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CHEMICAL ENGINEERING DOCTORAL SCHOOL

New indigenous mineral resources in special cement

- Doctoral thesis abstract -

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SUMMARY

Note: The same notation for figures, tables used in the PhD thesis were kept when writing the abstract.

List of abbreviations

A = Al_2O_3

DTA = differential thermal analysis

C_4AF = $4CaO.Al_2O_3.Fe_2O_3$ = brownmillerite

$C_4A_3\overline{S}$ = $4CaO.3Al_2O_3.SO_3$

$C\overline{S}$ = $CaO.SO_3$

C_2S = $2CaO.SiO_2$ = belite

C_3S = $3CaO.SiO_2$ = alite

BSA cement = belite-sulfoaluminate cement

DTG = Differential thermogravimetry

H = H_2O

M = MgO

M_{Al} = alumina module

M_{Si} = silica module

N (K) = Na_2O (K_2O)

OPC = Ordinary Portland Cement

$\hat{S}$ = SO_3

S_k = calcium oxide saturation index

TG = Thermogravimetric analysis

INTRODUCTION

This work sets out certain primary objectives, concerning the current stage of sustainable development, maximum efficiency, regarding material consumption, energy and human resources consumption, in parallel with environmental protection.

In this setting, the capitalization of indigenous mineral resources that are easy to exploit and transport and especially the capitalization of industrial waste, i.e. red mud, is one of the main objectives.

Red or nepheline mud, waste generated in the industrial production of alumina, in processing apatite-nepheline ore or phosphate fertilisers, stored in huge amounts in our country, is one of the most consequential pollutants, mainly because of its high alkalinity. Not only does it use large areas of land which would could be used otherwise (forestry, agriculture etc.) but the mud also widely and deeply infests the soil.

The selection of raw materials that are convenient from an economic and energetic perspective implies the capitalization of local mineral resources, inexhaustible reserves, in obtaining new binders that can be classified as" ecological", with low energy consumption.

The binder manufacturing technology also takes into consideration the ecological balance, to avoid affecting the local flora and fauna. The technology involves a reduction in noxious emissions which contribute to the "greenhouse effect".

The objective of this paper consists of using indigenous mineral resources and industrial waste in the manufacture of special belite-sulfoaluminate cement, with economic and ecological consequences.

The indigenous mineral resources that were considered are: Bodoc clay, Varghis limestone, Filia diatomite, Racosul de Sus tuff, Racosul de Jos basaltic scoria, Nucsoara gypsum.

The industrial waste is red mud – nepheline mud from Oradea.

Using available materials, a decreased energy consumption in transporting and processing the raw material mixture on one site and burning it to turn it into clinker on the other, represent significant energy savings.

Belite-sulfoaluminate binder manufacturing also concerns certain ecological aspects, such as using industrial waste, with all known consequences and significant decrease of carbon dioxide emissions during combustion, due to temperatures reduced by 200-300^{0}C, compared to ordinary Portland clinker.

The increased interest in belite-sulfoaluminate binder manufacturing can also be explained when considering the following potential advantages:

1. It requires lower quantities of calcium oxide (and therefore limestone) in the raw material mixture, forming the main mineralogical constituents; by 15-20% lower compared to the raw mixture used in ordinary Portland clinker. The saturation index of calcium oxides is lower, in the range of 0.75 – 0.85, when compared to ordinary Portland cement where it greatly exceeds these values, being in the range of 0.9 – 1.00.
2. For the synthesis of mineralogical components of low-energy cement, such as: belite – $2CaO.SiO_2$; brownmillerite -$4CaO.Al_2O_3$. Fe_2O_3 and ylmenite -$3(CaO. Al_2O_3).CaSO_4$ the temperatures required are lower, around 1200-1250^{0}C instead of 1450 -1500 ^{0}C, which is the temperature used for ordinary Portland cement.
3. Due to the lower clinker heating temperature the emissions of NOx are decreased, which has positive consequences on the greenhouse effect.
4. Positive consequences on the greenhouse effect are also generated by the significant decrease in CO2 emissions as a result of using smaller quantities of limestone in the raw mixture. The total calcium oxide necessary for BSA cement is around 50 % (gravimetric) compared to 65 % (gravimetric).
5. The grindability of these substances to transform them in cement is increased by 40% compared to Portland cement; the result is more brittle, with burning temperature significantly lower by 200 – 300°C, and with a reduced vitreous phase.
6. BSA$^{1)}$ cement shows no signs of contraction during hardening and can even expand and are stable in hostile environments, especially when exposed to sulfide corrosion.
7. A remarkable advantage of the belite-sulfoaluminate cement is the high compressive strength, from the very first days of hardening (over 10 – 15 MPa after two days).

8. Mechanical resistance to higher limits can reach values greatly exceeding those of Portland cement, over 40-59 MPa after 28 days of hardening.

BSA[1)] – belite-sulfoaluminate cement

DOCTORAL THESIS STRUCTURE

The paper is divided in seven parts including an introduction, a literature review, the research performed and results obtained and finally, general conclusions.

The introduction highlight the paper's relevance, its objectives, reasoning and **objective**, which is using indigenous mineral resources and industrial waste in the manufacture of special belite-sulfoaluminate cement, with economic and ecological consequences.

The introduction is also used to list the potential advantages of using BSA cement.

1. LITERATURE REVIEW

The first chapter contains an ample literature review in the field, highlighting the positive aspects of BSA cement compared to Portland cement. It presents the standard and common types of cement in Romania, the most frequent admixtures, the classification of Portland cement based on mineralogical composition, the main mineral phases of belite-sulfoaluminate cement (BSA), as well as the properties of BSA binders.

It could be said that the manufacture of belite-sulfoaluminate cement has a series of advantages when compared to Portland cement.

1. It requires lower quantities of calcium oxide (and therefore limestone) in the raw material mixture, forming the main mineralogical constituents; by 15-20% lower compared to the raw mixture used in Portland clinker. The saturation index is lower, under 0.85.
2. For the synthesis of mineralogical components such as belite –$\mathbf{2}CaO.SiO_2$; brownmillerite - $4CaO.Al_2O_3$. Fe_2O_3 and ylmenite -$3(CaO. Al_2O_3).CaSO_4$ the temperatures required are lower by around 250-300^{0}C , meaning that the synthesis temperature is around 1200-1250^{0}C instead of 1450-1500^{0}C, which is the temperature used for ordinary Portland cement.

