Capítulo 106

Analysis Of The Technical Feasibility Of The Use Of Sericitic Filito As A Pozolic Material In The Production Of Structural Concrete

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ABSTRACT
The dilapidation of natural resources is mainly due to industrial activities such as mining and civil construction. Mineral extraction generates a large volume of by-products such as sterile, and in the cement production chain, there are several environmental impacts, such as the emission of carbon dioxide (CO2), which contributes largely to the increase in the greenhouse effect. The Pau-Branco mine, located in the municipality of Brumadinho - MG, belonging to the Quadrilátero Ferrífero, has the sterile one characterized as sericitic filitus, which has pozolanic properties. To promote a more sustainable destination and reduce the consumption of mineral resources for the manufacture of cement, this article presents the analysis of the technical feasibility of concrete produced with the replacement, of 30% by mass, of Portland CP V cement standardized by sericitic filitus. A hunk of concrete was produced that was evaluated in its fresh and hardened state. The results found for compressive strength at 28 days of cement concrete with addition of supplementary cementium material (MCS) demonstrate that this cement is viable for structural purposes.

Keywords: Portland Cement, MCS, Barren, Pozzolan, Filitto.

1 INTRODUCTION

The use of natural resources is essential for the maintenance and development of society, but such resources are limited and when exploited too much, environmental changes bring serious environmental, economic and vital consequences for society. Construction and mining are examples of activities that carry out the extraction of non-renewable natural resources

Portland cement concrete is one of the main products used in civil construction and its main component is cement, used as a linker. For the manufacture of cement, it is necessary to extract minerals such as limestone and clay, and these resources are non-renewable. In addition to extraction, Portland cement production is responsible for being a source of carbon dioxide (CO_2) emissions accounting worldwide for about 8% of total anthropogenic emissions due to its significant volume of production.

In the mining sector, the exploitation of iron ore, which is the main raw material for steel production, stands out, and is widely used in civil construction. Its activity is responsible for modifying the areas explored and generating waste during exploration and after the processing of the ore.

In addition, the sterile, which is a by-product of mining, promotes high costs and ecosystem impacts with its storage. However, this material can become beneficial to the cement industry from the moment it is proven, through technical analysis, that it can be used as supplementary cement material (MCS).

Because of this, there is a gain for mining, by reducing its waste and making the sterile a co-product, for the cement industry, transforming it into another option of adding to the clinker and, consequently, for the environment.

Portland cement is the result of the calcination of limestone and clay and after grinding, it results in a clinkle. Thus, the partial replacement of clinker with other materials is a way to obtain environmental, technical, and economic advantages, but for this, the ABNT NBR 16697 standard (ABNT, 2018) regulates the levels of mineral additions to Portland cement.

These materials to be added to the clinkle must have cementitious characteristics and are called MCS. According to Morais (2018) the sericitic filitus, much found in mining areas located in the Quadrilátero Ferrífero region of Minas Gerais, can be defined as POZOLANIC MCS.

Faced with this scenario, the scientific environment seeks sustainable alternatives through research that evaluates the performance of new materials in partial replacement of clinkle and simultaneously the use, with an adequate environmental disposition of those that harm the environment, so that natural resources can be used responsibly.

2 DEVELOPMENT

2.1 MATERIALS

2.1.1 Cement

Cement is a powdery material, capable of agglutinating various types of materials and which when coming into contact with water, reacts chemically and hardens.

There are several types of existing cement, and what differs from them are the additions that each type of cement receives, thus defining the type of cement that will be suitable for each purpose of use, considering the relevant physical and chemical properties.

The main additions are blast-oven slag and pozolanic and carbonate materials. For this substitution, percentages of these additions are regulated, according to ABNT NBR 16697 (ABNT, 2018).

2.1.1.1 Supplementary Cement Material (MCS)

Using MCS , it is possible to considerably decrease CO_2 emissions into the atmosphere, since the manufacture of cement without additions (ground clinker) releases on average 866 kg of CO_2 per ton produced. Therefore, the use of MCS can considerably reduce the environmental impact by reusing by-products from mining companies, steel mills, and other industries.

