

Use of carbonate rock mining by-products in the cement and concrete industry to assess its application in the Department of Huila: A review

Aprovechamiento de subproductos de origen carbonatado en la industria del cemento y el concreto: una revisión para evaluar su aplicación en el departamento del Huila

Received: 15-05-2017 Accepted: 14-11-2017

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Abstract

The Department of Huila has become an eye-catching focus in the development of mining activities due to its diversity of minerals and untapped deposits. It comes up for the Department, the pressing need for a joint between mining by-products and the building industry which will certainly play an important role in the region's economic growth. This article shows a literature review about the main characteristics and trends in the use of carbonate rock mining by-products in building applications, especially in the production of Portland cement and concrete, where negative environmental impacts and economic costs are minimized and beneficial mechanical properties are obtained.

Keywords: mining by-products; carbonate rocks; building; dolomite; calcite; portland concrete; portland cement.

Introduction

The utilization of industrial by-products is a matter object of investigation in order to promote that the industrial processes are sustainable and the environmental associated impacts diminish in the frame of an increasing world population. The most common use of industrial by-products is in civil works and in materials of construction, followed by applications in agriculture and horticulture (Castells, 2012; Fraccascia, Giannoccaro & Albino, 2018; Matthey, Robayo, Torres, Ramos and Delvasto, 2015). Generally, there is needed a detailed knowledge of his composition, physical properties and his variations in

quality, as well as the specifications of the virgin material that seeks to be replaced. In applications of civil works, the by-products have application as attachés in different structures: (e.g. roads, buildings, barriers of noise, landfills, dikes, between others), I use in pavements (García, Quereda, Mallol, Soriano, & Vicent, 2011), subcamps of dumps, masonry (Isa *et al.*, 2016), stabilizers of soils (Swart, & Schalkwyk, 2001) between others (Sources, Fragozo, & Biscayan, 2015; Highland, Perez, Toasted & Hernández, 2017; Wiemes, Pawlowsky and Mymrin, 2017). In materials for the construction, the use of volatile ashes, red mud, plaster derived from processes of desulphurization (FGD Gypsum), particulate of leak gases, drosses of nickel and copper, the sand of smelting like additives and cementing agents in materials of construction as cement Portland, concrete and asphalt. Residues of ferrochrome are used as the material of isolation in structures (Sorvari & Wahlström, 2014).

In the technology of the current construction, there is a very clear and irreversible trend towards the utilization of by-products from the mining industry. This trend is associated with the importance that has acquired the increasing environmental worry and the economic implicit benefits in its use.

Investigations have been carried out to find ways of taking advantage of the by-products of the extraction of the marble (Bilgin *et al.*, 2012; Hebhoub, Aoun, Belachia, Houari, & Ghorbel, 2011; Pappu, Saxena, & Asolekar, 2007; Saboya, Xavier, & Alexandre, 2007). In countries like Italy, Spain, Turkey, Iran, and Egypt, leaders in the industry of the marble worldwide, the utilization of residues product of the actions of the mining industry is imperative in view of the great volume of production that they handle and the high environmental derivative impact. The generation of residues from the extraction up to the obtaining of the finished product is 50 % of the mineral extracted (Aliabdo, Elmoaty & Auda, 2014). Due to the pressure on the utilization of the above mentioned by-products, there have developed simultaneously investigations of the use of the rock dolomite for the production of new synthetic materials for his use in the industry of the plastic ones, production of medicines, biomedical industry, ceramic refractory bricks for ovens, treatments of effluent waters of the mining industry, between others (Altiner & Yildirim, 2017; Aziz, & Smith, 1996; Iglesias, García-Romero, & Acosta, 2014; Niesyt & Psiuk, 2017; Rabah & Ewais, 2009; Romero, Flores, and Arévalo, 2010; Sadek 2012; Sadik, Moudden, El Bouari, & El Amrani, 2016).

In Colombia, diverse studies have developed concerning the utilization of by-products of the construction (Bernal *et al.*, 2009; Correa, 2005; Delgado

and Medina, 2003; Monsalve, Bolaños, Lopez & Toro, 2014; Robayo-Salazar, Mejía de Gutiérrez, & Mulford-Carvajal, 2016). Especially, there was realized a physical and mechanical characterization to recycled attachés from the construction and one concluded that it is possible to use them realizing a thin grinding to reduce the adhered mortar and the problems of water absorption due to porosities (Mattey, Salazar, Forest, Álvarez & Delvasto, 2014). Later an evaluation was realized on the substitution of sand in panels of ferrocement by thin recycled attaché product of crushing rubble of concrete, concluding that the substitution is possible up to in 100 % generating increase in the resistance to the compression of the above mentioned panels up to 7,3 % (Mattey *et al.*, 2015). The review presented in this work demonstrates the potential uses of by-products of the calcareous origin of the mining industry in department of the Huila.

