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THE POSSIBILITIES OF USING THE AGRICULTURAL WASTE AS AGGREGATE IN PRODUCING SUSTAINABLE CONCRETE

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Abstract: Concrete is the most widely used construction material. However, large volumes of natural resources and raw materials are being consumed in concrete production. This reduces concrete industry sustainability and increase its environmental negative impact. On the other hand, the agriculture sector is facing problems that require more efforts in agro-waste managements. To resolve this problem and binifit from agrowaste, in this study, the potential of using different types of agro-wastes in concrete as a total/partial replacement of aggregate will be evaluated. Three types of agro-wastes, which are categorized based on their fibrosity, fine and coarse, were tested. In addition, two types of binding materials, namely, ordinary cement and activated slag were used. Full characterization for different agro-waste and corresponding variations in compressive strength, density and microstructure were evaluated. Results showed that the compressive strength is directly affected by the physical properties of the incorporated agro-waste and the type of the binding material. Fibrous agro-wastes exhibited the highest strength with respect to other wastes. Successful use of such agro solid wastes as whole or partial replacement of natural aggregates contributes to energy saving, conservation of natural resources, and a reduction in the cost of construction materials.

Keywords: Agricultural waste materials, physical propriety, compressive strength, workability, environmental impact, green concrete.

1 Introduction

With more than 10 billion tons produced annually, concrete is the most important construction material (Meyer 2009). It has been predicted that the world's population will increase to 11 billion by the end of this century, which will considerably increase the concrete demand. It is expected that the concrete production will grow to reach approximately 18 billion tons by 2050 (Mehta & Monteiro 2006). Consequently, the concrete industry is going to consume high amount of natural resources to produce cement and concrete.

During the last decade, the green rating for infrastructure and buildings has been recognized worldwide. Generally, the current Green Building Rating (GBR) systems evaluate the sustainability of infrastructure and buildings according to various categories Ref. Various organization world together with Canada green building council are working to Lead and accelerate the transformation to high-performing, healthy green buildings, homes and communities. Green construction materials has recently attracted the attention as one of the main factors affecting GBR for any structure. This can be ascribed to their lower carbon foot print. Building with traditional types of concrete and the use of cement and the significant amount of energy, water, aggregate and fillers used for concrete production has negative impact of the Carbon foot print of the structures. Moreover, at the end of its life cycle, construction waste from the demolition of concrete structures has another negative environmental impact. Hence, there is a need to make this important construction material compatible with the environmental requirements of the modern sustainable construction industry.

One possible way to increase the sustainability in concrete industry is to utilize industrial and agricultural waste. Industrial waste materials, such as fly ash, silica fume, Metakaolin, ground granulated blast furnace slag (GGBFS) and others have been successfully used in concrete for long time (Meyer 2009), (Federico & Chidiac 2009). Recently, agricultural solid wastes, such as oil palm shell, coconut shell, corn cob, pistachio shell have attracted researchers as replacement for natural aggregate in structural and non-structural concrete. The use of these agricultural solid wastes as total or partial replacement of natural aggregates, which makes up about 60–80% of the volume of concrete (Badur & Chaudhary 2008), represent substantial energy saving, conservation of natural resources, and a reduction in the cost of construction materials. In addition, it solves the disposal problem of the agricultural solid wastes helping in environmental protection (Ramezani pour et al. 2009), (Kurian 2005).

Due to variations in their properties, research on the use of agricultural waste materials is relatively new. More research on mechanical properties development and long-term durability of concrete incorporating such waste is still needed. The aim of this work is to characterize and give a preliminary evaluation for the potential use some agricultural solid wastes as aggregate replacement for concrete fabrication. Recognition of these materials, and their implementation in concrete production, would pave the way for other potential uses of agricultural wastes in the construction industry, as well as certain other industries leading to a more environmentally sustainable concrete industry.

