

Processing equipment for grinding of building powders

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Abstract. In the article questions of mechanical grinding up to nanosize of building powder materials are considered. In the process of mechanoactivation of the composite binder, active molecules of cement minerals arise when molecular packets are destroyed in the areas of defects and loosening of the metastable phase during decompensation of intermolecular forces. The process is accompanied by a change in the kinetics of hardening Portland cement. Mechanical processes in the grinding of mineral materials cause, together with an increase in their surface energy, the growth of the isobaric potential of the powders and, accordingly, their chemical activity, which also contributes to high adhesion strength when they come into contact with binders. Thus, a set of measures for mechanical activation allows more fully use the mass of components of the filled cement systems and regulate their properties. At relatively low costs, it is possible to provide an impressive and, importantly, easily repeatable in production conditions result. It is revealed that the use of a vario-planetary mill allows to achieve the best results on grinding the powder building materials.

1. Introduction

Modern building materials science has a tendency to a constant decrease in the dimension of materials. An increase in the specific surface area of astringent powders makes it possible to increase their surface undergoing a chemical hydration reaction by water quenching [1, 2]. Grinding of binding agents is the most important technological operation, consisting in the mechanical grinding of the raw mix. As the fineness of the grinding increases, the activity of binders increases as well as their mechanical strength during hardening. At the same time, it should be noted that for each binder, the optimum fineness of grinding is established, in which its properties are most fully utilized. The excessively high fineness of the grinding is not always desirable, since increasing the dispersion of the powder requires more water to produce the paste, which in turn leads to increased shrinkage and cracking during hardening.

Mineral binders are finely milled mineral powders that form a plastic mass when mixed with water, which, over the course of time, under the influence of physical and chemical processes, transforms into a stone-like state. This property of binders is used to produce artificial stone materials (concrete, etc.). The purpose of this study was to determine the impact of various industrial grinders on the properties of composite binders.



2. Results and Discussion

To achieve the aim, composite binder, obtained by the joint grinding of cement, hyperplasticizer, fly ash and limestone, was developed. The problem of increasing the density and strength of concrete has been researched in a large number of works by both Russian and foreign scientists. It is known that one of the ways to improve the performance characteristics of concrete, reduce permeability parameters is the use of highly active additives of various composition and genesis, both micro- and nanodispersed levels, which contribute to the optimization of structure formation processes by initiating the formation of hydrate compounds. So in the works performed earlier, the effectiveness of using a nanostructured silica-containing composition as an active mineral additive was proved. In addition, the possibility of reducing the permeability parameters of concrete due to mechanical grinding of the components of the composite binder has been studied.

Properties of composite materials largely depend on the structure of disperse systems, on the basis of which they are obtained. The structural strength of a disperse system, its stability, the concrete placement behavior, the rate of destruction and reconstruction of the structure are interrelated. Building conglomerate material - concrete belongs to the class of composites. As a matrix substance of concrete, cement-sand stone, cement stone (micro concrete), cementing agent, cementing substance neoplasms, solid phase of tumors, the substance of a single structural element of the neoplasm, which corresponds to the scale order from the macro- to the nanoscale structure, act as a matrix substance of the concrete. The orderliness of the structure of composites is due to the proportionality of the scale levels of the structure - the correspondence of the properties of the composite at each scale level. The combination of a number of factors contributes to the achievement of high strength concrete: increasing the density of systems as a result of optimizing the grain composition; reduction of pore volume of cement stone due to reduction of water-cement ratio; filling of pores between cement particles and improvement of rheology as a result of the effect of lubrication; the formation of secondary hydration products in the process of pozzolanic reaction with $\text{Ca}(\text{OH})_2$ when adding additives with microfill effect to the concrete.

To select the optimum method of grinding, tests were carried out in a ball mill, vibratory mill and vario-planetary mill.

The ball mill is a hollow drum, revolving around its axis, which is approximately half filled with crushing balls (impact elements). As a result of the rotation, the balls rise to the upper part of the drum, and then fall down under the action of gravity. Through one of the pins, the grinding material is continuously fed, and the drum is unloaded through the other (Figure 1).

