

## Chemical and mineralogical composition of different particle size fractions of fines from dimension stone processing

### *Composição química e mineralógica de diferentes frações granulométricas dos finos de beneficiamento de rochas ornamentais*

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**Abstract:** The processing of dimension stones generates a muddy residue called fines from dimension stones processing - fdsp. This residue is considered a potential raw material for the production of "eco-products," motivating more detailed studies of its composition. The objective of this study was to perform a detailed analysis of the chemical and mineralogical attributes of different particle size fractions of fdsp. The samples were submitted to particle size, chemical, and mineralogical analyses; the last two conducted according to the particle size fractionation. Results show that the fraction that passes through a 0.053 mm sieve has an important increase in the loss from fire and in its contents of Ca and K, in addition to a decrease in the contents of Mg, Na and Fe. Synthetic diamonds that can be repurposed are preserved in coarser fractions and there is a need to control the entry of dirt that can compromise fdsp quality, if it is used as a raw material.

**Keywords:** Recycling; Solid wastes; Abrasive mud; FIBRO.

**Resumo:** O beneficiamento de rochas ornamentais gera um resíduo lamoso denominado Finos do Beneficiamento de Rochas Ornamentais - FIBRO. Esse material é considerado como matéria-prima potencial para fabricação de "ecoprodutos", motivando estudos mais detalhados de sua composição. O objetivo deste trabalho foi realizar uma análise detalhada dos atributos químicos e mineralógicos de diferentes frações granulométricas do FIBRO. As amostras foram submetidas à análise granulométrica, análise química e mineralógica, sendo as duas últimas realizadas a partir do fracionamento granulométrico. Os resultados mostram que a fração passante em peneira de abertura 0,053 mm tem um importante incremento da perda ao fogo e dos teores de Ca e K, além de diminuição dos teores de Mg, Na e Fe. Diamantes sintéticos passíveis de aproveitamento são preservados em frações mais grossas e há necessidade de controlar a entrada de sujidades que podem comprometer a qualidade do FIBRO, caso ele venha a ser aproveitado como matéria-prima.

**Palavras-chave:** Reciclagem; Resíduos sólidos; Lama abrasiva; FIBRO.

## 1. Introduction

The state of Espírito Santo is an important producer and exporter of dimension stones and claddings. The waste resulting from rock processing, including the cutting of stone blocks and the polishing of raw plates, generates a residue composed of the processed rock powders and the materials used for processing (KARACA *et al.*, 2012; LUODES *et al.*, 2012; STRZALKOWSKI, 2021). As a result of the high volumes discarded, a viable and sustainable option for waste management is to repurpose it, seeking to transform it into a source of raw material for other production chains (SOUZA *et al.*, 2010; RANA *et al.*, 2016; AMARAL *et al.*, 2019; BARRETO *et al.*, 2020; GOMES *et al.*, 2020; ALMADA *et al.*, 2023).

The composition of these materials depends on the technology used during the rock processing (ZICHELLA *et al.*, 2018; 2021). The conventional cutting method uses machines with steel blades, in which a processing sludge composed of grit (faceted steel particles), lime and water is used. There is also the cutting method that uses diamond wire machines (or multi-wire), which generates a muddy residue essentially composed of stone dust and water. After the cutting stage, the raw sheets are polished, which also generates a muddy residue, in which other types of materials, like coagulant products, resins and dyes, aggregate. All the waste resulting from each stage of the process is usually mixed before drying, which precedes disposal and storage in industrial warehouses or landfills.

These materials are called fines from dimension stone processing - FDSP by Normative Instruction 11-N of the State Institute for the Environment—IEMA (ESPÍRITO SANTO, 2023), which amends Normative Instruction 11/2016 of the same Institute (ESPÍRITO SANTO, 2016). The resolution establishes a Permanent Program for the Characterization of FDSP to study its properties and identify possible modifications over the years, which could result from the possible emergence of new processing materials, in order to assess the need to change the structure of industrial landfills intended for waste storage.

Previous studies have shown that it is possible to use FDSP as an aggregate in civil construction materials (e.g. MITTRI *et al.*, 2018; AZEVEDO *et al.*, 2019; SILVA *et al.*, 2019), as an agricultural input (e.g. RAYMUNDO *et al.*, 2013; TOZSIN *et al.*, 2015), in the recovery of degraded areas and treatment of effluents (e.g. PÉREZ-SIRVENT *et al.*, 2007; ZORNOZA *et al.*, 2013; NEVES *et al.*, 2019), among other possibilities. The use of waste in the so-called “eco-products” is a fundamental action in environmental management, as it enables a reduction in the extraction of natural resources and the minimization of waste disposal and environmental impacts.

Considering that FDSP is composed of particles of varied composition, it is assumed that certain components may be more or less concentrated in specific particle size fractions, whose separation would enable enhancing or removing elements that may be useful (or harmful) for certain applications. Thus, the objective of this work was to characterize FDSP using the detailed description of chemical and mineralogical attributes of specific particle size fractions. The treatment of waste from the dimension stone sector with the goal of repurposing it can improve or adapt the characteristics of the material, seeking to meet the requirements and quality control of the raw material that it may constitute.