Generalities of the mining extraction of the department of the Huila

The mining production of the department comes principally from Tesalia's municipalities, Palermo, Santa Maria, Neiva and Iquira in gold and silver, of the municipalities of Pleasure, Giant, Palermo, and Tesalia in materials of construction, in Pitalito's clays, and in the phosphoric rock of the municipalities of Aipe and Tesalia. In agreement with the National Agency of Mining industry of the Department of Mines and Energy there exist 229 mining in force titles in the region, which represent an area of 68508,21 It has, corresponding to 3,66 % of overlapping in the department. In general, the activities of the extraction of not metallic minerals prevail on the extraction of metallic minerals (Castillo, 2011), where the phosphoric rock, the rocks carbonated as the limestone, the marble and the barite shape an important link in the economy of the department, fact that can give place to technical, economic and ecological benefits. (Catastro Mining Colombian, 2017; Vargas, 2015).

At the present, the agri-mining is the principal activity for the use of the above mentioned materials as input in the process of production of mixtures, gypsy languages, carbonates of calcium and other products for the improvement of soils of the agricultural sector (Ordóñez & Bahamón, 2010). Especially, the exploitation of limestone and marble is given principally in the northwestern zone of the department in rural leases of the municipalities of Palermo, Teruel, Santa Maria, and Neiva. Due to the fact that the production of the mining activities depends on factors like climatic behavior and conditions in the

supply of explosives, it is not easy to obtain the estimated annual production of calcareous material of the region. According to a technical report and of management of the technical secretary of the chain agri-mining (Castillo, 2011), the average production of calcareous materials for a unit of exploitation is 10 tons a day. Bearing in mind 38 mining titles registered for the year 2011, the annual total production is estimated in 109440 tons. Bearing in mind a percentage of recovery of 50 %, the number of by-products of calcareous origin generated a year at present is estimated to be equal or bigger than 54720 tons than the year.

Characteristics of the carbonated rocks

The carbonate rocks are composed of two principal minerals: calcite or dolomite and a mineral not carbonated between phases. The calcite is the stablest form of the carbonate of calcium (CaCO_3) and is a mineral polymorphic (the same chemical formula with different crystalline structures) (Dietrich, 1999). The dolomite ($\text{CaMg}(\text{CO}_3)_2$) is a mineral metastable, the initially formed crystals can be replaced then by stabler phases route dissolution or re-rainfall. Provided that the phases of the dolomite evolve constant, a cap of dolomite can retain or create porosity and permeability to major depth and in environments of major temperature that the limestone (Warren, 2000).

When the carbonate contains a major calcite content it is called a limestone; in contrast, a carbonate with major content of dolomite is called rock dolomite. It is not usual to find a mixture with similar contents of calcite and dolomite in a carbonate, always there is a trend to the formation of one or of another one (Warren, 2000).

Additional to the mineral of dolomite, the rock dolomite is composed of some such associate impurities as SiO_2 , Al_2O_3 y Fe_2O_3 . When the rock submits dolomite to different temperatures there can be obtained varied compositions that can be used in diverse applications; Darweesh (2001), demonstrated the development of bricks of construction from the rock mixture dolomite (40 %) and siliceous clay siliceous (60 %) that on having been submitted to a temperature of 750 °C allowed that they should present thermal interactions that facilitated the obtaining of a material for construction of high mechanical resistance.

Production and cement consumption Portland in Colombia.

The concrete Portland is the structural material most emphasized in the civil construction, his discovery constitutes a real revolution due to the set of properties that he presents both in his workability and in his hydraulic activity. It is used commonly in civil construction and is not in nature, since it is actually the result of a mixture of several materials, such as cement Portland, sand, stone and water. The properties of the concrete one are determined by the quality and the percentages of the secondhand components, being able to be modified depending on the wished application (Abo- El-Enein, Hashem, Amin & Sayed, 2016; Martin, 2005).

Particularly, the cement Portland is composed of clinker and mineral additions as the control plaster of the time of plotted and different some as fly ash and steel slag. The clinker is obtained on having mixed and to incinerate together calcareous material and clay to temperatures superior to them 1350 °C, the process is described in Figure 1. This mixture is attractive because in water presence a chemical reaction is formed, this does that the system becomes viscous and immediately afterward it hardens, acquiring thereby a high mechanical resistance. Another advantage that he presents is that his obtaining is given from abundant raw materials in nature. This type of cement allows obtaining minor times of

hardening, it improves the rate of hydration and increases the resistance of the compounds of the cement in initial conditions (Ingram & Daugherty, 1992).