3. Due to the lower clinker heating temperature the emissions of NO_x are decreased, which has positive consequences on the greenhouse effect.
4. Positive consequences on the greenhouse effect are also generated by the significant decrease in CO_2 emissions as a result of using smaller quantities of limestone in the raw mixture.
5. The grindability of these substances to transform them in cement is increased by 40% compared to Portland cement (the result is more brittle, with a lower burning temperature, with an inexistent or reduced vitreous phase).
6. BSA$^{1)}$ cement shows no signs of contraction during hardening and can even expand and are stable in hostile environments, especially when exposed to sulfide corrosion.

2. RAW MATERIALS

Thanks to the relatively complex geological make-up available in Covasna County, the great structural formations harbour a large range of mineral deposits useful to the industry, especially in constructions.

This chapter offers an overview of raw materials on which the manufacturing of BSA cement is based: clay, limestone, basalt, tuff, diatomite and red mud waste.

Clay – the most important aluminosilicate in cement manufacturing – it is found in several varieties of high quality in the Carpathian Curvature area, the deposits being enormous.

Limestone – a sedimentary rock – is one of the most wide spread rocks on the earth crust, being present in various geological formations both as monomineralic rock and in combination with other minerals.

From an economic perspective, limestone is very important. According to data provided by the National Agency for Mineral Resources, limestone deposits are among the most coveted mineral deposits in the world.

Basalt is an extrusive igneous rock, made of alkaline plagioclase minerals (usually, labradorite), augite, amphibole, olivine, pyroxene, iron and magnesium silicates and volcanic glass. At Racos, there still are deposits of **basaltic scoria**. These were created from lava eruptions that were suddenly cooled down, in the the presence of water vapours, leaving a multitude of vesicles similar to cinders.

Tuff is a porous rock, made of the tephra ejected during volcanic eruptions, compacted and cemented. Tuff has a varied chemical composition corresponding to the composition of lava.

Diatomite and **tripoli** are rocks with a reach content of hydrated silica. Diatomite is a rock with a very fine structure composed of siliceous skeletons with sizes between 1-10 µm. The SiO_2 content is in the range 60-98 % .

Red mud also named nepheline mud, generated in the industrial production of alumina, in processing apatite-nepheline ore or phosphate fertilisers, often called red sludge, is used with very good results in the cement industry, in raw material mixtures, but also in the manufacturing of mixed binders.

3. RESEARCH METHODS

In order to determine the properties of the raw matters and mixtures and the properties of the end products, some standard analyses and determining methods in the production of binders were used: oxidic chemical analyses, mineralogical analyses, diffraction analyses, thermal analyses, physico-mechanical tests (particle-size distribution, specific density, Blaine specific surface, heat of hydration, volume constancy, setting time, strength in compression).

4. DESCRIPTION OF RAW MATTERS AND ROUGH MIXTURES

The raw matters presented in Chapter 2 were characterized through the oxidic chemical analysis, the petrographic analysis (petrographic microscopy, e.g. *(fig. 4.1)*

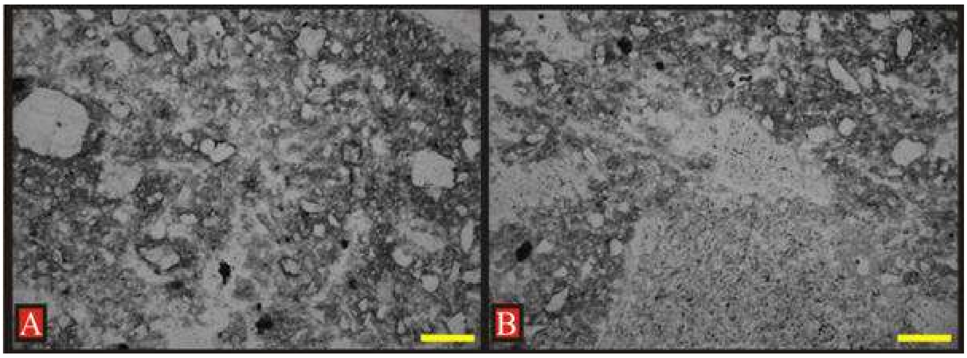


Fig. 4.1. Microscopic analysis of the Bodoc clay

The preparation of the raw matters was done according to the flow sheet shown in fig. 4.2