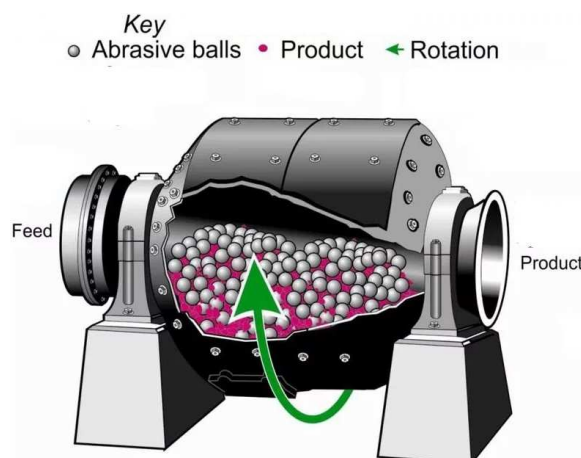


Figure 1. The principle of ball mill operation

One of the peculiarities of grinding by free impact is the fact that material is destroyed by the weakest bonds, structural defects at the junctions of crystals, grains, layers, etc. In the production of fractionated crushed stone or artificial sand, this is an undoubted advantage, since the product of

impact crushing is represented by isometric grains without internal defects with a small content of the ground product [3, 4]. At the same time, to obtain a greater fineness of grinding, hardening of the particles which occurs together with a decrease in their dimensions, creates additional difficulties.

At a certain moment, when the structural strength of each individual particle reaches its maximum and its mass is negligible, the free kick is almost completely replaced by abrasion. The rotor of the centrifugal mill ceases to fulfill the function of the accelerator and works more like a swirler of material-air flows. Attracted to the walls of the grinding chamber, large particles displace the smaller particles, which, moving from the periphery to the center, are crushed solely by mutual abrasion in turbulent flows [5, 6].

Argue by the energy consumption for the formation of a unit of a new surface of solid materials, this is one of the most inefficient methods of grinding.

The operating principle of the vibrating mill (Figure 2) is based on the intense motivation of the grinding bodies, when inertia and centrifugal forces are used instead of the forces of gravity causing the balls to fall.

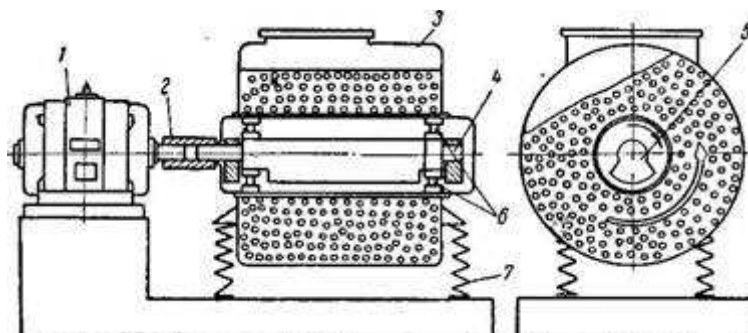


Figure 2. The principle of vibratory mill operation

1-electric motor; 2-elastic coupling; 3-body; 4-shaft of the vibrator; 5-unbalance; 6-bearings; 7-springs.

The rotation of the vibrator shaft, and behind it the mill body itself, causes the grinding bodies to move in accordance with the amount of eccentricity or radius of the carrier. The transfer of the energy of the grinding charge is carried out through the mill housing. Under the action of inertia, centrifugal forces, alternating loads, the balls inside the body move along a complex trajectory, press against the walls of the drum, strike against each other, as well as to the particles of the crushed material, breaking, crushing and rubbing them.

To produce highly disperse materials, vibrating mills are more efficient than ball mills. Shock impact on the grinding material in this case is small, but abrasive intensively, which allows for greater fineness of grinding [7, 8].

In a vario-planetary mill, the rotational speeds of the grinding jars and the support disc can be set completely independently of one another. By varying the gear ratio, the movement and trajectory of grinding balls can be influenced so that the balls strike horizontally on the inner wall of the grinding jar (high impact energy), approach tangentially (high friction) or simply roll over the inner wall of the grinding jar (centrifugal mills). All intermediate stages and combinations between pressure friction and impact can be freely installed (Figure 3).

Accordingly, grinding in the vario-planetary mills is more energy-efficient than by ball mills and vibrating mills. In addition, due to the joint action of shock, centrifugal shock and abrasive forces, it becomes possible to achieve more highly disperse powders.

During the comparison of the fineness of grinding of the claimed composite binder in various mills, revealed that a ball mill (1.1 kW, 90 rpm) is capable of grinding up to 400 m² / kg, further operation of the unit is economically impractical. The vibrating mill (2.2 kW, 1500 rpm) showed the ability to efficiently grind the composite binder to a specific surface of 430 m² / kg. The Pulverizette-4 (9 kW) planetary mill is capable of providing grinding to a nanoscale specific surface (900 m² / kg). (Figure

4).