## 2. Material and methods

The FDSP samples were collected in Cachoeiro de Itapemirim, a municipality located in the south of the State of Espírito Santo, Southeast Brazil. The collection sites were distributed in the processing plant of the companies, involved in transforming stone blocks into sheets and polishing these sheets, using both conventional machines and diamond or multi-wire machines (Table 1). The samples of block cutting were collected directly at the outlet of the machines, while the samples of the polishing process were collected in the decantation tanks, of which the liquid content returns to the processing plant after the decantation of the solid content. The number of samples collected in each sample set reflects the predominance of companies that use conventional machines, which still predominate over companies that use diamond or multi-wire technology.

The samples were homogenized and dried in an oven at 42° C at the Laboratory of Applied Geology of the Department of Geology of UFES (Federal University of Espírito Santo). After crumbling, 100 g aliquots were weighed on a precision scale and packed in resistant polyethylene bottles with screw caps, along with 200 mL of ultrapure water. The bottles were subjected to slow stirring in a rotating bottle shaker for 4 hours. Subsequently, the wet sieving process was carried out using a 0.053 mm sieve to separate the fine silt and clay grains from the coarser grains. The material that went through the sieve (particles suspended in the sieving water) remained resting in a high-strength polyethylene container for at least 24 hours, until the complete decantation of the particles occurred, thus obtaining a liquid fraction and a solid fraction. The liquid was discarded, while the solid content was dried in an oven for later analysis in a laser sedigraph, in which fractions between 0.0001 and 0.053 mm were quantified in the Sedimentology Laboratory of the Department of Oceanography and Ecology, UFES.

*Table 1 – Locations of FDSP sample collection in the processing plant of companies in the dimension stone sector, with the acronyms used in this work and the number of samples collected in each location.*

TYPE OF PROCESSING / COL- LECTION LOCATION	ACRONYM (TOTAL SAMPLE)*	ACRONYM (FINE FRACTION)**	NUMBER OF SAMPLES
Conventional / block cutting	CC	CC-FN	23
Conventional / decantation tank	CD	CD-FN	9
Multi-wire / block cutting	MC	MC-FN	3
Polishing / decantation tank	PD	PD-FN	6

*OBS: \* complete sample, no sieving; \*\* fine fraction, went through a sieve with an opening of 0.053 mm.*

*Source: Authors (2025).*

The material retained in the 0.053 mm sieve was dried in an oven at 40 °C and dry sieved with a mechanical agitator and a set of sieves with the following opening sizes: 0.250 mm (60 mesh); 0.125 mm (115 mesh); 0.090 mm (170 mesh); 0.075 mm (200 mesh) and frame (which received the fraction between 0.075 and 0.053 mm).

The chemical composition of the samples (total sample) and its fine fraction (less than 0.053 mm) was analyzed using x-ray fluorescence spectrometry (XRF). Cast pellets were made, mixing 1 g of the sample, 9 g of lithium tetraborate and 1.5 g of lithium carbonate. The mixtures were melted in a melting machine for 17 minutes at a temperature of approximately 1,300 °C. The cast pellets were analyzed at the Geochemistry Laboratory of the Department of Geology at UFES using Bruker's S8Tiger X-ray fluorescence spectrometer. That way, SiO<sub>2</sub>, Al<sub>2</sub>O<sub>3</sub>, Fe<sub>2</sub>O<sub>3</sub>, CaO, K<sub>2</sub>O, Na<sub>2</sub>O, MgO, TiO<sub>2</sub> and MnO contents were obtained and expressed as percentages. The determination of the loss on fire (LOI) was obtained after cleaning porcelain crucibles in a muffle furnace at 1000 °C for 20 minutes, which were then placed in a desiccator until they reached room temperature. An aliquot of 1,000 g ± 0.001 g of each sample was weighed in crucibles of known mass and the set was taken to calcination in a muffle furnace at a temperature of 950 °C ± 50 °C for at least 50 minutes. The crucibles were cooled along with the samples in a desiccator and a new weighing was carried out until a constant mass value was obtained. LOI was calculated by measuring mass loss after calcination.

The determination of the mineralogical composition of the coarser fractions was made at the Sedimentology Laboratory of the Department of Geology of UFES, using a Coleman magnifying glass with 40x magnification. These fractions were photographed using a Leica S8APO magnifying glass, with an attached camera, and aided by the LAS V49 program for image capture, in the Advanced Imaging Laboratory of the Department of Biological Sciences of UFES.

For mineralogical analysis of the finest fraction, the x-ray diffraction (XRD) technique was used. The preparation of the samples for XRD involved their comminution in agate mortar until reaching the particle size that could pass through a 325 mesh sieve. About 2 g of each sample were packed in eppendorf tubes and sent to the Chemical Engineering Laboratory of UFES for analysis in a Rigaku Miniflex 600-C X-ray diffractometer, with copper tube (CuK $\alpha$ ,  $\lambda$  = 1.5406 Å), operating at 40 kV and 20 mA. The initial 2 $\theta$  angle was 5° and the final angle was 70°, the step used was 0.02° and the scan rate was 10° (2 $\theta$ )/min. The diffractograms were analyzed and interpreted using the X'Pert HighScore Plus software from Panalytical, with an integrated database.

### 3. Results

#### 3.1 Granulometry

FDSP is composed of very fine grains, with particles usually in the range between 1,000 and 0,001 mm (Figure 1). In the samples of the cutting process on a conventional machine (CC), up to 10 % of the particles are between 0.09 mm and 2.00 mm, which, although fine, are coarser than the other sets (CD, MC and PD). This is probably due to the presence of grit, as shown below. In the other sets of samples, 10 % of particles are smaller than 0.1 mm.