2 Experimental program

Various tests were conducted to fully characterize samples of waste materials received from the Industrial partner including their chemical and physical properties in addition to their interaction with binding materials. Random samples were collected, divided into small quantities and sent to the Laboratory of the University of Sherbrooke and Concordia University for testing. The following testing were conducted on the DCW:

2.1 Materials investigations

Erreur ! Source du renvoi introuvable. shows the five samples used in this study. The first sample shown in Fig. 1a was labelled "ARTICHOKE". The second sample shown in Fig. 1b was labelled "SPRUCE". The Third sample shown in Fig. 1c was labelled "PIANK". The fourth one shown in **Erreur ! Source du renvoi introuvable.**d was labelled "SAVLE". The fifth sample shown in **Erreur ! Source du renvoi introuvable.**e was labelled "MYSCANYHUS" (silvergrass) .The particle size varies significantly within each sample. Table 1 summarizes the range of sizes in each sample.



Figure 1: different agro waste samples, (a) Artichoke, (b) Spruce, (c) Savle, (d) Piank and (e) Myscanyhus.

Table 1: Particle size for received samples

Samples	Artichoke	Spruce	Savle	Piank	Myscanyhus
Size	0.1 to 5.5 cm	0.05 to 3.5 cm	0.5-10.5cm	0.01 to 3 cm	0.01 to 4 cm

Experimental procedure

2.1.1 Tests applied to the agro waste samples

The chemical, physical properties—moisture content, water absorption capacity and microstructural analysis of the different type of agricultural waste materials were first determined following standard laboratory procedures. Moisture content and water absorption were evaluated for each received samples following the procedure of (ASTM D4442 – 16 2003), (ASTM D4933 – 16 1999)] and (ASTM D7433 – 13 2015). The table 2, Figure 3 and Figure 2 summarize the results.

Microstructural analysis (SEM and EDS): Scanning electron microscope (SEM) observations of the different agricultural materials samples performed using a KYKY-2800 scanning electron microscope (CCM, Sherbrooke, Canada). For the purpose of scanning electron microscopy, the agro-waste specimens were coated with a 20-nm thick platinum layer in an Emscope Sputter Coater model Sc 500 (Ashford, Kent, England) purged with Argon gas.

The mineralogy of agro-waste samples was assessed via X-ray diffraction (XRD) using PANalytical X'pert diffractometer equipped with Cu X-ray radiation operating at 40 kV and 40 mA. Peak intensities were obtained by counting with the Lynxeye detector every 0.05- 2h/min. Powder XRD was carried out at a

reflection angle range of $2\theta = 10-80^\circ$. Qualitative analysis of the XRD patterns yielded the mineral phases present in agro-waste samples. The degree of crystallinity was determined using the EVA software. It is calculated as the ratio of the area under all peaks to the total area under the curve (i.e., the area under peaks plus the area under the amorphous peak). The results of SEM and XRD analyses presented in Figure 4 and Figure 5.

Table 2 Chemical composition of samples

Samples	Carbon %	Hydrogen %	Nitrogen %	Sulfur %
Artichoke	44.728	5.9380	0.31533	0.11535
SPRUCE	52.072	6.3058	0.42796	0.10417
Savle	48.75	6.0519	0.40804	0.16727
Piank	47.095	6.1353	0.61554	0.0727
Myscanyhus	46.308	6.1098	0.47369	0.15446