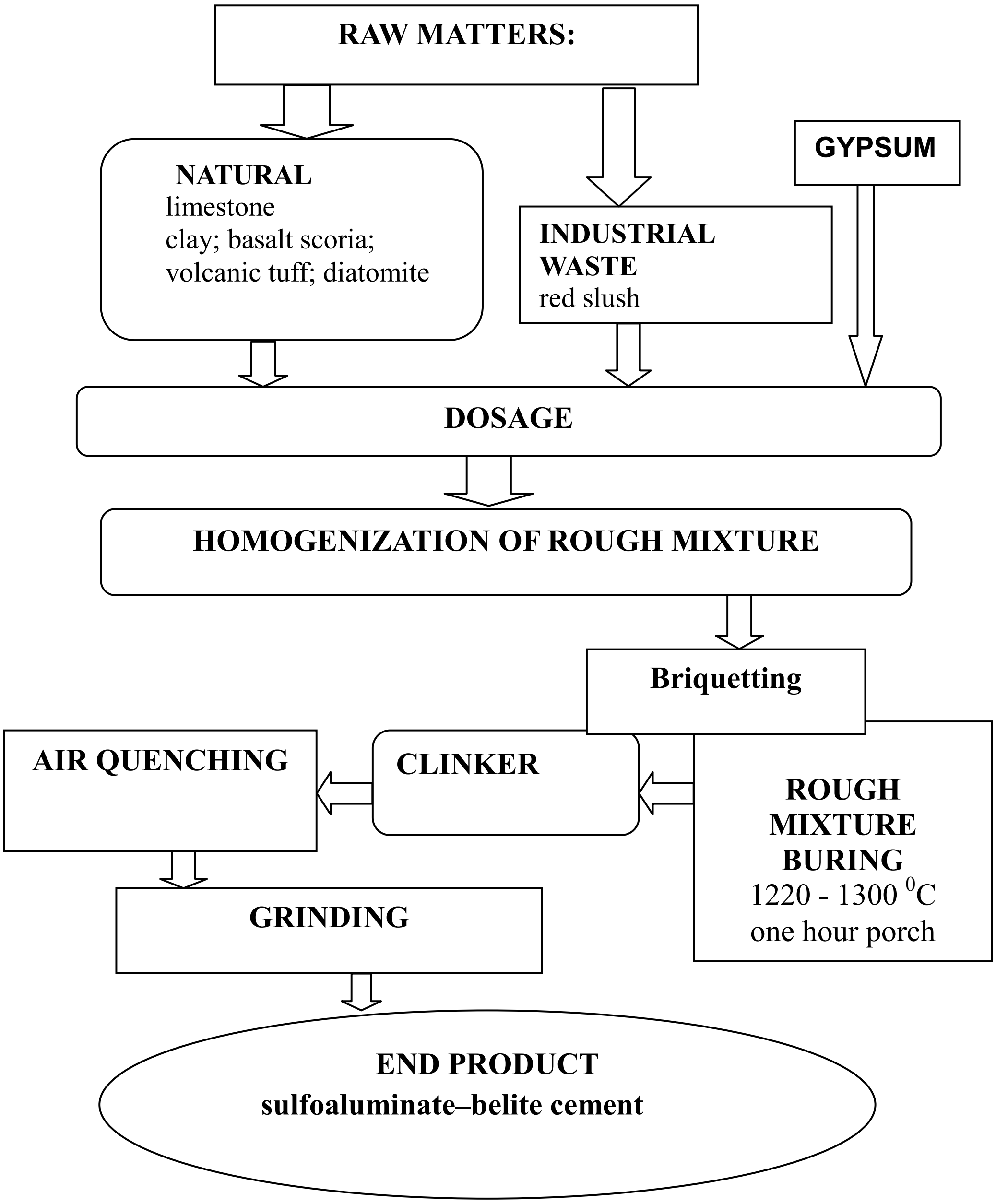


Fig.4.2.

The optimal clinker burning temperature was established through thermal analyses, e.g. ***Fig. 4.3***

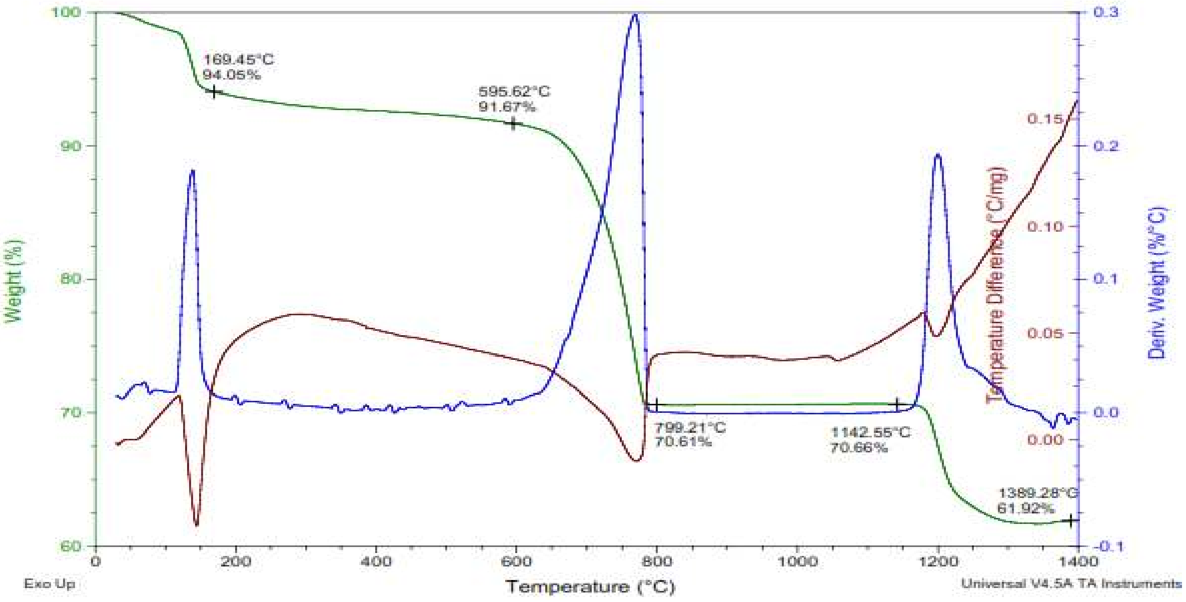


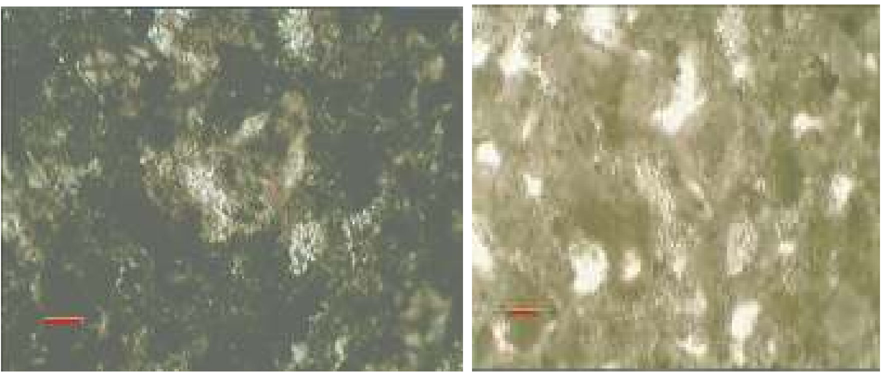
Fig 4.3. *A.T.D. assay C3 (limestone 54,35% +23,37 % volcanic tuff +22,28 % gypsum)*

The optimal synthesis range of the studied binding masses was established based on the careful analysis of the derivatographs performed on rough mixtures. It can be noticed that the maximum burning temperature must not exceed 1300^{0}C, thus to avoid the decomposition of the valuable compound – calcium sulfoaluminate (Ye'elimite).

5. CHARACTERISATION OF THE CLINKERS

The mineralogical characterisation of the clinkers has been made in great detail using **optical microscopy** and **X-ray diffraction analysis**. Thus, the results obtained have been compared and mutually completed.