In order to determine the optimum particle size, a joint grinding of cement with hyperplasticizer, ash and limestone to different specific surface areas were carried out: 500, 550, 600, 700, 800, 900 m^2/kg (Table 1).

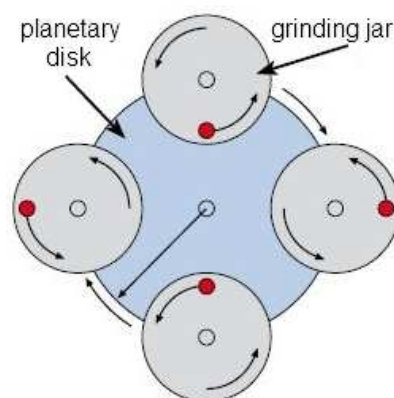


Figure 3. The principle of vario-planetary mill operation

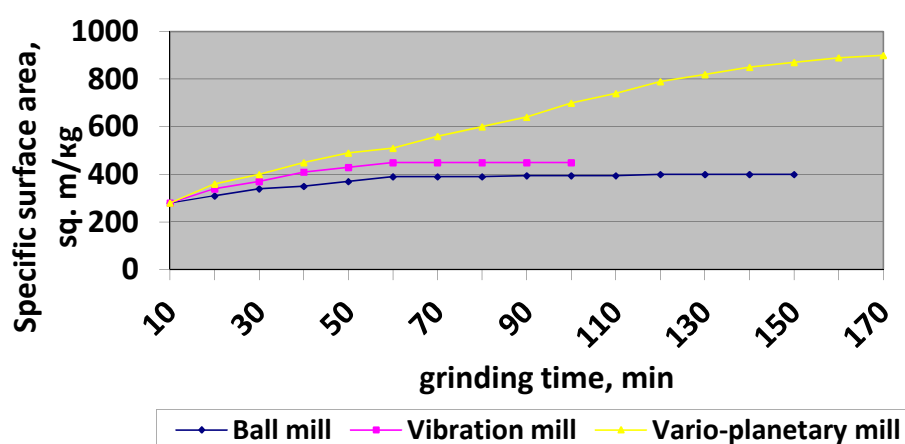


Figure 4. Dependence of the specific surface area of the composite binder of the grinding time for various mills

Table 1. The results of determining the compressive strength (MPa) of cement stone samples

Age of sample, days	The specific surface area of the composite binder, m^2/kg					
	500	550	600	700	800	900
3	46.1	47.4	47.2	46.0	45.6	45.5
7	50.3	54.2	54.1	49.1	48.6	48.4
28	68.1	77.3	70.2	65.8	55.0	65.0

It was found out that the specific surface of the binder is 550-600 m^2/kg . An increase in activity above these values has a negative effect on the structure formation. Using a binder with increased activity significantly accelerates the setting process - the end of setting the mixture ends after 35-40 minutes, while the temperature develops 95-97°C. Rapid setting of the raw material

prevents the formation of uniformly distributed spherical particles in the cement stone macrostructure.

In the process of mechanical activation of the composite binder, active molecules of cement minerals arise when molecular packets are destroyed in the areas of defects and loosening of the metastable phase during decompensation of intermolecular forces. The process is accompanied by a change in the kinetics of hardening Portland cement. Mechanical processes in the grinding of mineral materials cause, together with an increase in their surface energy, the growth of the isobaric potential of the powders and, accordingly, their chemical activity, which also contributes to high adhesion strength when they come into contact with binders. Thus, a set of measures for mechanical and chemical activation allows more fully use the mass of components of the filled cement systems and regulate their properties. At relatively low costs, it is possible to provide an impressive and, importantly, easily repeatable in production conditions result.

In addition to hydraulic activity, the increase in the strength of binders with the addition of highly disperse additives to their composition can also be explained by the formation, by the smallest grains, of additives of crystallization centers in the contact zone of cement. The "micro filler effect" can not be explained only by the formation of additional crystallization centers, since their immediate effect is to accelerate the initial stage of chemical hardening. At the heart of the "micro filler effect" lie both chemical processes of cement interaction with hydration products, as well as physicochemical phenomena, for example, the influence of the surface energy of particles of highly disperse additives.

In the presence of a fine-milled additive in concretes, the contact zone between the cement stone and the aggregate hardens. In Portland cement concretes without nano additives, the contact zone is usually less dense than the cement paste, and includes a large number of calcium hydroxide platelets, in which the longitudinal axis is perpendicular to the surface of the aggregate. Consequently, it is more susceptible to the formation of microcracks in the case of tensile forces arising from changes in the usual conditions of temperature and humidity. Thus, the contact zone due to its structure is the weakest in concrete and therefore has a great influence on its strength. The introduction of highly disperse additives significantly reduces the capillary porosity of the contact zone due to a sharp decrease in the total content of Ca(OH)_2 . (Figure 5).

