauer, 2013, emphasis added).

According to Bauer (2013, p. 270), the notion of workability is therefore much more subjective than physical. The most important physical component of workability is consistency, a term which, when applied to concrete, translates the intrinsic properties of the fresh mixture, related to the mobility of the mass and the cohesion between the component elements. The workability of the concrete is fundamental in order to achieve compaction that ensures the maximum possible density, with the application of a quantity of work compatible with the densification process to be used. Mixtures of cement, aggregate and water form air bubbles, which are trapped during mixing. The voids in hardened concrete that result from this air and the uncombined water that is removed are called pores.

With the optimum amount of water, the maximum density of the concrete will be obtained and there will be greater concrete strength and better adhesion and anchorage of the reinforcement, as well as better impermeability and resistance to aggressive agents. Consistency is the most important factor influencing workability. Each type of concrete must have a suitable consistency. Different workability is required for each type of mixture, transport, laying and compacting, so that there is no segregation and convenient compaction can be achieved. Manual or mechanized mixing, transport by wheelbarrow or pump, dumping with shovels or chutes, manual, vibratory, vacuum or centrifugal densification all require different skills (Lopes, 2017).

Workability is defined by the ease with which the materials that make up the concrete can be mixed. The ease with which concrete can be transported and placed with a minimum loss of homogeneity is a property made up of at least two, fluidity and cohesion. The workability of concrete is very high and must be met. Regardless of the dosing procedures used, such as cost, a concrete mix that cannot be easily cast or fully compacted will probably not provide the expected strength and durability characteristics. Table 1 lists numerous properties of fresh concrete linked to workability, such as consistency, texture, mass integrity, water retention capacity and specific mass. Here are some factors that affect workability (Lopes, 2017):

Factors affecting workability	
A - Internal factors: (linked to the concrete components)	B - External factors: (linked to production operations)
1: Consistency (water/dry mix ratio ➝A%) 2: Cement/total aggregate ratio➝ fines content 3: Proportion between aggregates➝ (a/p) 4: Proper grain shape of aggregates 5: Plasticizing additives (water reducers)	1: Types of mixing, transportation, pouring and densification 2: Dimensions and reinforcement of the part to be made

Table 1: Factors affecting workability
Source: Lopes (2017, p.164)

According to Lopes (2017), concrete can be defined as the result of mixing cement, water, fine aggregate (usually sand) and coarse aggregate (usually gravel). When mixing concrete, Portland cement and water form a fluid paste, depending on the amount of water added. This paste has the function of binding the aggregates (fine and coarse) together, forming a material that, in the first few hours, is in a state capable of being molded.

Also according to Lopes (2017), over time, water reacts irreversibly with cement, hardening the mixture and creating high mechanical resistance, which makes it an excellent material for structural performance in the most diverse exposure environments. The function of the paste is to envelop the aggregates, filling the voids formed and giving the concrete handling possibilities when freshly mixed, and also to bind the aggregates in the hardened concrete, giving it a certain impermeability, resistance to mechanical stress and durability against aggressive agents. Aggregates have the function of providing grains capable of resisting stresses, wear and weathering, reducing variations in volume due to various causes and cost, since the cost of aggregates is lower than the cost of cement.

According to Lopes (2017, p.161), “in addition to the paste and aggregates, chemical compounds are added, called additives or mineral products, and their main differences between additives and additions are in their origin and their properties”.

According to Lopes (2017), the dosage or mix of concrete can be defined as the proportion between all the materials that make up the concrete.

The proportion of each material defines the characteristics of the mix, so if you increase one input and decrease another, you get concrete with different characteristics. It is important that each material used in the dosage is previously analyzed in the laboratory (according to ABNT standards), in order to check the quality and obtain the data needed to prepare the dosage (specific mass, granulometry, etc.) (Lopes, 2017, p. 161).

According to Lopes (2017), the experimental dosage is made according to the following proportion:

1: Addition: a: b: a/c: adt%, where,

> **1:** Unit of cement by mass, e.g. 1 kg.
> Addition: Mass quantity of addition
> **a:** amount, by mass, of fine aggregate in relation to the mass of cement
> **b:** amount, by mass, of coarse aggregate in relation to the mass of cement
> **a/c**: ratio between water and cement, or between water and binder, by mass
> **Adt%:** relation between mass of additive and mass of cement, in percentage.
> (Lopes, 2017, p.162).