Colombia possesses six types of cement produced by seven companies in 19 plants, his market presents an unstable behavior, with productions over the million tons in the last 3 years. In August 2017 one presented in Colombia a production of 1034,8 thousands of tons whereas they finished off 2017), the difference explains with exports and in minor measure with reservations, the department with more offices of cement is Antioch with 17,4 %, followed by Bogota with 12,1 %, Cundinamarca and Valley of the Cauca with 8,8 % and 8,4 % respectively. The department of Huila receives 2,4 % of the national corresponding offices to 24789,6 tons.

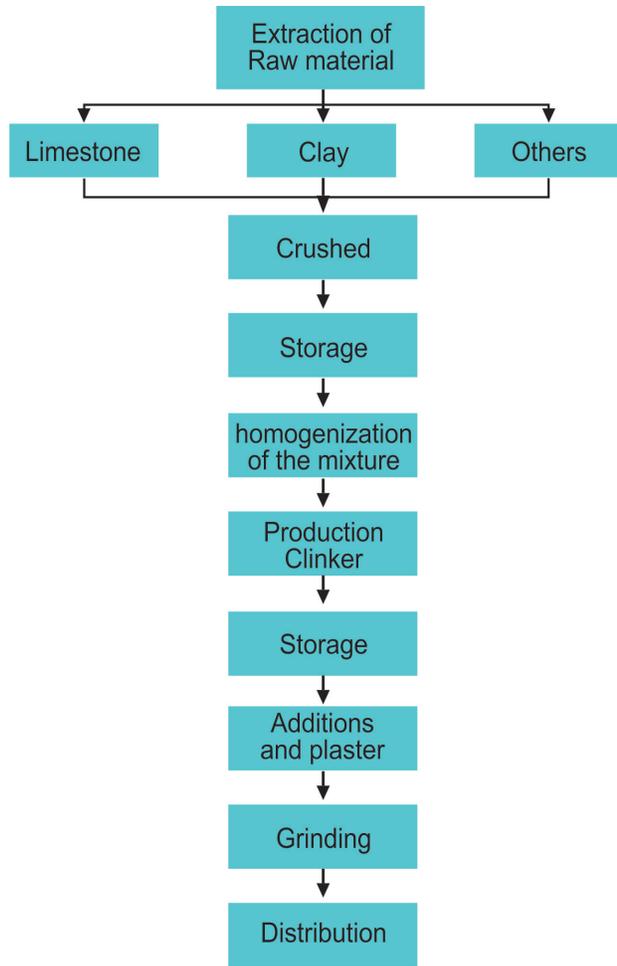


Figure 1. Schematic process of the cement production portland
Source: the authors

Use of carbonated rocks in cement and concrete Portland

Diverse authors have realized investigations on the effects of the carbonated rocks use as attached in the production of the concrete Portland. Not always it turns out easy to have sources of suitable attached for the concrete one, nevertheless, studies they coincide in indicating the advantages of using the dolomite. They reveal that the dolomite possesses a major absorption, density, module of elasticity, similar resistance and wear with regard to granitic attached on which abundant experiences exist (Alexander, & Mindess, 2010; Cabrera, 2017; Mangin, 2015; Milanese *et al.*, 2010). In relation with to limestone, the effect of the dolomite contributes physical properties and significant mechanics to the concrete one, enabling the cement production Portland (Mikhailova, Yakovlev, Maeva & Senkov, 2013).

Also, the replacement of the limestone has been studied by a calcareous dolomitic material as an alternative attached in the cement production Portland. One thought that the systems that 25 % contains in the weight of this attached presented major resistances to the compression. Additional improvements were obtained in the densification of the structure and a possible increase of the early resistance without harmful effects on the long-term properties of the concrete one (Mikhailova, *et al.*, 2013).

Other investigations bring that the dolomite like attached in the cement can present expansion as a result of the possible reactivity of the dolomites in a humid environment. This phenomenon was confirmed after the observation of certain hurts to the structures of concrete and for some tests of the laboratory. The processes of dolomitization are related to the attached of dolomite and dolomitic limestone. The mechanism and the reactions of the dolomitization are known and widely described. As result of the reaction of dolomitization, the dolomite ($\text{CaMg}(\text{CO}_3)_2$) it can turn in calcite (CaCO_3) or meerschaum (MgCO_3) and the calcification of the attached can be expected for the contact by solutions by high relations of $+/ \text{Mg}^+$ that flow freely for the pores (Debska, 2015; Smith, 1999). Additional, the calcareous dolomitic attached are highly reagents when they are in touch with the alkaline present cations in the cement, effect that might cause degradation of the final product, being necessary to realize studies previous of the quantities to be secondhand (Rocha, Da Luz & Cheriaf, 2002).

