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The Effect of Granulation Time of the Pan Granulation on the Characteristics of the Aggregates Containing Dunkirk Sediments

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Abstract

The wet granulation process presents complex interactions between equipment variables as well as material properties making the outcome of a granulation process hard to predict. A frequently encountered difficulty is the process control for optimal condition of the granulation. This requirement depends largely on the operator and the desired properties of the final product.

In this study, before the fabrication of aggregates by the pan granulation by associating the sediments with a specific hydraulic binder, the ingredients were characterised. Then, the evolution of the aggregate size with the granulation time has been explored. Finally, the physical and mechanical properties of artificial aggregates formulated by the pan granulation were discussed. The results of this study show firstly, that the use of marine sediments dredged from Dunkirk harbour in France in the production of artificial aggregates is a flexible and positive approach. Secondly, that the granulation time is an important parameter that controls the granulation by wet granulation plate.

Keywords: Dredged marine sediments, pan granulation, wet granulation, artificial aggregates, wetting liquid.

1 Introduction

The wet granulation techniques are based on the setting in motion and the agitation of particles, followed by the introduction of the wetting liquid. The different methods of granulation are different mainly by the mode of contacting particles: pneumatic agitation (fluidized beds and their derivatives); agitation by rotation of the walls (pan granulation and rotating drum) and agitation by mechanical mobiles (mixer-granulator). From point of view of stresses exerted, these different modes of action correspond respectively to low shear rates, moderate shear rates and strong shear rates. The approaches to formulation of the solid by introducing the wetting liquid are based on models and experimental tests that remain to be validated for each type of desired functionality: the size, the shape, the mechanical properties of aggregates, etc. A frequently encountered difficulty is the process

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control for optimal condition of the granulation. This requirement depends largely on the operator and the desired properties of the final product. The current regulations in environmental protection are increasingly restrictive, they represent an obstacle to the valorization of these waste. The research conducted in recent years are moving increasingly towards the valorization of dredging sediments for the use as a building material, also towards adapting the valorization in dredging projects and sediment management (Damidot, 2006). According to the physicochemical characteristics, geotechnical, mechanical and environmental dredging sediments, the valorization of these materials can be used in several areas such as road building (Azrar, 2014) ; (Kasmi, 2014) ; (Maherzi, 2013) ; (Liang, 2012) ; (Tran, 2009) ; (Dubois, 2006) ; (Colin, 2003) ; (Boutouil,1998) ; (Achour, al., 2014) ; (Dubois, al., 2008) ; (Zentar, al., 2008) ; (Wang, al., 2013), concrete (Azrar, 2014) ; (Achour, 2013); (Belas, al., 2011) ; (Zri, al., 2011), bricks (Chiang, al., 2008) ; (Samaraa, al., 2009) ; (Hamer, 2002), eco modeled landscape (Khezami, 2014) and artificial aggregates (Azrar, 2014). However, their use in artificial aggregates is not fully developed and deserving of special attention.

This work is devoted to the study of the wet granulation by the pan granulation by associating the sediments with a specific hydraulic binder. This device works in continuous mode and allows carrying out the granulation by the rolling of particles over each other. In order to show the importance of granulation time on the aggregates growth and their final characteristics, the granulation was studied for four different times.

2 Materials and Methods

The studied marine sediments are dredged in 2012 in Dunkirk's Eastern Port located in Northern France were employed in these experiments. In order to reduce their water content and to control the liquid-solid mixing ratio, these materials were pre-dried in an oven at 60 °C. Their initial water content is 123 %. The cement used to improve the strength of the aggregates is denoted CEM I 52,5 N-Type SR3 CE PM-CP2 NF. It was chosen for its resistance to aggressive water, high sulphate resistance and good frost resistance. This cement is produced in the factory of Lägerdorf in Northern Germany and contains 65.5 % CaO, 21.7 % SiO_2, 4.3% F_2O_3, 3.8 % Al_2O_3, 2.66 % SO_3 and other minor components.

The pan granulation consists of a flanged circular plate with relative low height ($H / D < 0.2$), which rotating about the central axis inclined from 30 to 70° relative to the horizontal (Figure 1). The angle and the speed of the pan granulation are adjusted to ensure a suitable rolling of aggregates. The particles are spread on the plate and the wetting liquid is dispersed continuously on the moving particles. A good wettability of the powder surface is a prerequisite for ensuring good adhesive bonding of aggregates. For this reason, the wetting position should be chosen and optimized according to the characteristics required for the aggregates. The addition of the wetting liquid leads to the growth of the aggregates by the mechanisms of nucleation and coalescence/consolidation.

The preparation process of the materials used in this study consists, in the first step, in mixing 30 % cement and 70 % dredged sediments for one minute. In the second step, water is introduced to reach water content of 27 % which reduces the time required for the considered granulation. This mix is homogenized during three minutes. The obtained material is kept at constant water content in an airtight bag.

The aggregates were manufactured using the pelletizer GTE of the company ERWEKA GmbH, Germany, as shown on Figure 1. The angle of plate inclination is set to 53° in the entire tests and the speed of rotation was varied from 12 to 28 rotations per minute. For each granulation, 300 g of the wet prepared mixture was introduced into the pan, after initiating the rotation of the plate, water is added using a peristaltic pump for the desired time of granulation. The added water during this operation represents 6 % to 9 % of the dry mix. This induces a final water content of the mix between 33 % and