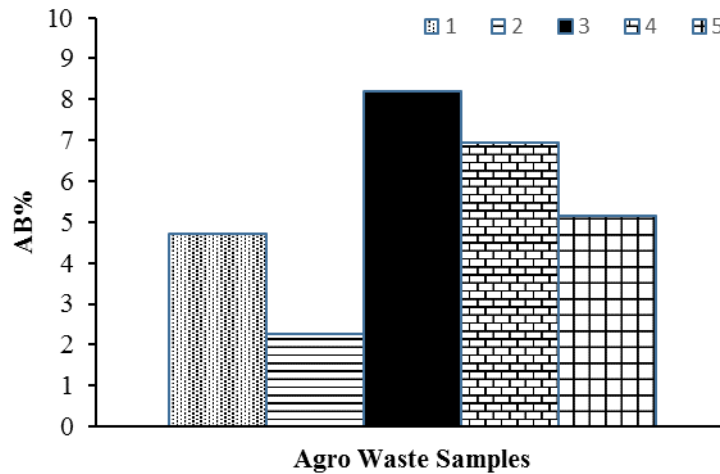


Figure 2 Absorption values (AB) of samples (1) Artichoke, (2) Spruce, (3) Savle, (4) Piank and (5) Myscanyhus

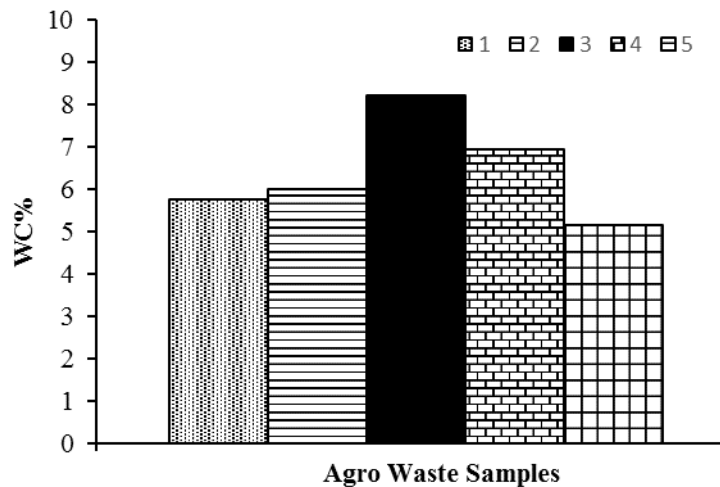


Figure 3 Moisture values (MC) of samples (1) Artichoke, (2) SPRUCE, (3) Savle, (4) Piank and (5) Myscanyhus

2.1.2 Preparation of the agro-mortar mixes

General use cement (GU) was used as the main binder to prepare six different mortar mixtures. The mixtures differentiated based on the type and the portion of partially replacement of agro-waste materials as represented in Table 3. The amount of HRWR ranged from (2.0% to 3.5%) of the cement weight was used. Air-entraining admixture (AEA) was added in the range of 35–65 ml/100 kg binder targeting a fresh air content of $5 \pm 1\%$.

The mixtures prepared according to ASTM C305 "Standard Practice for Mechanical Mixing of Hydraulic Cement Pastes and Mortars of Plastic Consistency". The water amount and admixtures was introduced into the mixing bowl, then added the designed amount of cement and mixing at low speed (i.e. 140 ± 5 r/m) for 30 seconds. The portion of sand was added to the bowl slowly and mixing at a medium speed (i.e. 240 ± 10 r/m) for 30 second. Finally, each type of agro-waste materials was added slowly to the mixtures within 30 seconds and remixing for 60 second.

The specimens are cured in water until testing age. For each mortar mixture, 24 cubes 50×50 mm were prepared to evaluate compressive strength. The compressive strength for all tested samples were evaluated according to ASTM C109 "Standard test method for compressive strength for hydraulic cement mortars (using 2 in.- or [50 mm] cube specimens)".

3 Results and discussion

3.1 Physical proprieties of different ago-waste materials

The Artichokewaste is a very light weight and looks like chopped corn stover waste (shown in fig1a), artichoke particles are angular, irregular and porous, and have a smooth surface texture, their particle size ranged between 0.1 to 5.5cm, artichoke is lighter and more brittle compared to natural sand. The particle size of spruce from 0.05 to 3.5cm, it looks as short tree waste (shown in fig1b), it is particularly are angular, less porous and have a rude surface texture. The third samples shown in fig1c, was labelled Piank it looks like long wheat straw waste. It is range size from 0.5 to 10.4cm it is very longer compared to agricultural waste study and are angular, have a rude surface texture. The fourth sample is Savle which looked like wood chips waste shown in **Erreur ! Source du renvoi introuvable.**d, its particle size range between 0.01 to 3cm and thickness of 2-6mm, this particularity help to performing more workability in using the Sable waste as aggregate in the mixes. The last sample was labelled Myscanyhus, it is similar to the irregular paink waste as shown in fig1. It's darker than the other agro waste samples. Its texture is hard, angular and have a good resistant to traction. The particle size range between 0.01 and 4cm.