The results of the petrographic analysis of the burnt masses obtained from the rough mixtures that have been previously prepared (chapter 4) are presented chronologically. E.g. ***fig.5.1.***



a (N+) b (1N)

Fig.5.1. *Assay 1 (52.88% limestone; 7.09% clay; 40.03% gypsum, 1220 ^{0}C) , 50 µm*

c (N+)

Fig.5.1. *Assay 1, (52. 88% limestone; 7.09% clay; 40.03% gypsum, 1220 ^{0}C) , 50 µm*

Corroded particles of belite III {a (N+) and b (1N); white-yellowish belite nests and a belite II nest can be observed.

The belite III nests have sizes of around 50 µm and pleochroic colours from brownish yellow to yellow. The pores are circular, intensely elongated and plastered with alkaline sulphates, with grey-whitish birefringence (see fig.5.1. c).

The matrix of the clinker has a dark colour and small quantities around the belite crystals and it is represented by yellow-brown brownmillerite crystals associated with a smaller celite (isotropic aluminate) quantity and very little vitreous phase.

Similar analyses have been performed on all the clinker assays.

In conclusion, based on the petrographic analysis we can confirm that all synthesised masses presented C4A3$\overline{S}$, which crystallises in the cubic system, with high refraction index.

As opposed to the literature, said masses are characterised by a yellow pleochroism.

C4A3$\overline{S}$ can easily form solid solutions with Fe3+ (replaces Al3+) or with Mn2+ ions (can substitute Ca2+), therefore it is slightly coloured in the green-brown matrix of said masses.

Belite, in various polymorphous forms (BI, BII and BIII), together with the phaneritic phases {C2F – C4AF) are present in the majority of synthesised masses.

The vitreous phase appears in extremely small quantities, even in the case of masses that have been burnt at high temperatures (1300^0C). The binding masses are very porous and friable.

The diffraction analyses have enabled the identification of the crystallne phases that can sometimes be compared from a petrographic point of view. For example, C4A3$\overline{S}$ can be compared with alite or anhydrite.

Table 5.1 presents the main mineralogical phases identified from the assays that have been burnt at 1240°C, from a qualitative perspective (the last two assays burnt at the temperatures provided in the table).

In accordance with the microscopic analysis, all the masses presented:

β -C2S, CaSO4 , C4A3$\overline{S}$, and C4AF. Some of the assays also presented small traces of aluminates and aluminosilicates; however, said quantities proved to be insignificant as binding properties.

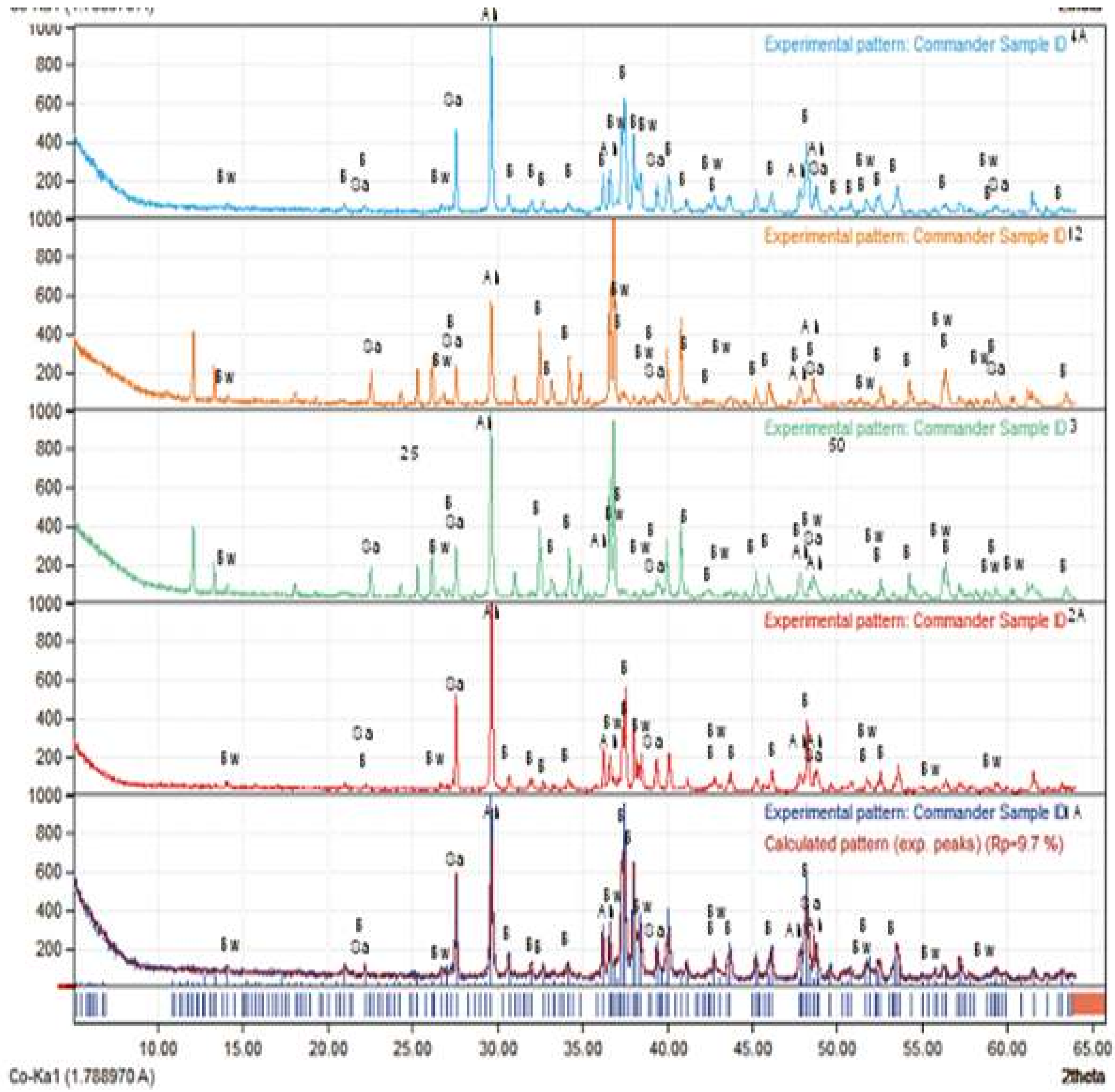


Fig. 5.2. *Diffractograms of the assays with variable content of clay*

1-7.09 %; 2- 10.88 %; 3 -0.05 % clay; 12 -2.74 % and 4-2.60 %.