Mortar is a building material made up of a homogeneous mixture of one or more binders, fine aggregate and water. They differ in that they have plastic and adhesive characteristics and, when applied, become rigid and resistant after a certain period of time.

> Additives are added to the mix, in small quantities, with the aim of improving one or more of the mortar's properties in both the fresh and hardened states. The use of additives is often related to reducing drying shrinkage (to reduce cracks), increasing setting time while maintaining plasticity and also to increase the adhesion of the mortar to the substrate (Lopes, 2017, p. 168).

According to Petrucci (1998), cement can be qualified from the point of view of its resistance to mechanical stress in two ways: the first considers the order of their quality, and the second, the future use of the binder in known mortars and concretes, by means of previous cement behavior tests. Mechanical resistance is tested with cement in the form of mortar, which is easier to make and more representative.

According to Santos (2018), compressive strength is the property most used in the technological control of concrete. This parameter can be associated with other concrete properties (creep, modulus, etc.) and is also associated with durability.

According to NBR 5739 (ABNT, 2018), compressive strength is determined by testing cylindrical specimens, with the 10 x 20 cm dimension (diameter x height) usually used due to its ease of handling.

According to Santos (2018), when determining the dimensions of the test specimen, a height/diameter ratio (h/d) between the range must be met: 1.94 < h/d ≤ 2.02, the maximum permissible ratio being 2.02. If the h/d ratio is less than 1.94, a correction factor must be applied. The equation for determining compressive strength is as follows:

$$f_c = \frac{F}{A} . 0{,}098\ f_{hld}$$

Figure 1 - Equation for determining resistance.
Source: Santos (2018, p.60).

Where f_{hld} *is the shape correction factor.*

NBR 5738 (ABNT, 2015) prescribes the procedure according to the concrete's slump, establishing the use of immersion vibrators or manual densification (tamping with a tamping rod). Incorrect densification leads to concrete failure (known as pitting) and consequent variation in strength between specimens of the same age and at different ages, compromising the expected test results.

According to Fusco (2013), the strength measured using the control specimens does not represent the strength of the concrete in the corresponding structure, as the concreting and curing conditions are different for the two cases.

3 MATERIALS AND METHODS

The research was carried out in the laboratory of the University Center of Espirito Santo - UNESC. The main parameters for preparing the concrete mix followed the ABCP (Brazilian Portland Cement Association) method and Brazilian technical standards, taking into account mass dosages. Until the test age, the specimens were kept in a saturated curing process, under the conditions recommended by NBR 5738/2015, and compression was broken at a specified age, with time tolerances according to the recommendations of NBR 5739 (ABNT, 2018). The concrete mix was set at 25 Mpa in order to carry out the tests of characteristic resistance to axial compression and concrete consistency by cone trunk slump, as shown in Table 1.

TABLE 1: CONCRETE MIX

Mass trace (kg)	Kg
Cement	1
Sand	2.252
Gravel	3.195
Water	0.60

Source: Prepared by the authors.

The experiment consisted of producing conventional concrete with and without commercial additives, and concrete with 5 different dosages, in accordance with the requirements of NBR 5738 (ABNT, 2015), using synthetic detergent with a sample of 6 specimens for each group mentioned.

Table 2 shows the number of specimens made with the dosages of detergent and plasticizing additive used. For each group in the table, the consistency of the concrete was determined by the cone trunk slump, according to the requirements of NM 67/1996 *(slump-test).*

TABLE 2: NUMBER OF SPECIMENS.

Groups (treatment)	No. of specimens (n)	Detergent dosage (per Kg of cement)	Dosage of Plasticizing Additive (per Kg of cement)
Conventional concrete without admixture (reference)	6	-	-
Concrete dosed with synthetic detergent - dosage 01	6	10 ml	-
Concrete dosed with synthetic detergent - dosage 02	6	20 ml	-
Concrete dosed with synthetic detergent - dosage 03	6	30 ml	-
Concrete dosed with synthetic detergent - dosage 04	6	40 ml	-
Concrete dosed with synthetic detergent - dosage 05	6	50 ml	-
Conventional concrete with commercial admixture	6	-	4 ml

Source: Prepared by the authors.