The 24 h water absorption of different agro waste samples is shown in the figure 2. The water absorption artichoke value found to be 4.73%,3.26%,1.55%,4.65% and 4.41%, for the five ago waste sample respectively. It is clearly found the absorption capacity of piank it is very low that the other ago waste.

Figure 3 shows that the moisture content of different agro waste varied between 5.2% and 8.2%. The moisture content of salve is higher than other agro waste study (8.2%).

3.2 Micro structural analysis

Figure 4 shows full microstructural analysis with Scanning Electron Microscope (SEM) with energy dispersive X- ray spectrometer (EDS) for different agro waste materials, it is clear that the morphology of all agro materials are fibrous, especially, spruce myscanyhus and piank. Hence, can using the spruce, myscanyhus and piank fibre as a partial or full replacement for coarse aggregate in the concrete (Oyedepo 2012). The core of the artichoke waste is not dense and has a high amount of voids. The surface also seems to be smooth to rough (shown in fig4 a).

The SEM image of the Spruce waste prove that has a dense core, while it surface is rough and had many puckers (Fig.4 b,c,e). These may be possibly enhance the contact with binding materials. Show X-ray

diffraction (XRD) analysis were performed on a PANalytical X'pert Pro system using CuK α . It is clear from the XRD results that all the materials are amorphous and no crystalline structures existed.

Figure 5 shows X-ray diffraction (XRD) of different agro waste samples. It is clear from the XRD results that all the materials are amorphous and no crystalline structures are existed.