The use of waste from other industries such as MCS is an alternative for the disposal of these environmental liabilities, besides that such materials, have characteristics that technically aggregate in the production of cement, according to Morais (2018).

2.1.2 Mining Sterile

According to ABNT NBR 13029 (ABNT, 2017), sterile is any material not economically usable from the point of view of mining, the removal of which becomes necessary for the mining of the ore. Therefore, it is necessary to remove the barren from the mining, because it does not have enough ore of interest to be taken to the processing.

The volumes of sterile removed are deposited in piles and por not a natural structure, projects, and periodic monitoring are required to maintain it s estáveis. These batteries may also be more susceptible to erosion than a natural rock structure, which can cause the material to be carried in river beds, with alteration of the local ecosystem.

To promote the use of mining waste, Morais (2018) classified the sterile found in the Pau-Branco mine located in the municipality of Brumadinho, which belongs to the Ferriferic Quadrangle, as being a sericitic filitus and with properties analogous to that of pozolanic materials.

This material according to Morais (2018) has physical and mechanical characteristics that enable the use asMCS in the production of concrete for civil construction. Another important factor is its availability because it can be found in large numbers in the Region of the Iron Quadrangle.

2.1.2.1 Sericitic Phyllite

It is called sericitic filitus when it presents in its chemical composition more than 50% sericite (KA_{l2} $(AlSi_3O_{10})(OH)_2$)). To present characteristics similar to that of pozolanic materials, the sericitic filitus needs to be finely ground, and treated or not thermally, as stated by Morais (2018).

The characteristic that would justify the use of it as an addition to Portland cement, according to Morais (2018), would be its potential pozolanic property.

To evaluate the possibility of partially replacing clinkle with sterile sericitic filitus, physical and mechanical characterization tests of the materials were performed.

2.2 CHARACTERIZATION OF MATERIALS

2.2.1 Sericitic Filito

The collection of the sericitic filitus was performed according to the procedure described in ABNT NBR 8952 (ABNT, 1992). Approximately 40kg of sterile equipment was collected with the aid of manual excavation equipment.

The material was initially dried in a greenhouse for 24 hours and later the grain reduction process began through the ball mill. Grinding was performed for 30 minutes, using the amount of 5 kg of sericitic filitus per step.

To prove that the material was a sericitic filitus, the sample of the raw material was submitted to semiquantitative analysis by X-ray Diphratometry (XRD). This assay was carried out in the X-ray laboratory of the Department of Mining Engineering of the Federal University of Minas Gerais (UFMG). The result showed the characterization of the crystalline mineral phases, which according to analysis classified the material as sericitic filitus that presents quartz, among other minerals, with a percentage equal to 77.4%.

ABNT NBR 12653 (ABNT, 2015) defines that pozolanic materials, natural or artificial, classified as Class N, must show at least 70% of the sum of the percentages of minerals silicon dioxide (SiO_2), aluminum oxide (Al_2O_3) and iron oxide (Fe_2O_3). Therefore, the material meets the technical requirements of the chemical composition of pozolanic materials defined by ABNT NBR 12653 (ABNT, 2015) and validates that it is material similar to that presented by Morais (2018).

For the performance of heat treatment, we took as a basis the studies conducted by Morais (2018), which evaluated the performance of the sterile sericitic filitus to be used as MCS, calcinando under several temperatures. The best performance obtained was for the calcined material at a temperature of 700°C, and this was the temperature allowed for calcination of the material to be used in this study.

For the calcination process, the AN1222 muffle was used, and the material was divided into percentages rangingfrom 800g to 1300g, so that calcination occurred homogeneously, as happens in rotary furnaces used in cement industries. Following the material resulting from calcination has undergone grinding process

After heat and mechanical treatment, characterization tests were performed, determining the fineness index, according to ABNT NBR 11579 (ABNT, 2012), unit mass, according to ABNT NBR 16972 (ABNT, 2021) and specific mass, according to ABNT NBR 16916 (ABNT, 2021).