Notations: Sa= sulfoaluminate; B= belite; Bw= brownmillerite; Ah= anhydrite

The mineral phases of clinkers that have been determined by means of diffraction analyses are presented in **Table 5.1**.

Table 5.1 *Centralisation of the quantitative results of the mineral phases of clinkers*

Sample	C_2S	C_3S	$C_4A_3\bar{S}$	C_4AF	$C\bar{S}$	Standard alite	Standard belite
1240^{0}C	38.9	23.4	8.9	11.6	17.1	73-0599	70-0388 monoclinic
1	35	28.7	8	20.4	15.4	73-0599	70-0388 monoclinic
2	44.5	14.2	9.8	12.7	18.8	84-0594	77-0382 orthorhombic
3	39.9	23.1	8.8	11.4	16.9	73-0599	83-0465 monoclinic
4	39.9	23.1	8.8	11.4	16.9	73-0599	83-0465
5	39.9	23.1	8.8	11.4	16.9	73-0599	83-0465
6	39.9	23.1	8.8	11.4	16.9	73-0599	83-0465
7	35.7	31.1	7.9	10.2	15.1	73-0599	83-0465 monoclinic
8	34.8	31.8	8	10.4	15.3	70-1846	70-0388 monoclinic
11	35.7	31.1	7.9	10.2	15.1	70-1846	83-0465 monoclinic
11 - 1260^{0}C	36.4	30.8	7.8	10.1	15	70-1846	77-0388 monoclinic

Obs. The last two columns contain the standard codes of the minerals used for the identification.

In conclusion, based on the petrographic analyses and the X-ray diffraction analyses, we can assert that the synthesised masses are sulfoaluminate-belite. Said masses contain the $C4A3\bar{S}$ compound, together with anhydrite and significant quantities of belite and brownmillerite.

Belite occurs in all three forms, i.e. B-I, B-II and B-III, which are frequently found in normal clinkers as well. BI – elongated crystals with two-way striations, characteristic for higher temperatures; B-II – round crystals with one-way striations, characteristic for lower temperatures and B-III – in the shape of brownish stains that surround the B-I particles.

The optical microscopy is consistent with the X-ray diffraction analysis since the results generally complete each other.

6. PHYSICO-MECHANICAL PROPERTIES OF CEMENTS

In order to determine the physico-mechanical properties specific to the synthesised sulfoaluminate-belite, we have selected, as a base, binding masses C1- C5 burnt at 1300^{0}C and for the comparison we have selected similar oxidic compound masses burnt at a temperature of 1240^{0}C. The difference in burning temperature, as determined by the petrographic analysis and the roentgenographic analysis, does not determine significant differences in the mineralogical composition thereof. However, the quantity of vitreous phase is positively influenced once the temperature rises.

The density of the binding masses depends mainly on the nature of the raw matters included in the mixture and on the nature and proportion of the constituent metal oxides. Depending on the composition of the mixture, minerals of specific densities shall form within the binding system.

Table 6.1. *Specific density of certain cements*

Assay No.	**Mixture, %**						**Density [g/cm^3]**
	Limestone	Gypsum	Diatomite	Tuff	Mud	Sinter	
5	59.42	23.53	8.97	-	8.08	-	3.08
7	46.40	48.91	-	-	-	4.69	2.95
8	42.05	51.37	-	-	6.20	0.38	3.04
11.	46.55	42.88	-	10.57	-	-	2.91
C1	48.90	14.43	-	-	-	36.67	2.95
C2	54.08	32.22	13.70	-	-	-	2.84

C3	54.35	22.28	-	23.37	-	-	3.03
C4	54.66	12.83	-	-	0.98	31.53	3.05
C5	47.45	30.70	-	-	1.19	20.66	2.92

The grinding fineness of the cements is important when hardening the cement pastes using water. The hydration and hydrolysis processes and the transformation of anhydrite compounds into water compounds can be accelerated at an advanced fineness (Bouzidi, Mohamed Amin, 2014; Teoreanu Ion ş.a., 1987).

The grinding fineness of the binding masses has been determined by the Blaine specific surface and the grain-size distribution.

Table 6.2. *Blaine specific surfaces of cements*

Item no.	Cement/ temperature, [^{0}C]	Specific surface , [cm^2/g]
1.	5 -1240^{0}C	9580
2.	7 -1240^{0}C	9845
3.	8 -1240^{0}C	9610
4	11 - 1240^{0}C	9980
5	C1- 1300^{0}C	7367
6	C2- 1300^{0}C	8745
7	C3- 1300^{0}C	7963
8	C4- 1300^{0}C	6501
9	C5- 1300^{0}C	7553

Upon grinding under identical conditions, **the specific surface** shows the influence of the burning temperature on the grindability (the binding masses are similar from a compositional point of view). Masses 5, 7, 8 and 11 are much more friable than the masses burnt at 60^{0}C higher temperatures, C1-C5. In said masses, as determined by the petrographic analysis, the vitreous phase proportion is extremely small compared to masses C1-C5 burnt at 1300^0**C**.