Due to the trend of growth of transport by road also it has increased the utilization of local and alternative materials for the construction of routes. Studies have been realized to determine the applicability of the attached of limy rock in the mixtures of asphalt and there has decided that can be used successfully in concrete asphalt of high module for the pavement of ways (Haritonovs, Tihonovs & Zaumanis, 2016; Sybilski, Bankowski & Krajewski, 2010). In case of the pavement of concrete, the aspects that define his performance are given by the ruggedness, superficial texture and absence of cracks. A lot of these properties are attributed to the characteristics of the attached (Souza & Calo, 2008).

On the other hand, the production of clinker as the principal component of the cement Portland is an intense process, a partial substitution of clinker for mineral additions represents considerable energetic savings and decrease of the emission of CO_2 from cement and concrete industries. Additional, economic sense makes reduce the energy used in the cement production and I make concrete

and at the same time, to do sure use of what can be classified as a by-product of the mining industry. (Hartshorn, Sharp & Swamy, 1999; Li, Du & Huo, 2007; Piechówka-Mielnik & Giergiczny, 2011; Tsvilis, Batis, Chaniotakis, Grigoriadis & Theodosis, 2000).

Some studies show that the properties of performance of a cement Portland to generate a tertiary mixture on having added limestone (up to 20 %) and metallurgical dross of high oven (up to 30 %), it increases up to 35 % the resistance to compression in relation with a mortar of reference and in turn he presents minor coefficients of capillary suction, confirming the action so much of physical as chemical character of the materials of addition. Also, they mentioned that the contraction of dried diminishes with the increase of the calcareous component (Aquino, Inoue, Miura, Mizuta, & Okamoto, 2010; Díaz, Izquierdo, Mejía de Gutiérrez & Gordillo, 2013).

The replacement of natural sand by sands crushed of origin carbonated also has been evaluated. For the concrete one in hard condition, the realized experiences base on concretes elaborated with crushed sands calcite, dolomitic, granitic and quartz, and as a reference, natural sand was in use. All the sands were presenting equal modules of delicacy, and the concretes were designed by equal proportions. The results establish that the relation between this resistance and the module of elasticity than 28 days is bigger for attachés of dolomite and calcite (Cabrera, Ortega, & Traversa, 2010). Parallel, one has found in the production of concrete, that replacement of the sand with powder of marble because of 15 % to 75 %, increases the resistance to the compression in 20 % to 26 % due to the presence of carbonate of calcium (CaCO_3) and silicon oxide (SiO_2) in the chemical structure of the marble, developing a better mechanical performance in comparison with the concrete one in which the powder of marble replaces to the cement, which of fact diminishes the resistance to the compression and workability of the mixture in percentages superior to 20 % (Aliabdo *et al.*, 2014; Arel, 2016; Sadek, El-Attar and Ali, 2016; Sutcu, Alptekin, Erdogmus, Er & Gencel, 2015).

Finally, studies have developed on two component mixtures of partial substitution of the cement Portland. These are called cement of addition that corresponds to the cement with environmental sustainability. The substitution of the cement for mineral inert (limy) additions, or chemically active, such additions as puzzolans (smoke of silica, flying ash, ash of husk of rice) can present or not good characteristics depending on the quality and quantity of the addition. Such technical advantages as minor it demands of water, saving of energy, minor capillary porosity and

good behavior opposite to aggressive means (Águila, 2016; Carrasco, Cruz, Terrados, Corpas, and Pérez, 2014; Loayza Goicochea, 2014; Robayo, Matthey and Delvasto, 2013; Vegas, Gaitero, Urreta, García and Frías, 2014; Villaquirán, Rodríguez and de Gutiérrez, 2014).

Conclusions

The review of the literature allowed to find alternatives for a potential high place of application for by-products derived from the mining industry in the department of Huila. Advantages between which ecological questions can be mentioned, eventual reduction of costs and better mechanical characteristics open the door possible new models of business about the above mentioned by-products, especially the related ones to the calcareous rocks.

It is necessary to analyze carefully the percentage of the additions, the mineralogical characteristics and the porosity of the attachés due to the fact that the above mentioned parameters influence the mechanical properties of the concrete one. Particularly additions of calcareous material in cement Portland allow to reduce the costs of the processing of the concrete one, in addition it is a widely present by-product in the region and as advantage it allows to accelerate the rate of hydration of the mixture in an initial stage, providing a product with favorable characteristics.

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