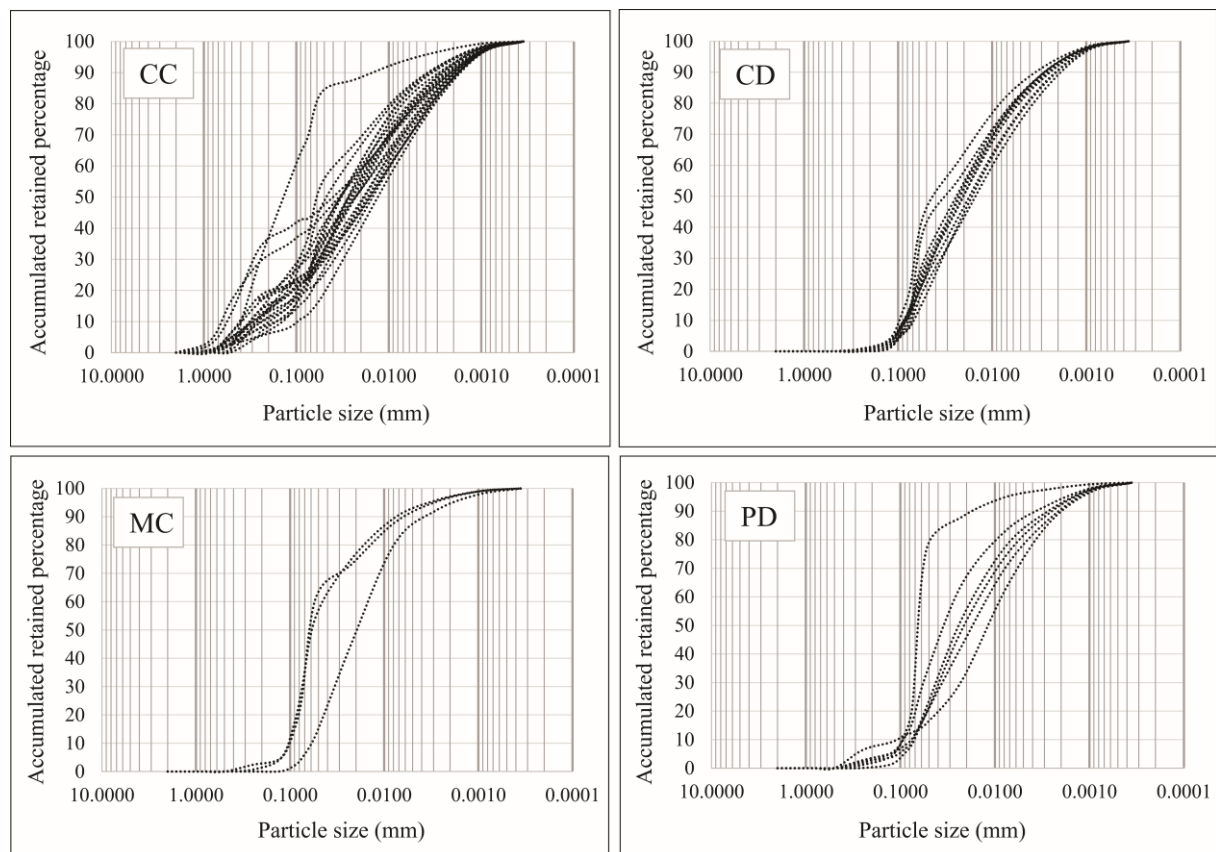


Figure 1 – Accumulated particle size distribution of cutting samples obtained from cutting in conventional machines (CC), conventional machines decanted material (CD), multi-wire cutting (MC) and polishing companies decanted material (PD).

Source: Authors (2025).

### 3.2 Chemical composition

For the analysis of the chemical composition of FDSP, two groups were separated: the total sample and its fine fraction ( $< 0.053$  mm) (Figure 2). With the exception of  $\text{Al}_2\text{O}_3$ , the other constituents suffered a significant change in content after sieving.

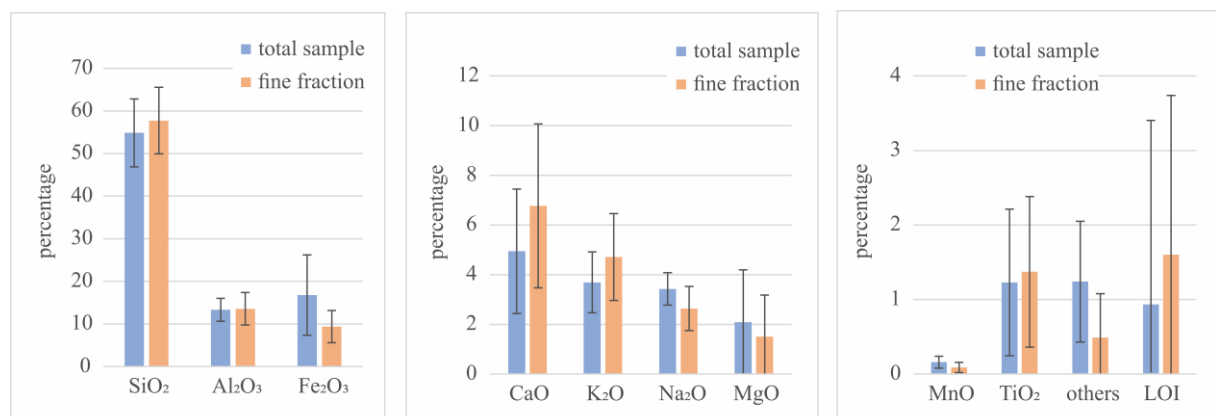


Figure 2 – Chemical composition of FDSP (total sample) and its fine fraction ( $< 0.053$  mm) ( $n$ : 36 samples in each group) (equal letters in different groups indicate that there is no significant difference with 5% confidence, using the Student's  $t$ -test in the case of normal distribution or the Wilcoxon's  $w$  test in case of abnormal distribution).