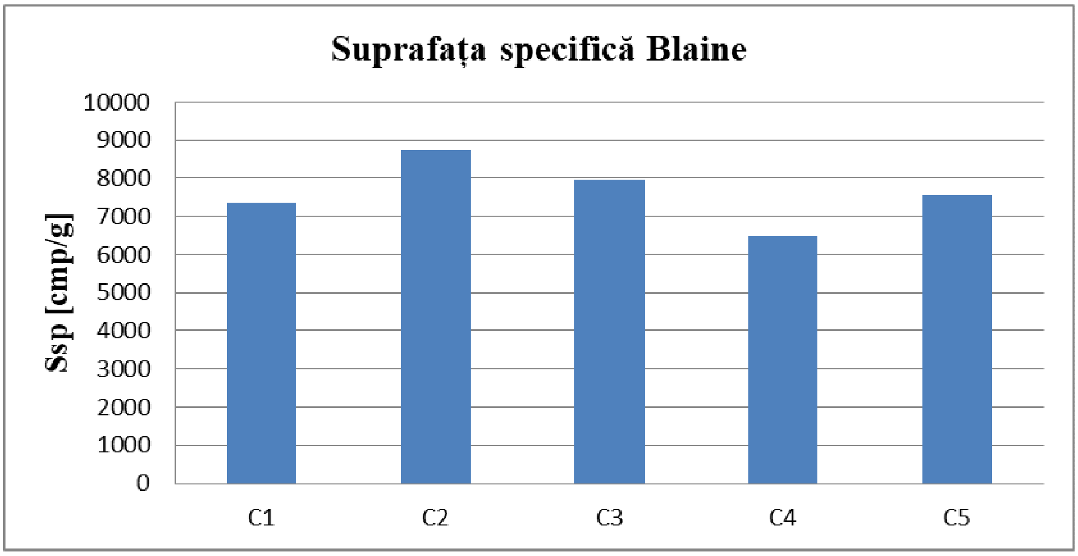


Fig. 6.1. *Blaine specific surface of the cement assays C1-C5*

The grain-size distribution has been monitored only for masses C1, C2, C3, C4 and C5 burnt at 1300^{0}C, which have presented more significant differences in the specific surface values, Fig. 6.2.

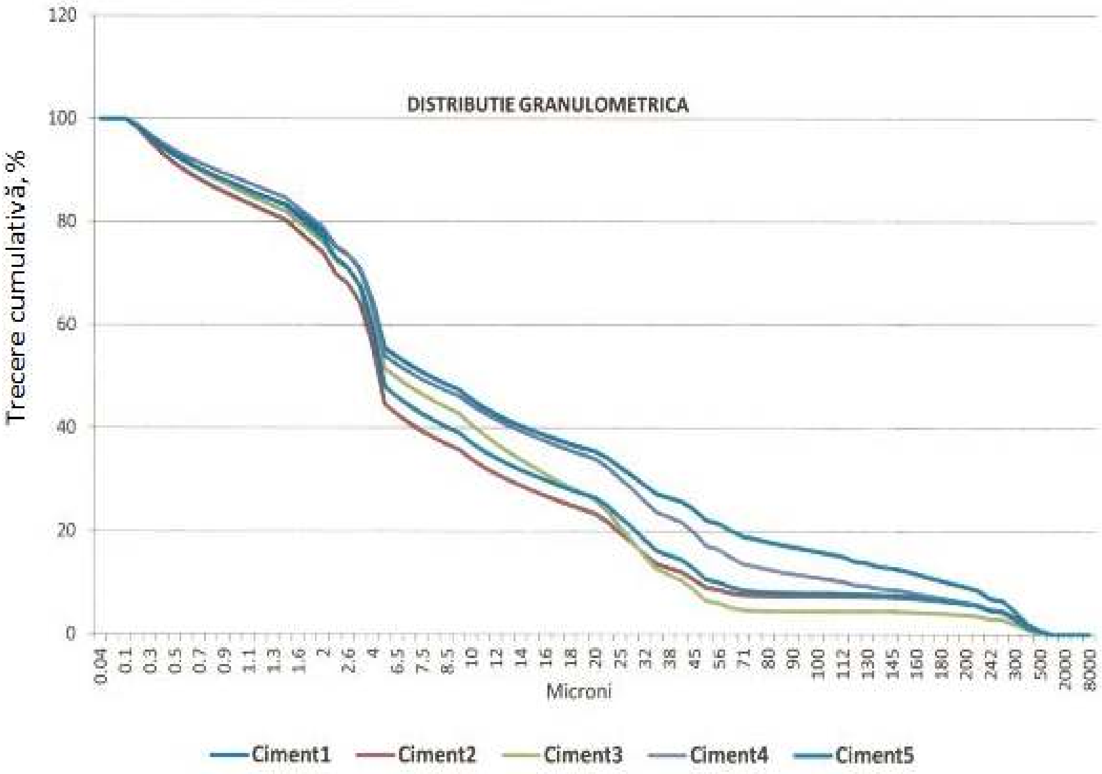


Fig. 6.2. *The grain-size distribution of cements C1-C5*

The rate of the distribution curves is quite similar, even though the values of the cumulative passages are rather different, as one may notice. As a matter of fact, the weight of particles sized less than 32 µm is quite different, but in a good correlation with the specific surfaces of the cements.

Hydration heat is influenced by the grinding fineness, the mineralogical composition, the oxidic compositions, the modular characteristics, and the water/cement ratio.

Normal consistency water is the one that secures the optimal plasticity of the cement pastes (xxx SR EN 196-3). This measure depends on the amount of hydraulically active compounds of the cement, but also on the specific surface. Normal consistency water essentially depends on the amount and nature of the mineralogical compounds as well. The obtained values may also be explained if the mineralogical composition is taken into account.

Volume constancy (Stability). As expected, the stability of the produced masses is good and even very good.

The setting time is affected by the same factors as normal consistency water: the mineralogical composition of cement, particularly the amount of calcium sulfoaluminate, the specific surface and the dispersive status of the cement.

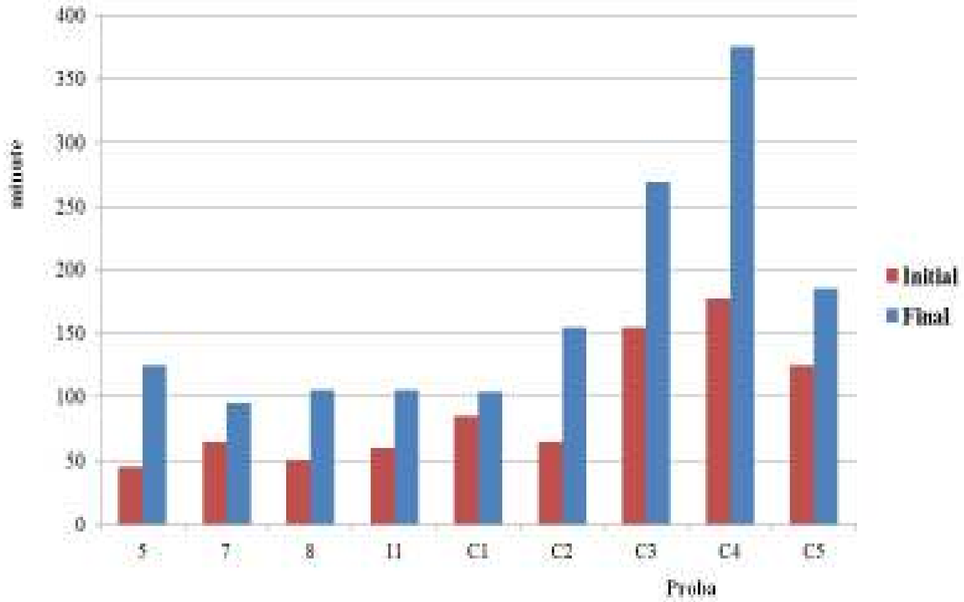


Fig. 6.3. *Setting time [minutes] for different cements*

Compressive strength

The investigated experimental cements have developed different strengths, based on their mineralogical composition, the burning temperature and the grinding fineness - specific area,