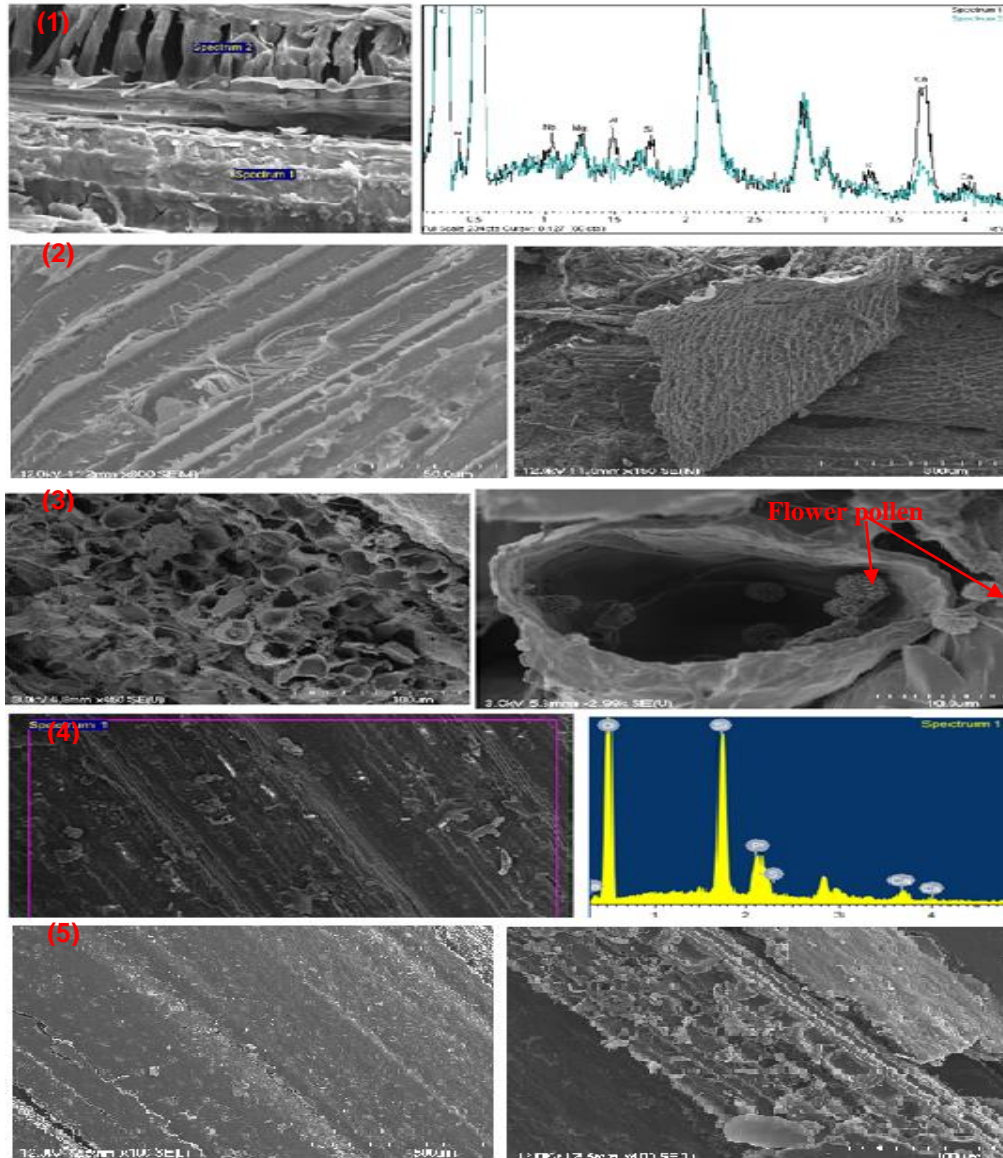


Figure 4 SEM image and EDS of 1) Artichoke waste, 2) spruce waste sample, 3) Savle waste sample, 4) Piank waste sample, 5) Myscanyhus waste sample.

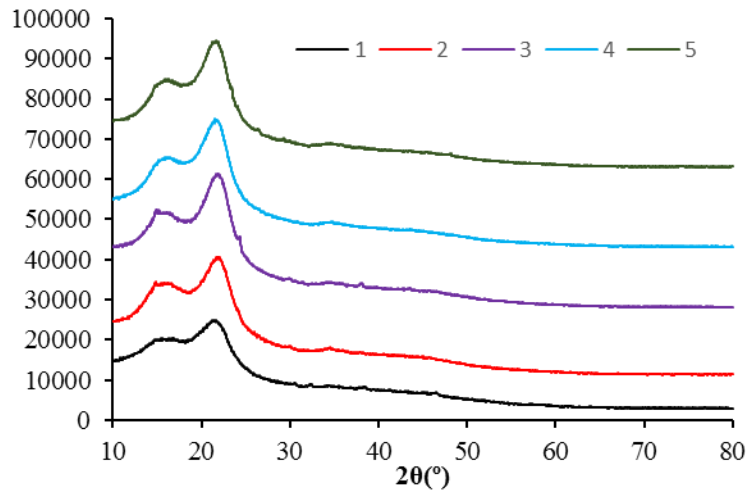


Figure 5 X-ray diffraction patterns for different powder samples (1) Artichoke, (2) Spruce, (3) Savle, (4) Piank and (5) Myscanyhus

3.3 Workability of agro waste cement mortar

Flow table test was conducted according to (ASTM C1437), which is a very common test to assess the workability of any kind of mortar. It was observed that for all mortars incorporating agro-waste, the flow value was maximum at 0% replacement and then it decreased significantly with increasing the amount of agro-waste. This type of behaviour in slump value was due to two reasons: 1) the high water absorption of agro-wastes which declined the flow ability of the mixture at same w/c ratio (especially Artichoke sample). 2) The angularity of particles for some tested wastes (especially Piank and Myscanyhus).