Source: Authors (2025).

By analyzing the samples pair by pair (total sample and its fine fraction), the mean percentage rate was calculated for the losses or gains of each element in the fine fraction, after particle size separation (Figure 3). There was an increase in the loss on fire (LOI) by more than 80%, as well as in the percentage of CaO present in the lime and marble carbonate, which increased by more than 40% in the fine fraction. K<sub>2</sub>O increased by approximately 25 % in the fine fraction, in addition to TiO<sub>2</sub>, by approximately 28%. SiO<sub>2</sub> increased by just over 5% and Al<sub>2</sub>O<sub>3</sub> presented no significant difference between fractions. The components that presented negative rates, that is, that had a decrease in fine fraction percentage, were Fe<sub>2</sub>O<sub>3</sub>, Na<sub>2</sub>O, MnO, and MgO. The decrease of almost 20% of Fe<sub>2</sub>O<sub>3</sub> in the fine fraction probably occurs due to the retention of grit particles during sieving, which may be desirable when intending to reuse FDSP. The same happens with Na<sub>2</sub>O and MnO, which reduced their content between 20 and 30 % in the fine fraction, as well as MgO, which decreased by around 58 % in the fine fraction.

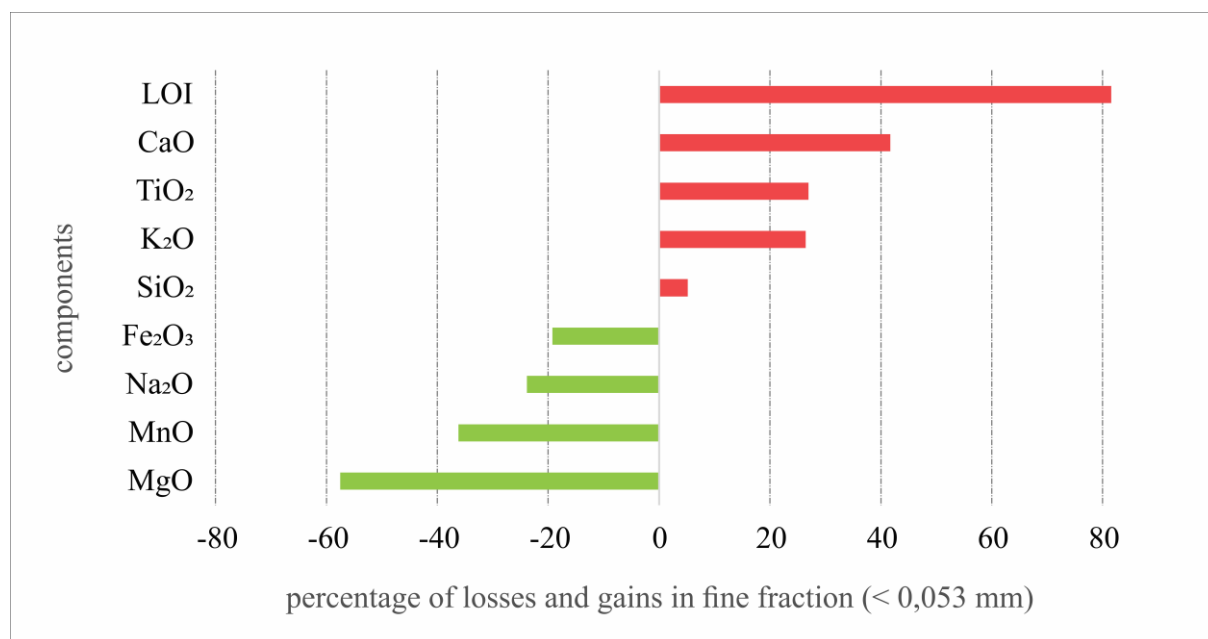


Figure 3 – Percentage change in the chemical composition of FDSP fine fraction (< 0.053 mm) in relation to the total sample. The red bars indicate the average gain regarding a specific constituent and, in green, the loss of the constituent in the fine fraction.

Source: Authors (2025).

### 3.3 Mineralogical composition

The mineralogical composition was analyzed in two ways: the coarse fractions (0.250 and 0.090 mm) were described under a magnifying glass with 40x magnification and the fine fraction (< 0.053 mm) was analyzed using x-ray diffraction (XRD).

The sample from the cutting process carried out on a conventional machine (CC) (Figure 4) denotes, in its 0.250 mm fraction, a high concentration of grit already in a state of oxidation and presenting rounded shapes due to wear by friction and abrasion in the cutting process of the stone blocks. Also, quartz, feldspar, garnet and biotite occur in expressive quantities, all with well-defined shapes and, in less expressive quantities, muscovite appears. The 0.090 mm fraction has similar mineralogy, but in this case the grit fragments are a minority, with quartz, garnet, biotite and muscovite predominating.