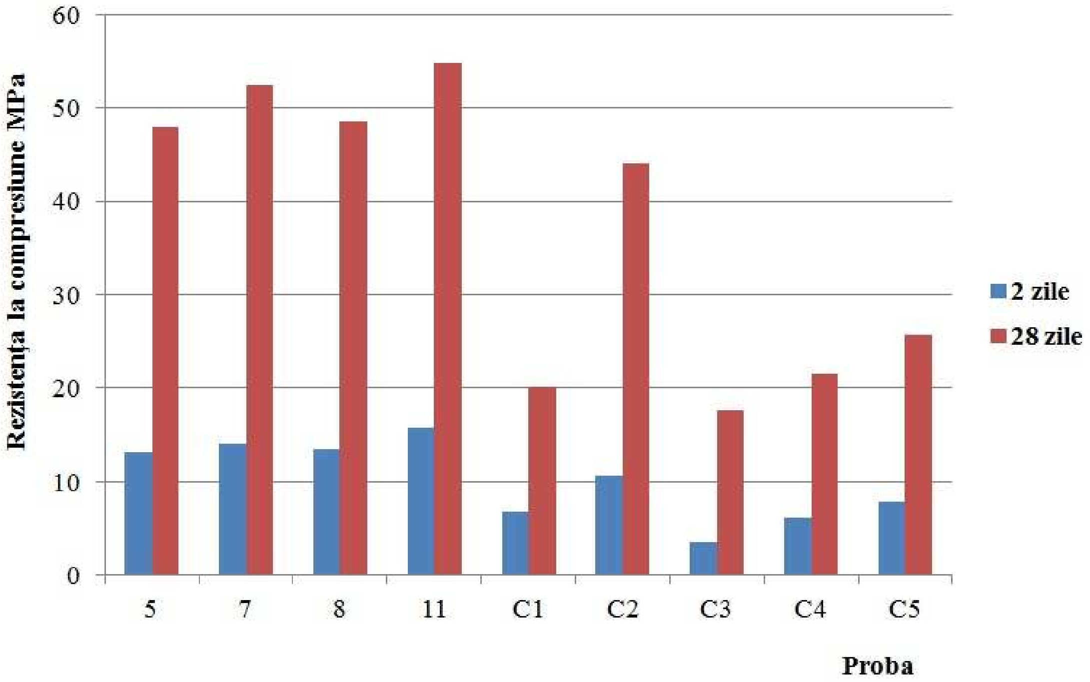


Fig. 6.4. *Compressive strength of cements, Mpa*

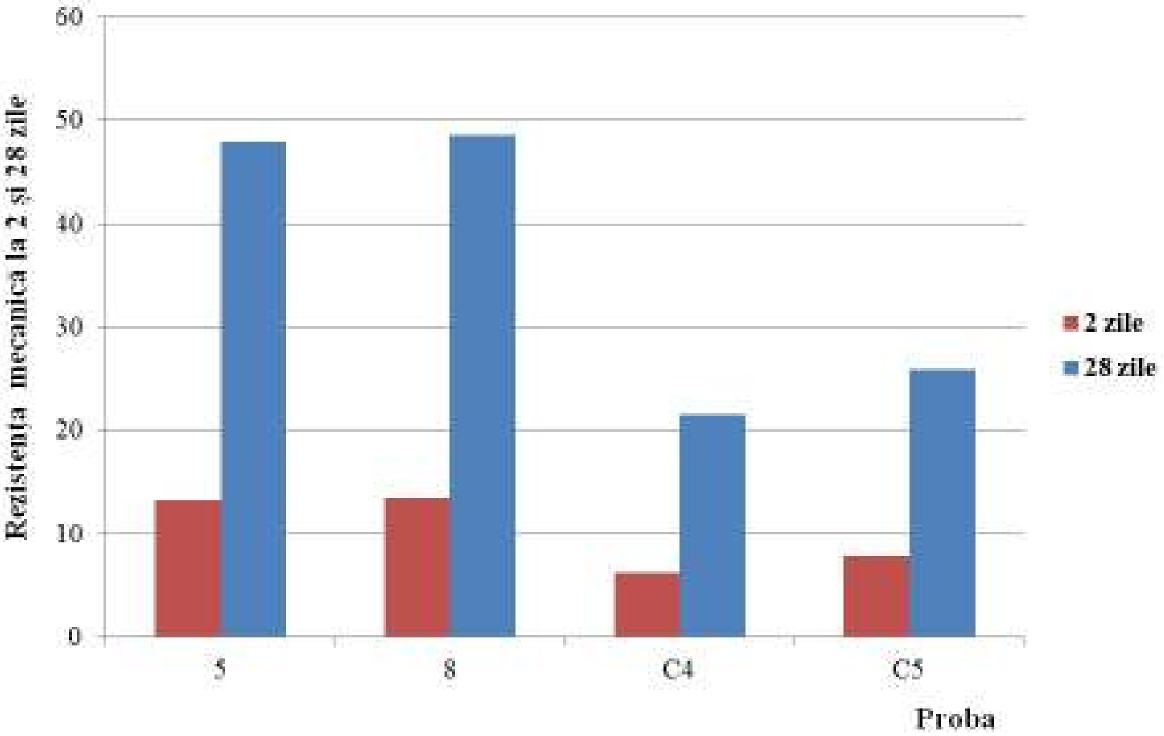


Fig. 6.5. *Strength after 2 days and respectively after 28 days*

CONCLUSIONS

By analysing the results obtained, the following important conclusions can be reached, according to the chapters previously elaborated herein:

- The importance of manufacturing low-energy consumption cement, in the current stage of cement manufacturing development, complying with a low level of greenhouse gas emissions, particularly carbon dioxide, led to the idea to manufacture new economical and ecological cement.

