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Durability study of concrete container

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1. Introduction

The Brazilian National Nuclear Energy Commission works to implement of national repository for final storage of low and intermediate level radioactive wastes, CENTENA [1]. The concept of the disposal is a near-surface one, bringing unique and centralized solution for the radioactive waste in Brazil. According to the standard [2] the disposal will be made using multi-barriers, a technique to prevent the liberation of the radionuclides present in the waste. These barriers or layers can be natural, using materials from the construction site, as rocks, soils, etc. or can be engineered barriers, as concrete container or module [3].

Concrete is one of the most used materials in the world in civil constructions [3] and it is a composite material made by mixing water, cement and aggregates, being a fragile material, which needs some aggregates to improve its strength, with additions as armors and plasticizers, these are called special concretes. Among them, the steel fiber reinforced concrete is a material with better tensile strength and other properties. The fibers act in order to distribute the tension generated by the load, so they are useful in providing greater resistance to plastic shrinkage cracking and service-related cracking [3]. Although the concrete is one of the materials most used in the world, due some requirements related to the disposal construction in the repository, studies are needed to predict its behavior in the operational phase and in relation to aggressive agents during the lifetime of the whole system.

The corrosion is the most aggressive process to degradation of concrete. The main corrosion agents are ions as chlorides, sulfates, and carbonates, they penetrate through the interconnected pores of the concrete, reacting with armor and with some important substances to the concrete durability and strength, causing its weakness. It is intended to study the reinforced concrete with different additions of steel fibers for the concrete container. The research focus is to analyze the concrete characteristics, prepared with two types and two proportioning of fibers, using the standards [2] and [4], aiming its application in the disposal barrier system.

2. Methodology

Initially it was made the experimental design, using the factorial factor 2^2, varying the type of fibers: hooked-end or type H (-) and crimped or type C (+), and the proportioning: 1.50% (-) and 2.00% (+), generating the experiments, as presented in Table 1. The hooked-end and the crimped fibers were respectively donated by Belgo Bekaert and by Matcon Supply, while the aggregates and the superplasticizer were donations of Martins Lanna and of MC-Bauchemie, in this order.

Table 1: Factorial Planning 2^2

Factor				Experiment	
Fiber type		Proportioning fiber			
H	-	1.50%	-	-	-
				-	+
C	+	2.00%	+	+	-
				+	+

The concrete samples for the tests were cured during 28 days in alkaline solution, to analyze the compressive and tensile strength, according to standards [5] and [6]. The test of porosity was performed in agreement with the standard [7], determining the void ratio and absorption. The chloride corrosion tests were made in accordance with [8] and [9], using a saline solution, with concentration of 3.5% NaCl. For the sulfate study a solution of 5% $NaSO_4$ was prepared, as in [10], and finally to analyze the environmental durability the specimens were exposed in open air.

Each test lasts 28 days with 2 specimens. After that time, the compressive strength test will be performed according to standard [5], to check the effect of aggressive systems on the concrete. The parameters of the standards [2] and [4] are used to qualify the concrete, aiming at producing containers to radioactive waste for disposal, as tensile and compressive strength bigger than 5 MPa and 54 MPa, respectively.

3. Results and Discussion

As stated by [10], the concrete void ratio should be lesser than 10%. The Figure 1 presents the results up to this moment, comparing the compressive and tensile strength with the void ratio (index), after the porosity test. The results of compressive strength from experiments H (1.5%) and H (2.0%) don't reach the value established by the standard, 54 MPa, differently of the C (2.0%). This result is due to the high void index in H (1.5%), affecting the tensile strength, which presented the smallest value. The H (2.0%) presented the smallest compressive strength value below the reference, due the difficult with molding. On the other hand, all tensile strength results were above 5 MPa, confirming the present of fibers can improve some concrete properties. The best results for these first experiments were for the concrete samples with 2,0% of crimped fibers.