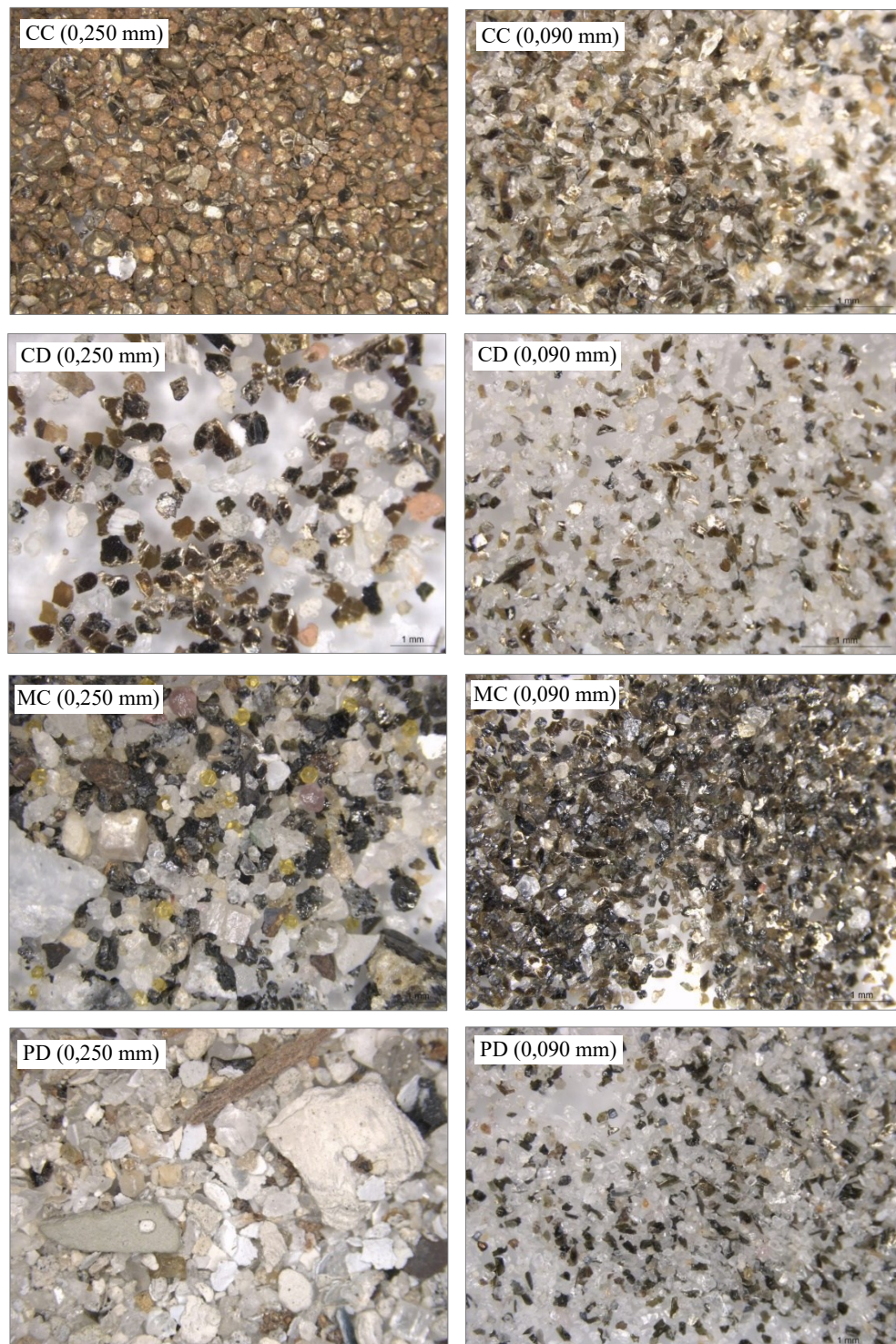


Figure 4 – Photomicrographs of the samples of conventional machine cutting (CC) and conventional decanted (CD) groups in the 0.250 mm and 0.090 mm fractions; multi-wire cutting (MC) in the 0.250 mm fraction, with details of the synthetic diamonds that detach from the wires, and decanted polisher (PD) also in the 0.250 mm and 0.090 mm fractions.

Source: Authors (2025).

The samples collected in the decantation tank, in companies that use the conventional process (CD) (Figure 4), have a lighter color, due to the greater amount of quartz and a small amount of grit fragments. In the 0.250 mm fraction,

quartz, biotite, muscovite, a small amount of grit and magnetite are present, which is repeated in the 0.90 mm granulometry, except for grit, which is practically absent.

The sample of the mud from the cutting stage of a multi-wire machine (MC) (Figure 4) presents, in its 0.250 mm fraction, a high concentration of fragments of quartz, biotite, garnet and feldspar, in addition to the presence of magnetite that stands out for its characteristic brightness and magnet attraction. The presence of synthetic diamond (from the diamond wire) is remarkable, with a yellowish color and preserved facets (Figure 5a). In the 0.090 mm fraction there is magnetite, and quartz is still present, in addition to garnet and biotite.

