# Cement After Expiry Date: Effect in the Concrete Properties

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**Abstract.** Portland cement has been widely used around the world to produce concrete. When Portland cement is not used correctly, following the normative prescriptions, its use can compromise the aesthetics and the safety of structures. The present research consisted of analyzing the workability of concrete in fresh state and compressive strength in its hardened state when using Portland cement with expired date higher than 90 days defined by the Brazilian standard NBR. For the tests, three cements were selected with different manufacturing dates: November 2018, July 2019 and August 2020. The workability was assessed through the slump test and the compressive strength test at the ages of ages 1, 7, 14 and 28 days. The mix used was for a compressive strength of 25 MPa at the age of 28 days. The slump tests showed divergent values regarding to the expired cements, leading to inconclusive findings, because even with the w/c change, the slump achieved for the 2019 cement-based concrete was lower than that recommended for common concrete. It was concluded that the compressive strength decreased for concretes produced with expired cement.

**Keywords:** Cement; Compressive strength; Concrete; Expired date; Workability.

## 1 Introduction

The production capacity of the cement industries in Brazil in 2018 was 102 million tonnes. Sales in the sector peaked in 2014 with 70.9 million tonnes, in 2019 with the crisis in the civil construction sector, sales reached 54.3 million tonnes [1]. The retail trade distributes approximately 2/3 of this production, generally selling the cement in 50 kg bags, with the cement "ant" consumer (the one who purchases cement with hired or own labor for small repairs, renovations, or small constructions size) one of the final destinations [1],[2].

Irregular constructions occur outside inspections, monitoring by civil engineers and with current regulations, without proper technological control of the concrete used.

One of the basic requirements to be observed is the expiration date and the storage period. The storage of cement is recommended for 30 days, which may increase this period by up to 60 days depending on weather conditions [3], as the expiration date is 90 days according to NBR 16697 [4].

To minimize the energy crisis and the impacts caused on the environment due to the cement manufacturing, several researches were carried out about recycling expired cement and about the closed packaging method in which active silica and aged props were added [5]. Besides, the use of waste in concrete research is widespread: silica, rice husk, glass, plastics, construction and demolition waste are some of the various materials used in recycled concrete [6-9]. However, these studies carried out with concrete using cement after expiration date stipulated by the manufacturer and standards are still recent.

The present work aimed to understand and quantify the loss of quality of concrete in its fresh state regarding its workability and compressive strength in a hardened state when Portland cement is used after the expiration date determined by the NBR 16697 [4].

## 2 Materials and methods

For the tests, the composite cement with the addition of Filler (CP-II) with a strength class of 32 MPa was chosen. To make the concrete, cements with three different manufacturing dates were used, namely: 2018 sample, manufactured on November 29, 2018; 2019 sample manufactured on July 1, 2019; and sample from 2020, with manufacturing dated August 4, 2020. The other materials used to carry out the tests were: washed sand, coarse gravel, fine gravel and water.

Concrete composition followed ABCP method, an empirical method that uses basic information for the characterization of the component materials [10]. The mix 1:2.6:2.8:0.53 was used (cement, sand, gravel and water-cement), which should reach a characteristic compressive strength of 25 MPa at 28 days. After homogenization, the slump test was performed according to the Brazilian NBR NM 67 [11]. For the test, a slump of 70 mm was used, considering a concrete for an ordinary structure with plastic consistency [3].

Cements with the manufacturing date in November 2018, July 2019 and August 2020 were used. For the compressive strength, the specimens were tested at the ages of 1, 7, 14 and 28 days. Three specimens per cement per testing age (totaling 36 specimens) were tested.

After the 24-hour period of molding, the specimens were demolded, the specimens aged 1 day were submitted to the compressive strength test. Those scheduled to be tested at other ages were stored in a saturated solution of calcium hydroxide for the curing period and awaited the compressive strength test date provided for in the schedule. The compressive strength tests were carried out in a hydraulic press with manual activation, the results are displayed on a side panel to the equipment in tonne force, in compliance with the NBR 5739 - Concrete - Compression test of cylindrical

specimens [12]. The cylindrical mold used has dimensions of 10 cm in diameter and 20 cm in height.

## 3 Results and discussion

### 3.1 Analysis of the properties of fresh concrete

Workability is the most important property of concrete in fresh state [SOBRAL 8]. Slump between 60 and 80 millimeters is recommended for structural concrete of common use without the use of vibrators for consolidation [3]. The slump test was 80 mm for the 2018 sample, 20 mm for the 2019 sample and 70 mm for the 2020 sample.

To carry out the mix, a water-cement factor of 0.53 was initially established, but only the cement manufactured in 2018 was used. The concrete with cement manufactured in 2019 had to be corrected to 0.58 water-to-cement ratio (w/c) because the aggregates do not present cohesion with the cement paste during the homogenization process. Despite the small slump, it presented a homogeneous aspect among the constituent materials of the concrete and an adequate consistency. For the 2020 sample, the 0.58 ratio in the w/c factor was maintained, producing a concrete with the expected slump.

There are five factors that can modify the slump test: water content in relation dry mix; cement type and fineness; granulometry and grain shapes of aggregates; combined action of factors; time, temperature, and relative humidity. Bringing these parameters to the experiment, it was possible to preliminarily discard only one of them, granulometry and forms of the grains of the aggregates because aggregates of the same origin were used [13].

The water content in relation to the mixture was changed so that the concrete presented a homogeneous appearance after the mixture. The 2019 and 2020 samples used the same w/c factor, but presented divergent results, which leads to considering other parameters to understand the results.

