The basic properties study of the dust particles entering the localization system and emissions cleaning in the aerated concrete production and building gas concrete blocks

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Abstract. At most of the construction industry large enterprises, focused on the building materials and products production, where bulk materials are used as charge stock and there are crushing, grinding operations, etc. as a part of the technological chick, atmospheric dust emissions are not reduced in air to normalized values. Especially it concerns fine particles PM10 and PM2.5. The basis for solving the problem of ensuring environmental safety in the aerated concrete production is the efficient dust removal systems development. To solve this problem, it is necessary to study the released dust properties.

Introduction
In the course of the studies carried out in the development of measures to improve the enterprise dust-removal plants efficiency for the aerated concrete production, dispersed analysis of dust released from the process equipment at various production line points was carried out. The study consisted in conducting a dispersion analysis of dust, in assessing and analyzing the size of the released dust [5–8].

Main part
The study used a microscopic method for determining the dispersed dust composition, which is based on digital photographing of fields of dust-like particles magnified 200-1000 times under a microscope, followed by transferring photographs to a PC.

The filters were clarified after sampling. The AFA filter was placed on a glass slide with a dusty side to the glass and, in a slightly tense state, was glued along the edges. Then the filter was exposed to acetone or dichloroethane vapor, or 1-2 drops of a mixture consisting of 94% xylene and 6% dibutyl phosphate or tricresyl phosphate were applied. Ultimately, the filter turned into a thin transparent film in which the dust particles are firmly fixed. Dried for 10-15 minutes at a temperature of 90 ± 5 °C, the preparation was examined under a microscope and photographs were taken with a digital camera. The captured image was subjected to computer processing in a graphical editor on a PC (in particular, AdobePhotoshop was used as part of the study.) Further digital processing of the obtained microphotographs was performed using the developed program Dust. After the mathematical processing of the results obtained, the results were graphically printed by constructing the differential size...
distribution curves in the form of integral curves or histograms.

The use of the microscopy method for the variance analysis also made it possible to study the shape and structure of dust particles released during the aerated concrete production.

Consider the dust particles’ shape, the methods for describing the shape by applying different coefficients, taking into account the actual shape deviation from the sphere shape.

Particles which shape is different from spherical can be taken into account using various coefficients. If we introduce the volume coefficient concept of the form $\alpha_v$, connecting the projected diameter of the particle and its volume, then the following relation will be true [1]

$$V_p = \alpha_v d_{ppr}^3, m^3$$

where $V_p$ – is the particle volume, $m^3$;

$\alpha_v$ – is a volumetric shape factor;

$d_{ppr}$ – is the projected particle diameter, determined by microscopy analysis of the dispersion analysis as the diameter of a circle with an area equal to the area of the particle projection, m.

It was experimentally shown [1] that the value of $\alpha_v$ is constant for particles of a given shape in certain size ranges and varies from 0.524 for particles of a spherical shape to 0.14-0.20 for the particles of irregular shape with sizes from 1 to 60 microns.

In some works, to characterize the particle shape, it is recommended to use the geometric factor of the form $F_g$, defined as the actual surface area ratio of the particles to the surface area of the sphere equal in volume, or the inverse $F_g$, the coefficient of sphericity $\Psi$, also called “the form factor” [1, 2]:

$$F_g = \frac{1}{\Psi} = \frac{S}{S_w} = 0.207 \frac{S}{V_w^3}$$

Where $F_g$ – is the geometric shape factor;

$\Psi$ – is a sphericity factor or form factor;

$S$ – is actual surface area of particles, $m^2$;

$S_b$ – is a surface area of the sphere, $m^2$;

$V_b$ – is the sphere volume, $m^3$.

For oblong particles the values $F_g$ and $\Psi$ make 1.800 and 0.555 respectively, for roundish particles with an uneven surface - 1.300 and 0.769, for spherical - 1.000 [1, 2].

For particles which shape is very different from the sphere shape, the dynamic coefficient of the form $F_d$, proposed by N.A. Fuchs [2], and representing the resistance ratio to the movement of a particle of irregular shape to the resistance for the same volume spherical particle. In general, the dynamic coefficient of the form can be determined from the system of equations [2]

$$F_d = \frac{F}{F_g} = \frac{d_{ps}^2}{d_{ppr}^2}, \quad Re_v = idem, \quad Vp = idem, \quad W - V = idem$$
where $d_{pe}$ – is the particle diameter equivalent in microns;

$d_{ps}$ – is the sedimentation diameter, defined as the diameter of the sphere with the same density, sedimentation rate and mass, as an irregularly shaped particle with a diameter of $d_{ps}$.