In the sample collected from the polisher residue (PD) (Figure 4), in the 0.250 mm fraction, the mineralogy is composed of rounded to angular feldspars, and a large amount of muscovite and biotite. Quartz has more orange parts, showing possible oxidation. In addition to materials originating from the stone, this fraction has dirt, such as pieces of cardboard, wood and plastic (Figure 5b). The 0.090 mm fraction is made up of magnetite, quartz, feldspar, biotite and muscovite.

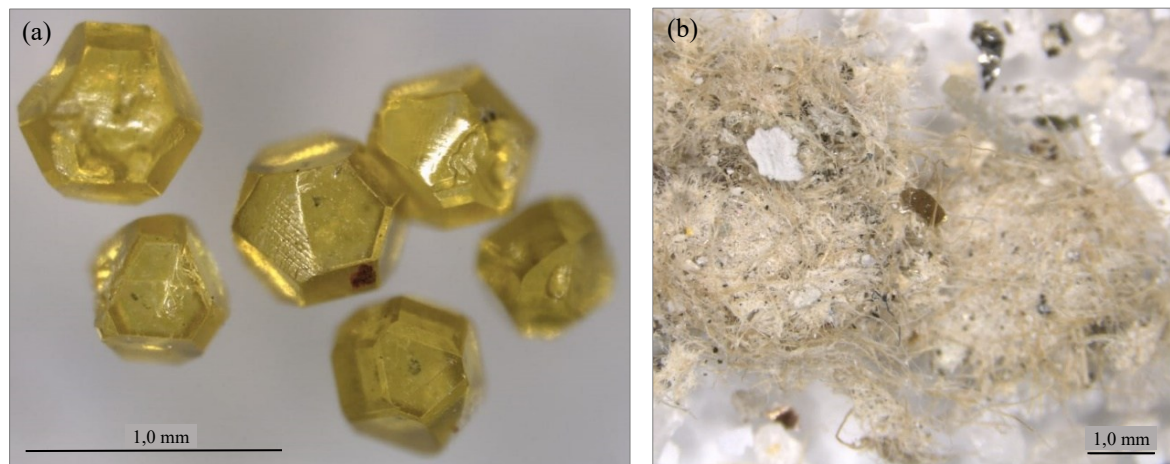


Figure 5 – Photomicrographs (a) of the synthetic diamonds present in the 0.250 mm fraction of the MC samples (cutting on a multi-wire machine) and (b) example of dirt found in the 0.250 mm fraction of the PD sample (polishing decantation tank).

Source: Authors (2025).

Fine fraction analysis (< 0,053 mm) using XRD (Figure 6) show similar mineralogies between samples composed of quartz—Qtz ( $\text{SiO}_2$ ); muscovite—Mus [ $\text{KAl}_2(\text{Si}_3\text{AlO}_{10}(\text{OH},\text{F})_2$ ); feldspar—Fdl [ $(\text{K}, \text{Na}, \text{Ca})(\text{Si}, \text{Al})_4\text{O}_8$ ], encompassing potassium and sodium-calcium; biotite—Bta [ $\text{K}(\text{Mg},\text{Fe})_3[\text{AlSi}_3\text{O}_{10}](\text{OH},\text{F})_2/\text{K}(\text{Mg},\text{Fe})_3(\text{Al},\text{Fe})\text{O}(\text{OH},\text{F})_2$  and, in some fractions and specific samples, garnet—Gra [ $(\text{Ca},\text{Mg},\text{Fe},\text{Mn})_3(\text{Al},\text{Fe},\text{Mn},\text{Cr},\text{Ti})_2(\text{SiO}_4)_3$ ]; cordierite—Crd [ $\text{Mg}_2\text{Al}_4\text{O}_{10}(\text{OH},\text{F})_2$  or  $(\text{Mg},\text{Fe})_2\text{Al}_4\text{O}_{10}(\text{OH},\text{F})_2$ ]; pyroxene—Pxn, with the general formula represented by  $\text{XYZ}_2\text{O}_6$  in which X = Mg, Fe, Ca or Na, Y = Mg, Fe,  $\text{Fe}_3$  or Al and Z = B with some substitution for Al; ilmenite - Imt [ $\text{FeTiO}_3$ ] and hornblende—Hbl [ $\text{Ca}_2(\text{Mg},\text{Fe})_4\text{Al}(\text{Si}_7\text{AlO}_{22}(\text{OH})_2$ ], which belongs to the amphibole group.