3.4 Compressive strength

In order to evaluate the effect of adding agro-waste on compressive strength for produced construction material, cubic samples of (50 mm) were cast and tested at ages 3, 7 and 28 days. The agro wastes were initially sieved to avoid long particles and then incorporated at two rates 25% and 50% by volume. These replacement ratios are actually higher than those reported in the literature Ref. The aim behind selecting these high replacement ratio was to investigate the upper boundary for implementation of such waste. Incorporating higher amount of waste will lead to more sustainable construction material. Moreover, in order to optimize the sustainability, two types of binders were used: 1) cement-based binder and 2) Green activated binder. Table 3 summarizes the compressive strength results for all tested mixtures. Regardless their types, it can be seen from the results that in general the addition of agro-waste as partial replacement of sand had reduced the strength. The higher the additional rate of agro waste, the higher the reduction in strength. One interesting point, in some mixtures applying the standard curing had an adverse effect on the achieved strength. Some cubic specimens had totally cracked and damaged as a result of expansion (Figure 6). Agro wastes absorb curing water and expand inducing internal stresses. This was more obvious in cement-based mortar, while specimens fabricated using green activated binder showed less expansion (Figure 7). This can be attributed to the lower porosity of the green activated binder which halts water migration inside the sample. On the other hand, Savle waste exhibited an opposite trend. It seems that the high alkalinity of the green activated binder had affected its stability.

Table 3 Compressive strength for green activated binder and cement-based binder mortar

Waste Type	% waste (by volume)	Compressive strength (MPa)							
		Green activated binder				Cement-based binder			
		1D	3D	7D	28 D	1D	3D	7D	28 D
-----	0	2.68	5.64	18.6	22.5	6.64	10.36	14.72	19.40
Artichoke	25%	1.48	1.64	9.9	17.4	4.64	7.04	11.68	13.80
	50%	2.32	1.76	6.32	15.4	1.56	1.88	7.16	10.50
Savle	25%	1.00	0.72	0.72	---	2.02	6.48	7.76	14.84
	50%	1.20	1.16	0.76	---	1.08	2.92	6.40	10.32
SPRUCE	25%	2.52	3.20	14.6	19.2	0.84	3.72	6.16	17.64
	50%	1.48	2.20	8.28	15.1	0.64	1.36	2.52	14.20
Myscanyhus	25%	1.56	4.64	6.84	15.8	0.68	1.16	5.44	----
	50%	1.40	1.64	4.60	13.2	0.48	0.4	0.88	----
Piank	25%	2.28	2.60	4.28	14.4	1.28	3.68	2.36	----
	50%	1.72	2.04	2.84	8.76	0.44	0.52	----	----



Figure 6 Expansion for samples with cement-based binder and agro waste a) Piank and b) Myscanyhus



Figure 7 Expansion for samples with cement-based binder and agro-waste a) Piank and b) Myscanyhus

3.5 Microstructure analysis for cement paste

Figure 8 shows the microstructure for portland cement paste mixed with different types of agro-waste. It is clear that the addition of agro waste did not halt the hydration process for cement. Different hydration products can be detected as confirmed by Scanning Electron Microscopy (SEM) and EDS.