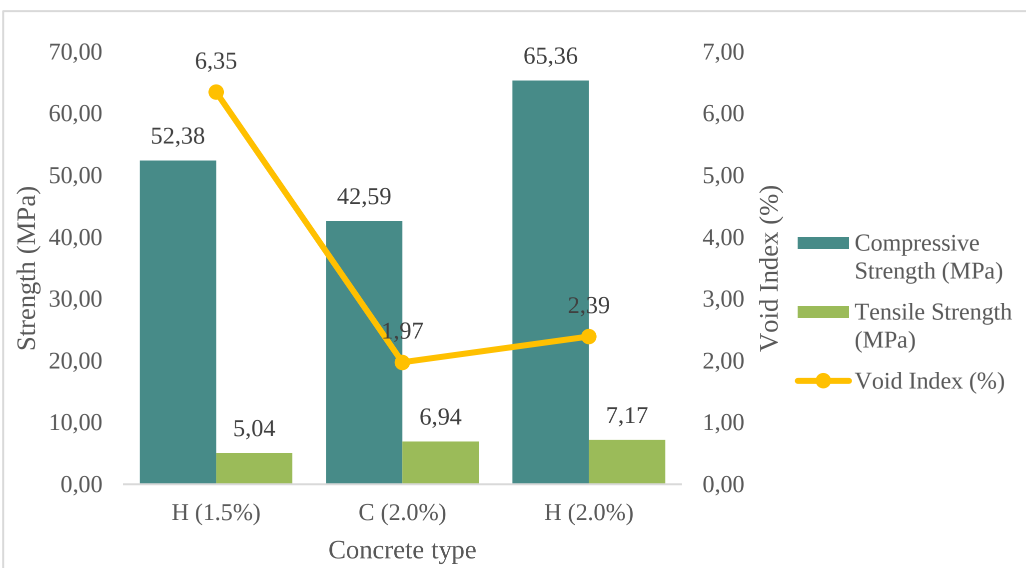

Figure 1: Partial results of porosity, compressive and tensile strength tests.

The results from the corrosive tests are not ready, because of the COVID-19 restrictions. According to [11] and Table 2, the higher aggressive process is class IV, for the ratio water/cement used is less than 0.45. Considering [12] the studied concrete is classified as C50, reaching compressive strength higher than 50 MPa, above C40. Therefore, from the partial results presented is expected the strength of corrosion tests will be smaller.

Table 2: Correspondence between aggressiveness class and concrete properties

Concrete	Type	Aggressive class			
		I	II	III	IV
Ratio water/cement in mass	CA	≤ 0.65	≤ 0.60	≤ 0.55	≤ 0.45
	CP	≤ 0.60	≤ 0.55	≤ 0.50	≤ 0.45
Concrete class [12]	CA	≥ C20	≥ C25	≥ C30	≥ C40
	CP	≥ C25	≥ C30	≥ C35	≥ C40
Cement Portland consumption per cubic meter of concrete kg/m^3	CA and CP	≥ 260	≥ 280	≥ 320	≥ 360

CA Components and structural elements of reinforced concrete.

CP Components and structural elements of prestressed concrete.

The aggressive agents react with important components for concrete, affecting its strength and long-term durability. Due to its good structuring, that is, low porosity and high strength, it is expected that the decrease in strength does not reach the minimum value defined by the standard, allowed the use in the repository [2].

4. Conclusions

Concrete is one of the most used materials in the world, and it will be used as engineered barrier in disposal system at CENTENA. However, studies are needed regarding its degradation over time. In the study it was obtained tensile strength results above 5 MPa for all samples and compressive strength above 54 MPa only for the samples of C (2.0%). According to these partial results, the best concrete formulation would be with 2.0% of crimped steel fibers.

Even than the concrete exposed to aggressive environment, the degradation will be minimal. The void ratio obtained confirms that aggressive agents will difficultly penetrate the concrete, affecting minimally its properties. Therefore, from these partial results this concrete could be applied safely for the population and for the environment, due the properties as high performance and durability.

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