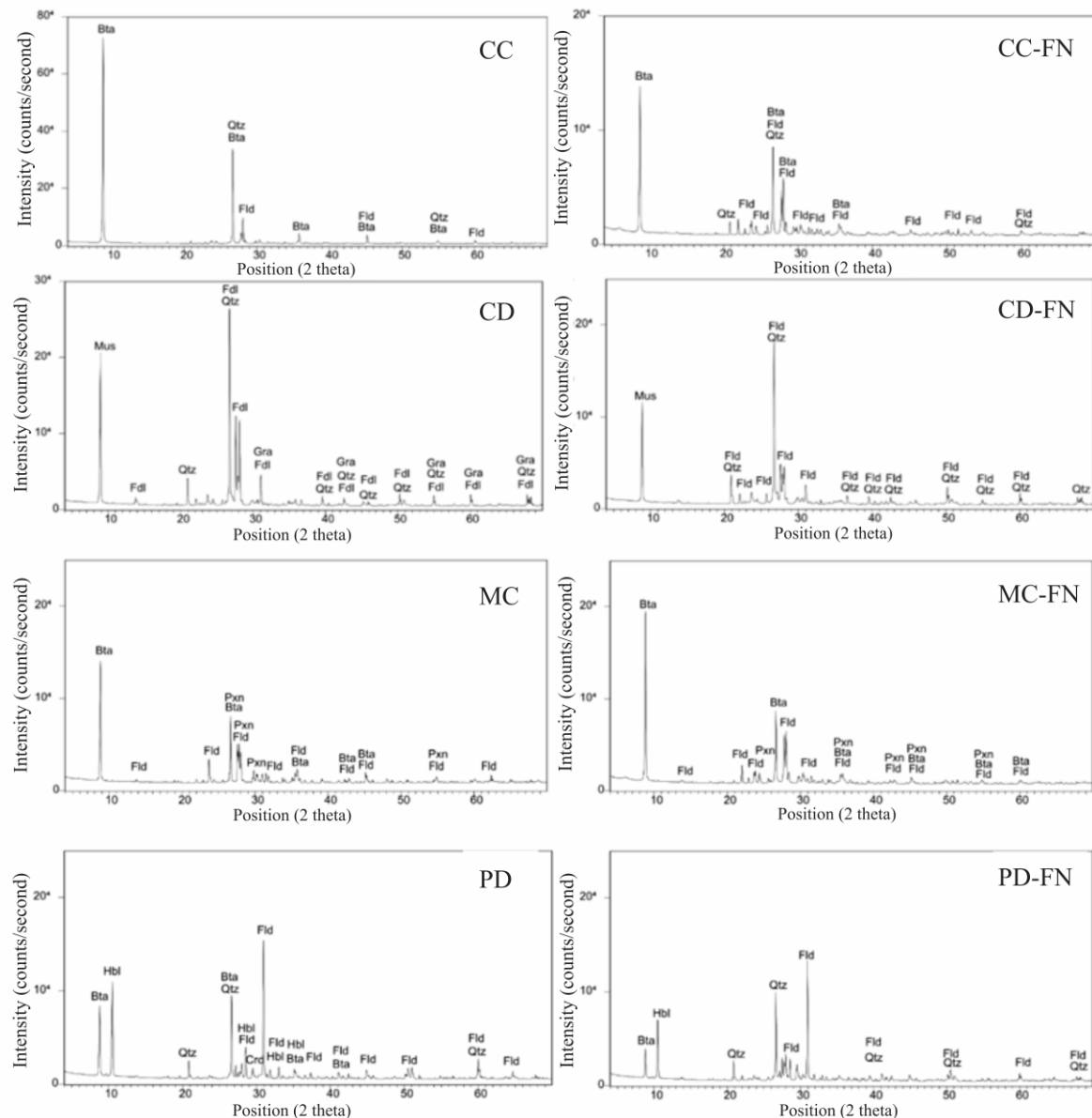


Figure 6 – Diffractograms of FDSP samples and their fine fraction (< 0.053 mm). (CC: conventional cutting and CC-FN: *idem* fine fraction; CD: conventional decanted and CD-FN: *idem* fine fraction; MC: multi-wire cutting and MC-FN: *idem* fine fraction; PD: polishing decanted and PD-FN: *idem* fine fraction (see the meaning of the acronyms that refer to the mineral peaks in the text, next to the respective chemical formulas).

Source: Authors (2025).

Mineralogy does not vary significantly as a function of particle size (Figure 6). In the cutting samples on a conventional machine (CC) and in its fine fractions (CC-FN), quartz, biotite and feldspar are present. In the decanted sample of the conventional machine (CD) there is muscovite, garnet, quartz and feldspar and, in the fine fraction (CD-FN), the mineralogy is repeated, except for the garnet, which does not occur in this fraction. In the samples of the cutting process on a multi-wire machine (MC and MC-FN), the minerals present are feldspar, biotite and pyroxene. In the decanted sample of the polishing process (PD), biotite, hornblende, quartz, feldspar and cordierite appear, while in its fine fraction (PD-FN) the mineralogy is the same, but there is no cordierite. That is, minerals commonly present in igneous rocks (quartz, feldspar, biotite and, secondarily, pyroxene and hornblende) occur in all fractions analyzed, while accessory minerals (garnet and cordierite) do not appear in the finest fraction. It is noteworthy that these minerals, in addition to being present in smaller quantities in the stones, are more resistant and therefore may not have been comminuted by the processing, remaining in the coarser fractions.



#### 4. Discussion

This work presents the analysis of different granulometric fractions of FDSP seeking to direct the applicability and use of the waste, considering that the literature already points out some viable ways of application of these materials, as long as they meet the technical standards of each sector or basic industry.

The separation of a fine fraction, composed of grains smaller than 0.053 mm, led to a relative increase in certain constituents (mainly LOI and CaO) and a decrease in others (such as Fe<sub>2</sub>O<sub>3</sub>, Na<sub>2</sub>O, and MgO), which may have implications for specific intended uses. A possible explanation for this fact lies in the solubilization of some constituents (which attribute higher LOI, in addition to Ca and K, elements that are highly soluble in water). As particle size separation was done using a wet separation method, the most soluble constituents were concentrated in the fine fraction, which was separated by decantation. On the other hand, the toughest minerals, in addition to iron grit, tend to be retained in the coarser fraction.