2.2.2 Cement Cp V + Sericitic Filito

To perform the composition of the modified cement, portland CP V cement was used as a base because it presented a higher concentration of clinker, allowing a closer analysis of a clinker + sericitic filito composition. The percentage of substitution of 30% by mass of Portland CP V cement was established, from there a new cement was formulated with properties similar to those of CP IV.

For the physical characterization ofCP V cement with the addition of seric icfilite, the assays were performed to determine the unit mass, according to ABNT NBR 16972 (ABNT, 2021), the specific mass, according to ABNT NBR 16916 (ABNT, 2021), the fineness index, according to NBR 11579 (ABNT, 2012), the normal consistency paste, according to NBR 16606 (ABNT, 2018), and the cold expandability of the material according to NBR 11582 (ABNT, 2016).

2.2.3 Concrete

To evaluate the concrete resistance produced with the use of the cimento with the addition of sericítico filitus, two different masses were produced, one using as a ligand the cement with the addition of seric ic filitus and the other using Portland CP IV 32 whose results of physical and mechanical characterization were provided by the manufacturer. CP IV was used as a comparison, since CP V + sericítico filitus has properties analogous to that of POZOLANIC CP IV cement. In both mixtures, the same materials were used as aggregates whose characteristics were obtained experimentally.

Thus, with all the materials properly characterized, the calculation of the dosage of concrete was made according to the method of the American Concrete Institute (ACI) adapted, according to Ribeiro (2015). The production of concrete class C30 was to calculate the dosage of the materials. The trace obtained in the calculation, and used for the mass dosage of the material components of the concretes, is 1:1,21:0.77:1,78:0.45, indicating the proportions of cement, sand, gravel 0, gravel 1 and water-cement factor, respectively.

The molding, determination of consistency by the reduction of the cone trunk, cure andco-pressure resistance assay for ages three, seven and twenty-eight, were performed according to the standards NBR 5738 (ABNT, 2015), NBR NM 16889 (ABNT, 2020), NBR 9479 (ABNT, 2006) and NBR 5739 (ABNT, 2018), respectively.

3 ANALYSIS OF RESULTS

3.1 SERICITIC FILITUS

Table 1 shows the results obtained in the tests of fineness index, loose and specific unit mass of the sericitic filitus.

Table 1 - Characterization of the sericitic filitus

	Fineness index (%)	Unit mass (g/cm³)	Specific mass (g/cm³)
Essay	7,55	0,98	2,65

Source: Elaborated by the authors (2021).

Theresidue perce ntual in the sieve 75 °m presented by the analyzed material meets the limit established by NBR 12653 (ABNT, 2015) that for pozolanic material must be less than or equal to 20%.

As for the specific mass obtained for the material, although the NBR is not specificin terms of this value,the value is close to the s presented by the cement s marketed in the Brazilian market.

3.2 CP V CEMENT + SERICITIC FILITUS

Table 2 shows the results obtained in the tests of finura index, loose and specific unit mass of Portland cement with the addition of sericitic filitus.

Table 2 - Cement characterization

	Fineness index (%)	Unit mass (g/cm³)	Specific mass (g/cm³)
CP V + Sericitic Filitus	2,30	0,95	2,92
CP IV 32 *	-	-	2,96
16697 NBR	≤ 8		

**Manufacturer data.*

Source: Elaborated by the authors (2021).

The percentage of residue in the sieve 75 °m presented by the analyzed material meets the limit established by NBR 16697 (ABNT, 2018) that for pozolanic cement (CP IV) should be less than or equal to 8%.

Table 3 shows the results obtained in the portland cement start and end time trials with the addition of sericitic filitus.

Table 3 - Portland cement handle time with addition of sericitic filitus

	Start of handle (min.)	End of catch (min.)
CP V + Sericitic Filitus	6th 5th	35th
CP IV 32 *	231	270
16697 NBR	≥ 60	≤ 720

**Manufacturer data.*

Source: Elaborated by the authors (2021).