The fresh state of the concrete was used to determine its slump by means of the slump test, as shown in Figure 2,

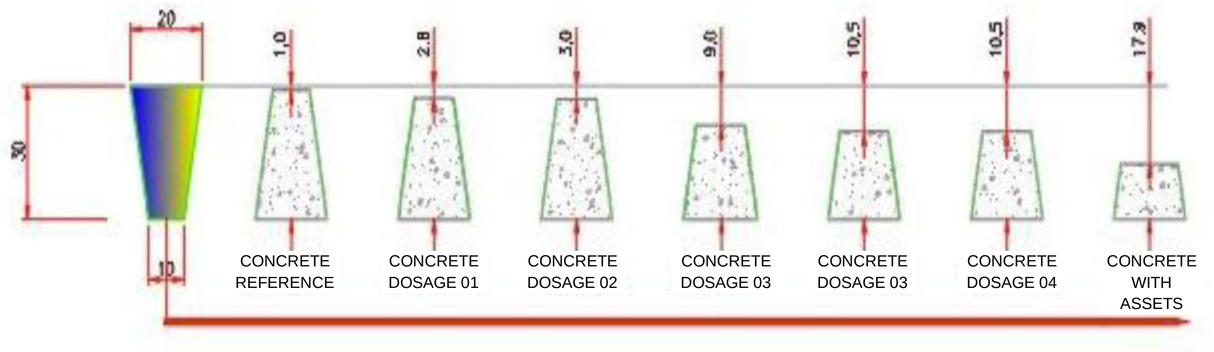


Figure 2 - Slump test, data in cm
Source: Prepared by the authors.

To produce the test cups, the materials were weighed on a scale with a capacity of 15 kg available in the laboratory. Once the specific dosage had been made according to table 4, the specimens were placed in the molds for 24 hours. After this period, they were submerged for 28 days, as shown in Figure 3.

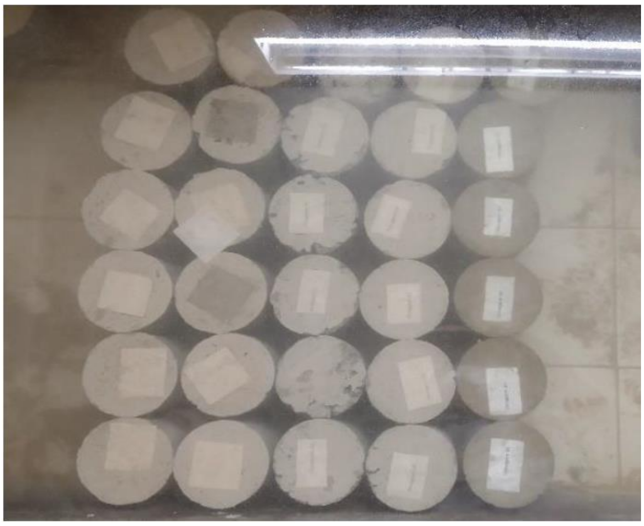


Figure 3-Test specimens
Source: Prepared by the authors.

All the specimens presented were manufactured in the same way in the laboratory and underwent the same curing conditions until the simple compression tests (28 days) to determine the characteristic strength of each group.

A hydraulic press was used for the axial compressive strength test, as established by NBR 5739 (ABNT, 2018), as shown in Table 3.

TABLE 3: COMPRESSIVE STRENGTH TEST

Groups (treatment)	Resistance Average (Mpa)	Standard Deviation
Conventional concrete without admixture (reference)	21.44	1.38
Concrete dosed with synthetic detergent - dosage 01	17.69	0.78
Concrete dosed with synthetic detergent - dosage 02	13.30	1.63
Concrete dosed with synthetic detergent - dosage 03	13.39	0.81
Concrete dosed with synthetic detergent - dosage 04	10.79	0.39
Concrete dosed with synthetic detergent - dosage 05	11.63	0.54
Conventional concrete with commercial admixture	16.58	0.78

Source: Prepared by the authors.