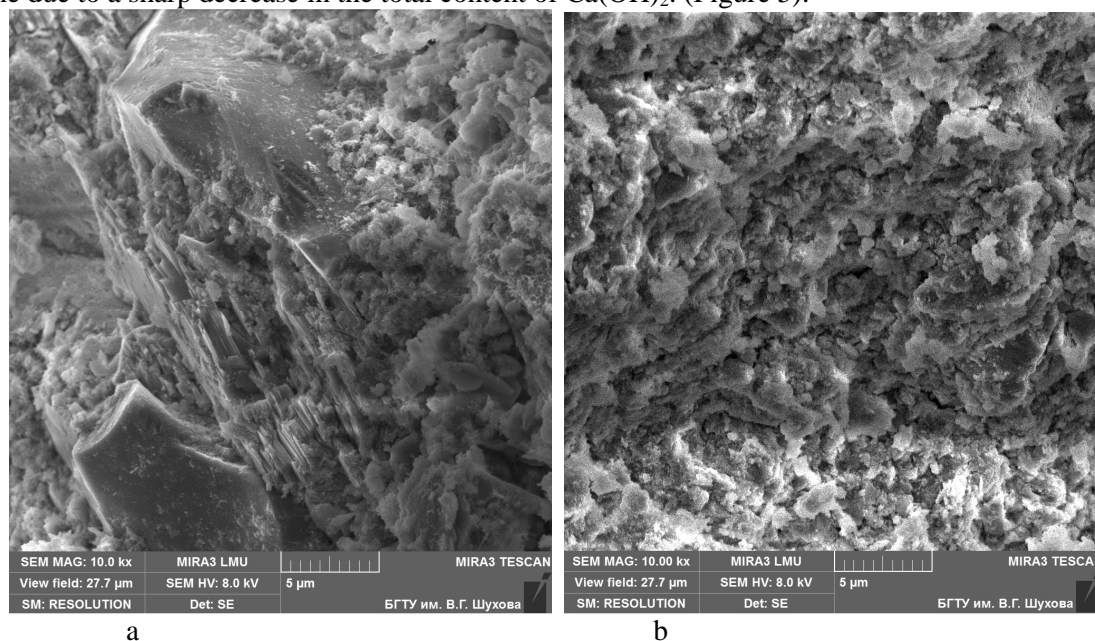


Figure 5. The micrographs of neoplasms: a – cement stone without additives; b – cement stone with fine-milled additives

3. Conclusion

Thus, the addition of finely ground limestone is a chemical method of increasing the activity of ash and sand. It has a catalytic effect on the reaction activity of ash and sand surface during machining in a vario-planetary mill. In addition, the introduction of limestone increases the alkalinity of concrete, which leads to more formation of cement hydration products per unit time.

The possibility of increasing the physical and mechanical characteristics of concrete due to varying the number and type of additives, fineness of grinding, and synthesis parameters is established. This allows you to create materials with a compressive strength of up to 100.9 MPa, with a low permeability in real operating conditions. Joint grinding of cement, hyperplasticizer, acid ash and limestone in an amount of 55%, 40% and 5%, respectively, accelerates the process of neoplasm synthesis, transforming the hydrated alite CaO to calcium hydrosilicates of various basicity. Optimizing the microstructure of the cement stone thus, it is possible to obtain a binder with activity of 77.3 MPa.

A mechanism is proposed that explains the effect of using a "cement-ash" binder in combination with a hyperplasticizer and limestone in mechanical and chemical activation in a vario-planetary mill. Due to mechanical grinding, the reactivity of the "cement-ash" binder increases, the hyperplasticizer in combination with limestone increases the density of neoplasms and adhesion of the binder with a filler, which allows to obtain concrete of increased impermeability.

The principles of optimizing the structure of fine-grained concrete at the nano level are proposed through the use of a nanodispersed composite binder; at the micro level due to the creation of a high-density packing of the aggregate. This allowed the development of a wide range of fine-grained fibrous concrete with a vapor permeability of up to 0.021 mg / m·Pa, water permeability up to W14, air permeability up to 0.0253 cm³ / s, water absorption by mass up to 2.5%, gas permeability, effective diffusion coefficient up to 1.34 • 10⁻⁴ cm² / s and high strength characteristics [9, 10].

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