Even with the use of a cement of the same brand, type and strength class, the fineness of the cement cannot be guaranteed due to the cement pre-hydration process that occurred due to its exposure in the environment over time. It can be inferred that the 2018 cement was the most affected, the 2020 sample can be disregarded as this factor as the cause of divergent results due to the short period of exposure and absence of rain and low relative humidity in the opening period packaging and carrying out the tests.

### 3.2 Analysis of the concrete compressive strength

The cement manufactured in 2018 was cobbled due to the long storage period, with different sizes amidst the characteristic powdery material, according to Fig. 1(a), being necessary to carry out the sieving of the cement before mixing the materials, as shown in the Fig. 1(b). The particles retained by the sieve were discarded to carry out the trace. It is noteworthy that the cement was sheltered in the concrete laboratory, protected from the most severe weather such as sun and rain, but still exposed to

moisture since it was in direct contact with the floor and with the open package. When removed from the molds, the samples showed edge breakage, as shown in Fig. 1(c).


**Fig. 1.** Visualization of the cement produced in 2018

The cement manufactured in 2019 was in the concrete laboratory stored in contact with the concrete floor and protected from the sun and rain. The poor storage associated with the long period was possibly responsible for the cementitious material clogging, as can be seen in Fig. 2(a), in the same way as the 2018 cement, it was necessary to carry out the preliminary sieving of the cement, the material retained in the sieve has been discarded. When removed from the molds, the samples presented good apparent quality similar to that expected for a concrete within the validity period, as can be seen in Fig. 2(b).

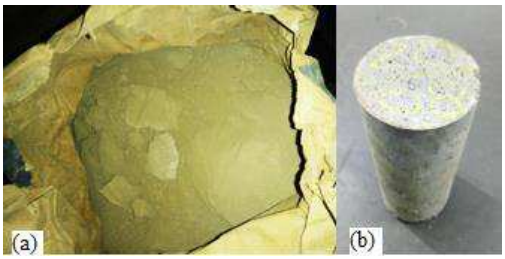


**Fig. 2.** (a) Cement manufactured in 2019, (b) concrete specimen with cement manufactured in 2019.

When removed the molds, the specimens from the cement from 2020 presented an appearance of good quality. The 2020 cement-based concrete presented satisfactory performance for all ages tested, reaching the expected strength at 28 days.

After an individual analysis of the concrete, it is important to observe the behavior of the specimens in comparison with the concrete produced with cement manufactured in 2020. Fig. 3 allows us to observe the trend line of each concrete for all ages until the 28th, notice the behavior analogous to a logarithmic function with a tendency to decrease the strength gain after 28 days. Concrete with cement out of date had a low value for the first ages, later showed a very gain in strength, with emphasis on cement from 2019, with values approaching that of cement from 2020.

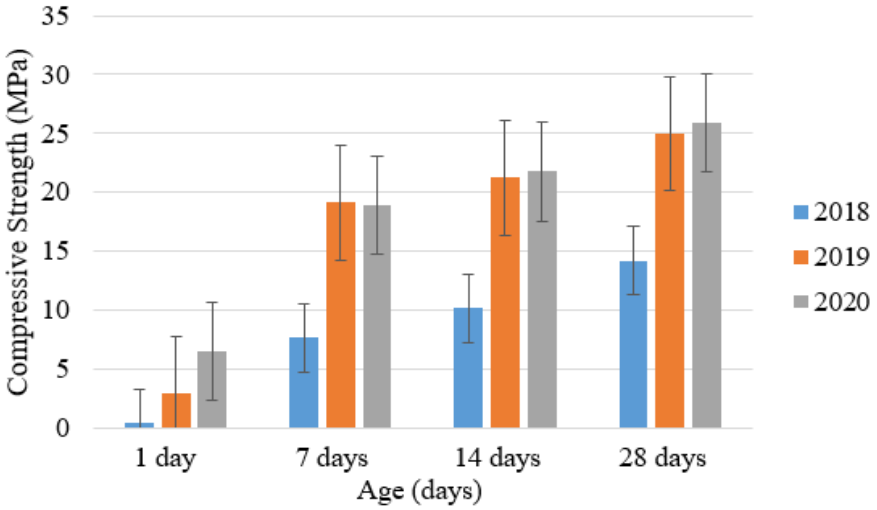


**Fig. 3.** Average compressive strength trendline.

As a guide, NBR 6118 [14] presents the values of 78% and 90% for the ages of 7 and 14 days of the estimated value for the age of 28 days. Analyzing this parameter, the 2018 concrete had much lower values for these ages, 30% and 40%. Concrete with cement from 2019 and 2020 had similar values and very close to those recommended by the standard.

The storage and storage of cementitious material in an inappropriate place and for a long period caused the pre-hydration of the cement, a fact that may have contributed to the low results of expired cements. The pre-hydration causes changes in the chemical composition and increases the surface area of the binder, forming a barrier that prevents chemical reactions when the cement meets water [15].

## 4 Conclusions

The present work investigated the loss of slump and of compressive strength of concrete when a cement with more than 90 days of manufacture. From the results, the following remarks are taken:

- The slump test to verify the workability was inconclusive when using cements beyond the expiration date, since even with the increase in the w/c factor for concrete with cement from 2019, it showed a lower reduction in relation to the concrete with cement from 2018.
- In regarding to the compressive strength, the cement manufactured in 2018 presented a low performance for all ages. The cement-based concrete manufactured in 2019 had a low compressive strength for the age of 1 day, approximately 45% of the value recorded for the cement-based concrete manufactured in 2020. However, for the other ages, the concrete showed satisfactory results for the test averages to compressive strength.

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