4 RESULTS AND DISCUSSION

4.1 LAYING THE CONCRETE

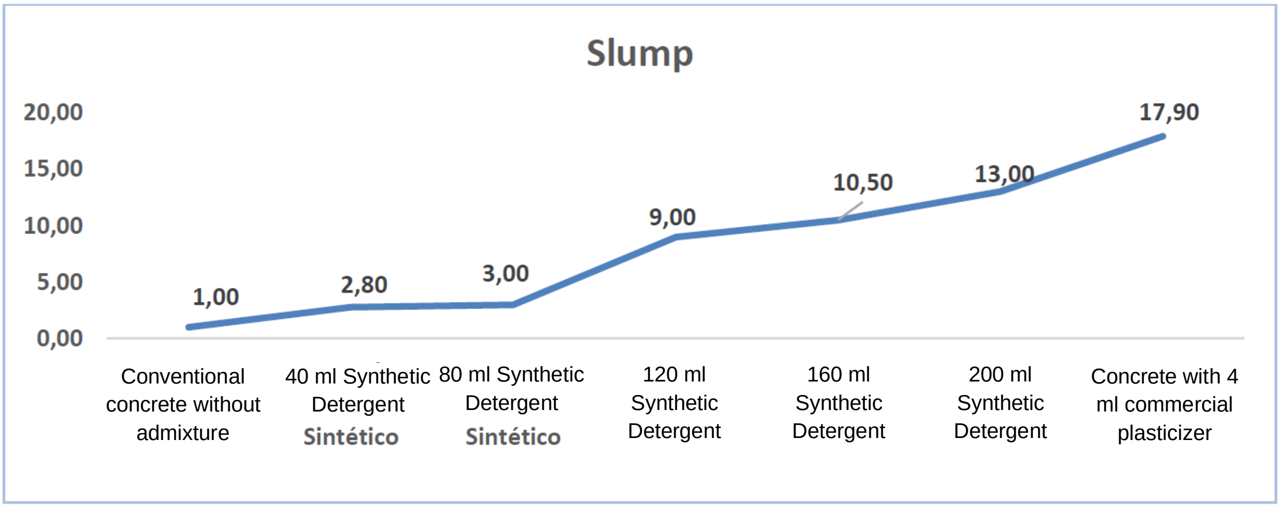
The cone slump test *(Slump)* of the concrete was carried out (table 4) in accordance with NM 67/1996 (slump-test). The method has the specific aim of determining the consistency of fresh concrete by measuring its settlement. Finally, it serves as a parameter for studying the workability and consistency of the concrete that will be used on site.

TABLE 4: CONE SLUMP TEST.

Groups (treatment)	Slump (cm)
Conventional concrete without admixture (reference)	1.00
Concrete dosed with synthetic detergent - dosage 01	2.80
Concrete dosed with synthetic detergent - dosage 02	3.00
Concrete dosed with synthetic detergent - dosage 03	9.00
Concrete dosed with synthetic detergent - dosage 04	10.50
Concrete dosed with synthetic detergent - dosage 05	13.00
Conventional concrete with commercial admixture	17.90

Source: Prepared by the authors.

The *Slump* reading of the concrete was measured in centimeters. It was observed that the behavior was directly proportional to the amount of detergent added, tending to be denser and less workable for percentage increases in detergent. In the results of the *Slump test* (graph 1), the conventional concrete without additive obtained a *slump* of 1 cm, very different from the result observed in dosage 01 with 40 ml of detergent, in which the slump rose to 2.8 cm. The other dosages, 02, 03, 04 and 05, followed the linear growth trend with values of 3.0, 9.0, 10.50 and 13.00 centimeters, respectively.



Graph 1: ***Slump test***
Source: Prepared by the authors.