Table 4 shows the results obtained in portland cement compressive resistance assays with the addition of sericitic filitus.

Table 4 - Average compression strength of Portland cement with sericitic filitus

Ages (days)	CPIV - Class 32 (NBR 16697, ABNT, 2018) (MPa)	CPV with FS (MPa) addition
3	≥10.0	21.8
7	≥20.0	23.3
28	≥32.0	33.8

Source: Elaborated by the authors (2021).

3.3 CONCRETE

Table 5 presents the results of the compressive strength of the concreteproduced with CP V cement with the addition of sericitic filitus and CP IV cement obtained for the three ages.

Table 5 - Results of compressive strength tests

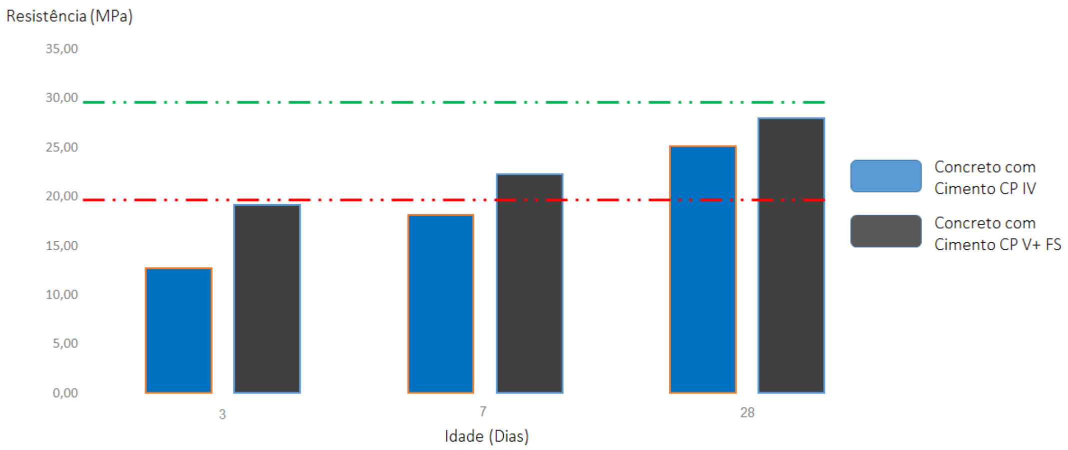
Concrete with Cement CPV + FS		Concrete with cement CP IV	
Age (days)	Medium Compressive Strength (MPa)	Age (days)	Medium Compressive Strength (MPa)
3	19,1	3	12,7
7	22.3	7	18.2
28	2nd 8.0	28	25,1

Source: Elaborated by the authors (2021).

According to ABNT NBR 6118 (ABNT, 2014) the minimum compression strength for structural concrete at 28 days of age should be equal to 20 MPa with passive reinforcement and 25 MPa with active reinforcement and the characteristic compressive strength (fck) of design for which the trace for the concrete dosage was calculated was 30 MPa at 28 days.

Figure 1 shows the values obtained for each sample tested compared to the indicated fck value of the project for which the trace for the dosage of the c30 concrete intake was calculated. It is also observed the indication of the minimum fck for structural concrete according to ABNT NBR 6118 (ABNT, 2014).

Figure 1 - Compressive strengths of tested concrete



Source: Prepared by the authors (2021).

4 CONCLUSION

In terms of strength, the concrete produced with CP V with the addition of sericitic filitus has reached the minimum required for structural concrete, according to what the NBR 6118 standard (ABNT, 2014) requires. In this sense, the use of filitto as MCS is feasible for the production of structural concrete in the proposed dosage.

It is perceived in the other parameters obtained in the tests performed point to the same meaning, that the CP V with the addition of sericitic filitus and the Portland cement pozolanic CP IV have equivalent characteristics.

In this way, it is possible to conceive cement in a more sustainable way through the use of sterile as MCS, being able to replace part of the clinker without losing the binder properties and still being a way of using this material for the mining industry.

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