The following equations are recommended to determine the dynamic particle shape coefficient depending on the Reynolds parameter and the geometric shape factor:

$$ F_d = \left( 0.843 \log \frac{1}{0.065 F_g} \right)^{-1} \quad \text{at } Re_p < 0.2; \quad (4) $$

$$ F_d = F_g^{0.9} Re_p^{0.15} \sqrt{F_s}^{-1} \quad \text{at } 0.2 < Re_p < 2 \cdot 10^3; \quad (5) $$

$$ F_d = 1 + 11.6 (\sqrt{F_g} - 1) \quad \text{at } Re_p > 2 \cdot 10^3. \quad (6) $$

**Results**

According to the research results, it was established that dust particles formed during the aerated concrete production are spherical or elongated, oblong and are characterized by the form factor $F_g$ geometrical factor values and the sphericity coefficient (the shape factor is from 1.061 to 1.564 and from 0.939 to 0.631, respectively.

To determine the apparent density, which is the particles unit volume mass, including the closed pores volume, a manometric method [2], based on the Boyle-Mariotte law was used, according to which the pressure product and gas mass volume remains constant at the same temperature.

A device for determining the density of powders by manometric method consists of a measuring flask, a liquid manometer and a reservoir with a measuring tube, which are connected through taps to a pressure vessel filled with water. The air volume in an empty device at atmospheric pressure $B$ is $V_0$. After reducing this volume by $V_1$, the pressure increases accordingly by $\Delta P_1$, i.e. the gas volume $V_0 - V_1$, will be under pressure $B + \Delta P_1$. By the Boyle-Mariotte law:

$$ V_0 B = (V_0 - V_1) (B + \Delta P_1), $$

From here:

$$ V_0 = V_1 (B + \Delta P_1) / \Delta P_1. $$

A certain amount of the studied powder $G_n$ is placed in the space $V_0$, occupying the volume $V_n$. The free volume of the device will be equal to $V_2$, will be less than $V_0$ by the volume occupied by dust ($V_2 = V_0 - V_n$), and will be under pressure $B + \Delta P_2$.

Then the formula for calculating the amount of dust is

$$ V_n = V_1 B (\Delta P_2 - \Delta P_1) / \Delta P_1 \Delta P_2, \ m^3 \quad (7) $$

and the particle material density will be equal to $\rho = G_n / V_n$, kg/m³.

The dusts bulk density (i.e., the mass of a unit volume of powdered material that is freely poured into any container immediately after it is filled) is determined using an installation consisting of a measuring cylinder with a straight ring, a funnel and a tripod. After preliminary weighing, the measuring cylinder was filled with the test material, then the receiving ring was removed, and the excess powder was
removed at the cylinder upper edge level. After weighing the cylinder with the contents, the bulk density was determined by the formula [3]

\[
\rho_{\text{bulk}} = \frac{(G_2 - G_1)}{V}, \text{kg/m}^3
\]

where \(G_1\) — is the empty cylinder weight, kg;
\(G_2\) — is the weight of the cylinder with material, kg;
\(V\) — is the measuring cylinder volume, m³.

According to the research results, it was determined that the apparent and bulk density of dusts released during the aerated concrete production varies between 200-1710 kg/m³ and 80-1100 kg/m³, respectively.

The repose angle, i.e. the angle between the horizontal surface and the resulting cone of powdered material poured on it is an indirect indicator characterizing the complex dust properties — flowability, aeration, arch formation [3].

The dynamic repose angle (the angle at which the outer surface of the granular material is located when particles fall on the plane) was determined by pouring powder onto a disk. The device intended for this purpose consists of a bunker with a bolt fixed on a rod, which is rigidly connected at a right angle with a horizontal base. A disk is installed parallel to its base parallel to its plane. The dust sample placed in the bunker through the half-open valve is poured into the middle of the disk before it is filled and the cone is completed to stabilize its height. Based on the diameter of the disk \(d\) and the height of the cone \(H\), the dynamic repose angle is calculated as \(\arctg \left(\frac{2H}{d}\right)\) [3].

The static repose angle or the collapse angle (the angle of the material surface inclination resulting from the collapse of the particle layer upon the retaining wall removal) was determined using a transparent rectangular container having an opening side wall [4]. After filling the container with the test material, the removable wall is removed. In this case, a portion of the powder in the form of a triangular prism slips to form a slope. After measuring the tank’s \(a\) vacated edge value and the slope height \(h\), the static repose angle is defined as \(\arctg \left(\frac{h}{a}\right)\).