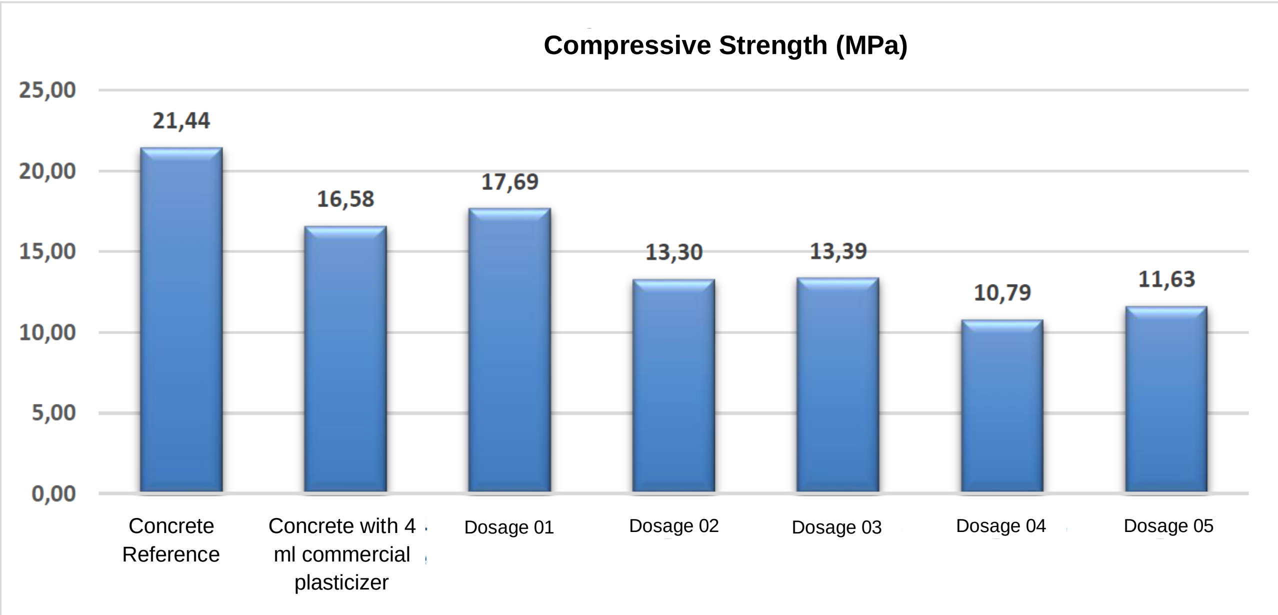
The *slump* in figure 4 consists of dosage 01 of synthetic detergent. We added 40 ml and obtained a reduction of 2.80 cm.

Figure 4: Dosage 1
Source: Prepared by the authors.

In figure 5, the synthetic 05 dosage was used, with 200 ml added, showing a 13.00 cm drop.

Figure 5: Dosage 4
Source: Prepared by the authors.

In the results of the compressive strength test (Graph 2), with the dosages with detergent 01, 02, 03, 04, 05, it can be seen that they did not meet the NBR 8953 standard (ABNT, 2015), in which, to be a structural concrete, it needs to be above fck 20.0 Mpa. Only the reference concrete achieved the performance established by the standard. It can be seen that the addition of detergent to the concrete generated a lower characteristic axial compressive strength when compared to the reference concrete.



Graph 2 - Compressive strength test results
Source: Prepared by the authors.

5 CONCLUSION

With this work we can conclude that the concrete has excellent workability with the addition of neutral detergent, but poor mechanical strength.

Therefore, with the addition of the neutral synthetic detergent, which allows for better workability in concrete, but makes its use unfeasible due to its low compressive strength, its use in concrete and its indiscriminate use in construction could lead to future structural problems.

With the results obtained, it was noted that, in the characteristic compressive strength test carried out with the addition of detergent, the average strength was below 20Mpa, so it was not considered a structural concrete, according to the strength class of NBR 8953 (ABNT, 2015).

Therefore, the use of detergent in construction is a vice, with its use incriminated and incompatible when added to concrete as an additive. Due to a lack of technical knowledge and qualified professionals, this trial and error method of using detergent and its use will cause economic losses under the false illusion that a product suitable for construction purposes is being used.

For future studies, it is suggested that an electron microscope be used on the concrete to investigate whether there is a physical-chemical transformation that leads to problems in hydration, setting, curing and, subsequently, to the various processes that generate concrete degradation.

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