An important point to be highlighted is the possibility of reusing the synthetic diamonds present in diamond multi-wire machines, in view of the manufacturing costs of this material, as has been proposed in some studies (PONCIANO *et al.*, 2024). The crystals that are released from the diamond wire during block cutting are added to the mud and have their characteristics well preserved, which means it is therefore possible to easily reuse them after granulometric fractionation. There needs to be an awareness of the presence of dirt, which should be avoided when attempting to transform waste into raw material, as the quality control of a raw material goes hand in hand with its added value.

Regarding the use in ceramics, some authors (CABRAL *et al.*, 2019) report that the fine granulometry and high alkali content in certain clays increase the mechanical resistance and reduce the water absorption of the ceramic product. These properties are found in FDSP, which is corroborated by several studies that have tested its use as an aggregate to conventional clays (e.g. SOUZA *et al.*, 2010; EL-MAGHARABY *et al.*, 2011; PRADO *et al.*, 2012; RODRIGUES *et al.*, 2012; TAGUCHI *et al.*, 2014; REIS *et al.*, 2015). However, the composition of the residue can interfere with the properties of the ceramic. Residues in which carbonate contents are higher and, consequently, LOI is higher, produce ceramic pieces with higher water absorption and lower apparent density (PRADO *et al.*, 2023). The fine fraction of the samples studied here had an increased loss to fire (LOI) in relation to the total sample and, as a result, the coarser fraction will present lower LOI. It is important to emphasize that the granulometry of the total sample is already fine enough for this type of use, thus not precluding the possibility of having a prior particle size fractionation to reduce LOI. In the coarse fraction, the Na content increased by about 20%; Na is an element of the alkaline group, which is beneficial to this type of use, as reported above. In the opposite direction, Fe was higher in the coarse fraction, mainly in the CC set due to the presence of steel grit. This element can have a negative effect on ceramics, as it can cause darkening of the pieces and the appearance of stains.

Waste with high CaO, SiO<sub>2</sub>, MgO and Al<sub>2</sub>O<sub>3</sub> contents may become possible raw materials for the production of glass, considering that SiO<sub>2</sub> contributes to the formation of glass networks and Al<sub>2</sub>O<sub>3</sub> acts as a network former (RODRIGUES *et al.*, 2011). CaO and MgO act as modifiers and perform the function of disrupting glass structures. However, its use in glazing is the most restrictive regarding Fe content, requiring further analysis to allow for use in this type of product (MOREIRA *et al.*, 2021). Waste from multi-wire machines, mainly from cutting quartzite, aggregated with materials rich in Ca, can be adequate for this type of use. It is important to remember, however, that the presence of Fe affects the color of the glass, which may be an undesirable effect (RODRIGUES *et al.*, 2011). It is also worth noting that the loss of about 58% of MgO in the finest fraction of FDSP, as shown by the data presented here, would impair its potential for use in glass materials, according to the already cited literature.

Moreira *et al.* (2021) showed, based on the compilation of data from several published studies, that the use of FDSP in materials such as concrete, cement, mortar and bricks are the least restrictive in terms of chemical composition, that is, the use of these residues is feasible even with a wide variation in the levels of most of its components. However, the MgO content is more restrictive, because this component, when hydrated, can expand and generate porosity in rigid concrete structures (SALOMÃO & PANDOLFELLI, 2008). Thus, the granulometric segregation presented here favors this type of use, since there is a reduction of almost 60% in the Mg contents in the fine fraction.

Some studies indicate the possibility of using these residues in the remineralization process due to the macronutrients, such as Ca, Mg and K, contained in them (e.g. NUNES *et al.*, 2014; MACHADO *et al.*, 2016; NEVES *et al.*, 2021). On the other hand, Duarte *et al.* (2021) point to a possible problem related to Na that, when excessive in the soil, can impair plant growth, depending on the type of soil and some of its environmental characteristics. The data presented here show considerable loss of Na in the fine fraction, reaching more than 23 % compared to the total sample, which means that particle size selection can favor the obtaining of materials that can be used in remineralization. The same can be said with regard to excess Fe, which, often linked to other elements such as Mn, can cause toxicity in the soil (DUARTE *et al.*, 2021).

Still in the field of agriculture, some studies (e.g. RAYMUNDO *et al.*, 2013) show the applicability of certain types of dimension stone residue as soil correctives, a process known as liming, aimed at reducing soil acidity. In this regard,

the fine fraction of FDSP, enriched in Ca and carbonates (reflected in LOI), has great potential for this type of use.

## 5. Conclusions

The improvement of the characteristics of discarded FDSP can contribute to the suitability of the material for specific uses. The comparison between the chemical composition of the total sample and its fine fraction showed that there is an enrichment of some elements and loss of others in each particle size fraction. In the fine fraction there was considerable enrichment in LOI, CaO, K<sub>2</sub>O and TiO<sub>2</sub>, accompanied by the loss of MgO, MnO, Na<sub>2</sub>O and Fe<sub>2</sub>O<sub>3</sub>.

The expressive amount of synthetic diamond found in specific fractions of some samples after particle size fractionation points to the feasibility of directing these materials for separation and subsequent use, thus diminishing costs in the consumption of this type of material. On the other hand, there needs to be attention to the presence of dirt in the FDSP, as the generation of raw material with added value must undergo strict quality control.

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