- Low-energy consumption cement was classified based on data drawn from literature in mixed and unitary cement.

- Special attention was paid to belite-sulfoaluminate unitary cement, which has a series of advantages compared to Portland cement: it requires lower combustion temperatures (1200-12500 ^{o}C instead of 1450 -15000 ^{o}C), it contains 15-20% less limestone in the raw mixture, NOx and CO_2 emissions are reduced with positive consequences on the greenhouse effect, and the grindability is decreased by 40% compared to Portland cement, due to the reduces vitreous phase - chap.1.

- The raw materials tested for use in BSA cement manufacturing are indigenous mineral resources such as: Bodoc clay, Varghis limestone, Filia diatomite, Racosul de Sus tuff, Racosul de Jos basaltic scoria, Nucsoara gypsum. The industrial waste use is red mud from Oradea- chap.2.

- The research methods used are the standard ones in the cement industry, an overview thereof being available in chap.3

- The characterisation of raw materials was made both from a chemical perspective (chemical analysis, EDAX), and from a petrographic one (optical microscopy).

- The calculation to determine the mixture content was made using the modified Bogue formula (Appendix 2). 17 mixtures were made by combining natural raw materials and red mud (six mixtures).

- Raw mixtures were made so that they keep the same oxidic content, starting from different raw materials, to observe and effect the character of the raw material; for example: *mixture 5* (59,42% limestone; 8,08% mud; 8,97% diatomite and 23,53% gypsum), with an oxidic content identical to mixture 11

(46,55% limestone; 10,57% tuff şi 42,88% gypsum) and to *mixture C4* (54,66% limestone; 0,98% mud; 31,53% scoria and 12,83% gypsum).

- The synthesis conditions for raw mixtures were established based on the differential thermal analyses, taking into consideration the physical and chemical changes of the selected mixtures. The changes that took place at the temperatures 12200 ^{o}C, 12400 ^{o}C, 12600 ^{o}C 13000 ^{o}C, one hour reference at maximum temperature, were tracked.

- Derivatograms of raw mixtures showed that a combustion temperature of 12000C is sufficient for the formation within the system of the valuable compound, yelmenite, C_4A_3. Higher temperatures can determine the separation of SO3 from the mixture caused by the dissociation of $CaSO_4$. In most samples a start of the vitreous phase (melting) can be seen at temperatures over 12000 ^{o}C.

- The optical microscopy (petrography) and diffractometric analyses are coherent, the results complementing each other in most cases. Therefore it could be said that the synthesised mixtures are belite-sulfoaluminate. They contain the compound $C_4A_3\overline{S}$, together with anhydrite and significant amounts of belite and brownmillerite.

- $C_4A_3\overline{S}$ can easily form solid solutions with Fe3+ (replacing Al3+) or with Mn2+ ions (can replace Ca2+), which is why the petrographic analysis shows it slightly colours in the green-brown matrix of these mixtures.

- Belite crystals were found in all the clinkers under petrographical and mineralogical analysis (X rays). The belite appears in all its three forms B-I, B-

II and B-III, frequently seen in ordinary clinkers as well. BI – elongated crystals, with two-ways streaks, characteristic to high temperatures; B-II – round crystals with one-way streaks, characteristic to low temperatures, and B-III as brown spots surrounding B-I elongated particles. The size of belite crystals can vary in a wide range, from 20-50 µm up to 100-150 µm.

- Calcium ferrites and aluminoferrites (particularly brownmillerite) are also present together with belite, ylmenite and anhydrite in the synthesised mixtures. Their content is modified depending on the iron oxide ratio in the mixture in the field of known solid solutions:C2F – C4AF.

- Most samples also contain alite crystals as small groups at the surface of belite crystals (aureole) or grouped together in the pores of the matrix, with the size around 25 µm. The presence of mud in the raw material mixture, as well as of diatomite and/or tuff facilitated the formation of alite crystals –see Appendix 3.

- he vitreous phase is extremely reduced even in mixtures burned at higher temperatures (13000 ^oC). Therefore, the binders are very porous and brittle, with high grindability.

- The main physical and mechanical cement characteristics such as density, Blaine specific surface, hydration heat, volume constancy, hardening duration and compressive strength fundamentally depend on a series of parameters such as:

  - oxidic content and compound properties, content of melting oxides (Fe_2O_3, alkaline oxides) etc.,

  - synthesis temperature, vitreous phase ratio; the presence of hydraulically active compounds in initial hydrating conditions: alite, ylmenite,$C_4A_3\overline{S}$, as well as of compounds determinant of final resistance, at high limits: belite, brownmillerite.
  - the granularity and particle ratio under 30µm, insuring a quick interaction with water and influencing normal consistency water, hydrating heat, stability, hardening time and mechanical characteristics of grout.

- The behaviour of mixtures containing variable ratios of red mud, nepheline or belitic mud, is particularly important. The positive influence of waste mud can be better seen in mixture 5 -1240^{0}C, with a mechanical resistance of 13,20 MPa after /2 days and 47,90 after 28 days and in mixture 8 - 1240^{0}C with similar resistance of 13,50 MPa after /2 days and 48,60 after 28 days.

- The mud encourages the apparition of alite in the system. it contains premade belite and can easily initiate the apparition of alite crystals, according to the reaction in the solid phase $2CaO.SiO_2 + CaO \rightarrow 3CaO.SiO_2$.
- Even in small amounts, the alite favours both the initial resistance, after only two days of hardening and the final resistance after 28 days of hardening.
- Considering the main physical and mechanical characteristics of BSA cement, we can state that the optimum synthesis temperature is under 1300^{0}C. In terms of grindability, considering the physical and mechanical

cement characteristics, the synthesis at 1240^{0}C is preferable, when no visible amount of vitreous phase appears.

- Mixtures 5 -1240^{0}C and 8 -1240^{0}C containing red mud (nepheline mud) in ratios of 8,08% and 6,20% respectively behaved very well.

As a general conclusion, we can say that the **objective of the paper**, which is using indigenous mineral resources and industrial waste in the manufacture of special belite-sulfoaluminate cement, with economic and ecological consequences was met.

The binders obtained had good and very good mechanical properties, high stability, compensating the contraction of grout during hardening.

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