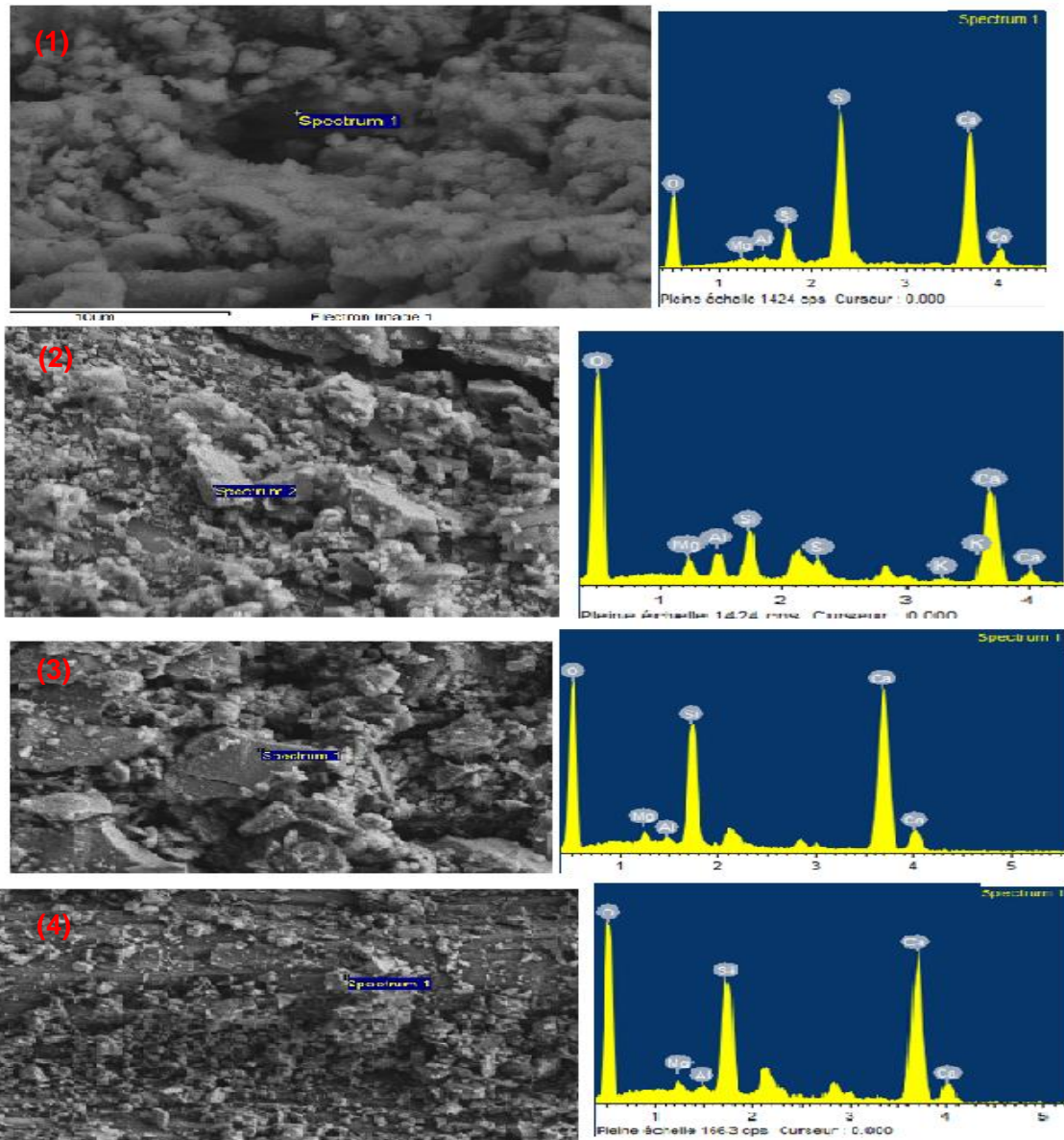


Figure 8: Scanning electron microscopy of cement paste mixed with different ago waste samples: 1) Artichoke waste, 2) Spruce, 3) Savle waste, 4) Myscanyhus.

4 Conclusion

This preliminary experimental program was carried out to examine the optional of using five different agricultural wastes in construction concrete production. The reported results were used to compare between the different types of wastes and their potential to be used in construction.

Based on the outcomes from the preliminary experimental program, it was found that there is a potential for using the tested agricultural wastes in producing sustainable concrete for some construction applications. Many aspects need to be considered while using these materials including physical properties of waste, addition rate, curing regime for produced materials and type of binding materials. Optimizing the mixture design based on each agricultural waste properties will possibly lead to a higher quality and more sustainable performance.

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