According to the data obtained, the values of the repose angle — dynamic and static — for the dust being studied vary between 39-53 degrees and 44-73 degrees, respectively.

Dusting ability (dispersibility) is a dust property, which characterizes the possibility of the product becoming suspended, as well as the tendency of the material to aerate. By the magnitude of dusting capacity, dust can be divided into the following groups: highly dusting — more than 70%, dusting — from 51 to 70%, weak dusting — from 31 to 50% [3].

The dispersibility of dusts generated in the aerated concrete production was determined by the method of N. E. Pestov [3]. In accordance with this method, the dispersibility determination is reduced to the fact that a known material volume is directed in portions into an air stream. The air stream sprays the product, part of which is deposited on the mold, installed under the air stream. The mold center is located 300 mm from the funnel center, through which the powdered material is transferred. The air flow rate at which the dispersibility is determined is recommended to be 2 m/s.

Sprayability is determined by the expression

\[
\Pi = \frac{G_1 - G_2}{G_1}, \%
\]

where \(G_1, G_2\) — are the initial sample mass and the product deposited on the crystallizer, respectively, g.

It is established that the studied dust has a high dust-forming ability (from 45 to 88%). The complex rheological properties of dusts include flowability, aero-capacity and arc formation.
Flowability is a characteristic of the material ability to form a discrete-continuous steady flow and determines the feasibility of using an additional booster when dust is released from the dust collector bunker. Flowability largely depends on moisture, ductility, electrical charge and other properties of dust, which characterizes its adhesion and caking. The simplest way to experimentally determine the flowability is to determine the material free flow maximum speed from the vessel through a hole with a certain diameter [3]. In addition, to assess the flowability, it is recommended to use the dynamic repose angle and the collapse angle as an indicator. In terms of flowability, powdered materials are divided into seven classes [3].

Aero-capacitance characterizes the tendency of a material to form a pseudo-liquefied system with an unstable avalanche-like expiration. This complex characteristic, taking into account the flowability and dispersibility of dust, shows the possibility of using pneumatic transport systems, vacuum pneumatic cleaning, etc. By the bulk aeromobility materials are divided into five classes [3].

Flowability and aeration properties reflect the powder-like materials properties most influence. However, for the completeness sake, their assessment deals with the third complex characteristic — arc formation, i.e., the ability to form stable arched structures that cause the product to hang above the outlet. The arched structures’ strength depends on the physical and mechanical properties of the bulk material, the design of the dust collecting apparatus or bunker, etc. When evaluating the propensity for arc formation, the flowability class and the amount of dust generating ability are the determining factors [3].

The properties studies of dust released during the aerated concrete production showed that dust data is characterized by a high dust-forming ability (from 45 to 88%).

Dust is characterized by good flowability, that is, the ability to form a discrete-continuous steady flow. As noted earlier, this dusts’ property determines the feasibility of using an additional booster when dust is emitted from the dust collector bunker.

Also, industrial dust is characterized by a high aeration capacity, weak arc formation.

Disperse analysis of industrial dust showed that particle sizes vary from 1 to 22 microns.

The apparent and bulk density of dusts released during the aerated concrete production varies between 200-1710 kg / m$^3$ and 80-1100 kg / m$^3$, respectively.

According to the data obtained, the repose angle values — dynamic and static — for the dust being studied vary between 39-53 degrees and 44-73 degrees, respectively.

Summary
According to the results of the research it was established that the dust studied has a high dust-forming ability and is characterized by good flowability. Studies have also shown that the dust generated in the production under consideration is polydisperse. At the same time, the majority of particles have a shape close to spherical, or elongated, oblong. The data obtained from the field studies indicate that dust enters the aspiration systems, from 25 to 100% of the mass which falls on particles with the size up to 20 microns. While the median diameter varies from 5.5 μm to 28 μm, the proportion of particles with size less than 10 μm (PM10) is from 6% to 65%. Analysis of the results, which characterize the dust particles’ dispersed composition, as well as the content of PM10 particles in emissions and in atmospheric air, allows us to conclude that there is insufficient fractional efficiency of dust-collecting equipment used in dust-cleaning systems. It was also found that when cyclones are used in dedusting installations for emissions from the aerated concrete production and aerated concrete blocks in the atmospheric air, PM10 particles may be exceeded [5-12]. The industrial dust basic properties studies results released during the aerated concrete products manufacturing formed the basis for further research aimed at reducing the dust emissions mass into urban air at construction enterprises, in particular, focused on the aerated concrete blocks production [9-12].

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