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METHOD OF INCREASING THE DENSITY OF
A MASS OF GRANULAR MATERIAL

Donald W. Ross, Washington, Pa.

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7 Claims. (Cl. 25-156)

This invention relates to the production of massive bodies from granular material, and consists in a method of increasing the density of such bodies. It finds practical application in concrete building and in the production of articles of ceramic ware and refractories. It is advantageously employed in the production of refractories whose ingredients in finely divided condition are size-graded according to the teaching of the specification of an application for Letters Patent filed by me November 12, 1941, Serial No. 418,832, and consisting in a continuation in part of an application filed by me November 5, 1938, Serial No. 239,184.

This application is a division of my earlier application, last named.

My present invention lies in the discovery that a graded mass of granular material may be yet more closely consolidated, and its density yet more greatly increased, by subjecting it to further particular treatment.

It is common knowledge that, in clays, exchangeable bases take up definite positions in the crystal lattice of the ultimate clay particles; that in clay suspensions in water, and other suspending media, such exchangeable cations serve as the connections between clay particles; and that, in cases in which such cations bring about coagulation of clay particles, it tends to be an oriented coagulation. Further, it is known that clay particles in such suspensions can be oriented by passing electric current through the suspensions and by subjecting the suspensions to electric fields.

Reasoning from the above and other known chemical facts, I have concluded that such suspended ultimate clay particles, and similar suspensions of many other kinds of particles, carry, or are capable of carrying, electrical charges. By altering the direction of an electric current that I may cause to pass through such a suspension, or by altering the direction of lines of force of an electric field to which I may subject such a suspension, it is possible to break down given orientations and form still other orientations in conformity with the altered directions. Still further, since the ultimate particles of such a suspension can carry electric charges, it is possible to orient and alter the positions of the particles relative to each other by subjecting the suspension to any electric, electronic, magnetic field, electromagnetic induction, or positive or negative ray forces of sufficient magnitude. Similarly, by more or less continuously altering the direction of such a force, it is pos-

sible to keep the ultimate particles in more or less continuous movement relative to one another. By using such forces of sufficient intensity and by varying the intensity I am able to gain maximum and desirable time of disorientation of ultimate particles and produce other desirable effects.

Multiple forces of the nature specified may be simultaneously applied; they may be applied in parallel directions or at angles to one another, in the same plane or in different planes, and in changing directions relative to one another. Conventional means may be employed that the dispersions may be penetrated by direct or alternating current, or may be brought within and made subject to magnetic fields, to electro-magnetic induction, or to positive or negative rays. The waves of force may vary, not in direction only, but in intensity as well. In case direct or alternating current is used directly for this purpose, I prefer to use a current of between 22 and 1500 volts, and, with amperage suitably small, the current becomes relatively safe to handle.

A specific means of accomplishing rapid change of orientation is to place a mass of the material within an annular coil, so wound that the particles within the mass of material will be rapidly oriented and their orientation altered when an alternating current is passed through the coil. The field intensity is, of course, sufficient to cause orientation.

In concrete and in ceramic masses containing granular and colloidal material, I may prefer to cause movement of particles relative to one another by causing at least some of the particles to vibrate by means of passing high-voltage high-frequency electric current through piezo-electric crystals, the piezo-electric materials being situated either outside of or within the mass being acted upon. I may prefer to use Rochelle salt, quartz, mullite, particles that are largely alumina, magnesium chloride, ammonium chloride, magnesium ammonium chloride, ammonium fluoride, ammonium fluo-silicate, and other materials, including constituents of the ceramic mass, as the piezo-electric material, and vary the frequency and voltage to suit the material used. I may prefer so to act on ceramic masses while they are under pressure. Crystalline constituents of ceramic masses frequently contain crystal strain, particularly in fired particles. I may vibrate a dispersion by means of piezo-electric vibration of these strained particles.

Piezo-electric excitation may be set up by caus-

ing particles of quartz present in a dispersion to vibrate. Particles of quartz are normally present in a concrete mix and in a ceramic casting slip also.

Piezo-electric excitation is commonly carried out by passing the exciting force through the crystal in a given direction. I may prefer to orient piezo-electric crystals in a mass of particles, such as concrete, ceramic materials, and refractory materials by the methods hereof; and, while so oriented, to pass a piezo-electric exciting force through such crystals in the most favorable direction. For instance, I may prefer so to orient particles of quartz, kyanite, clay, magnesite, chrome, and auxiliary piezo-electric materials, including organic piezo-electric materials, and to subject them to piezo-electric exciting force while so oriented.

In case the two sets of forces interfere, I may prefer to apply them alternately to the piezo-electric particles. In case alternating electrical forces are used for this purpose, I may choose to synchronize these forces, so that one is acting with minimum effect on the particles while the other is acting with maximum effect. For instance, one force might be one fourth of a cycle behind the other.

I may prefer to use this piezo-electric crystal vibration method in the forming of concrete masses and of ceramic masses containing minimum water contents, whether the ceramic mass be shaped by slip casting, by pressing, or by other forming method.

By subjecting the particles of the suspension to such orienting and piezo-electric influences rigidity of a mass may be diminished, facility of flow increased, and other good purposes served.

One specific practical application of the invention is found in decreasing the rigidity of water-containing masses of concrete, so that they can be flowed to position and form a relatively void-free finished product. Another application is found in doing the like in the case of a ceramic mass, so that the mass, containing an amount of water less than otherwise is practicable, may still be flowed into a mold, or otherwise shaped. I find a result of disorientation of particles in ceramic and other masses to be low porosity of the formed dried masses.

In particular cases I prefer to keep the particles disoriented only long enough to permit forming (as in a mold) the masses containing them. The particles may then be re-oriented, for the purpose of giving to the molded material a "set," so that the molded article can be removed from the mold within a minimum period of time, and so that other useful purposes can be served. The molding may be performed by slip casting, pressing, or by other suitable means.

Referring again to the crystal structure of clay particles, it is commonly known that the molecules of polar liquids, such as water, attach themselves to the ultimate particles of suspensions in definitely oriented positions with reference to the cation bonds between the particles. Reasoning from this and other known chemical facts, such water is, I believe, little attached to and hence more easily removed from disoriented particles than from oriented material. I, therefore, prefer to alter the orientation of ultimate particles and to disorient them during at least part of the time of the drying of masses containing them. Such treatment serves to permit easier removal of water from the masses.

In ceramic masses, such control of orientation of ultimate particles has the advantage that it permits of wider variety in the applications of a number of ceramic materials. Specifically, it permits the use of certain clays in slip-cast ware that give unusual strength to the ware, and whose particle-size range apparently is unusually great.

I may in particular cases and with good effect disorient the silica particles of silica jellies.

The combined result of this invention with particle-size grading according to the teaching of my earlier application named above is a dry porosity of ware which, to my knowledge and belief, is lower than has heretofore been achieved, either by slip casting or by any other method.

In the manufacture of cement, specifically, not only may the strength and covering power of the cement be improved by extending according to my formula the lower limits of particle size, but also (since concrete commonly contains quartz particles that can be piezo-electrically excited) such excitation may be resorted to in order to increase the fluidity of the newly mixed mass.

I claim as my invention:

1. The method herein described of increasing the density of a mass of granular material which consists in subjecting the mass to successive, differently directed polarizing stresses.

2. The method herein described of filling a mold with slip, which consists in subjecting the slip as it comes to place in the mold to successive, differently directed polarizing stresses.

3. The method herein described of increasing the density of a mass of granular materials that consists in part of grains that manifest the piezo-electrical phenomenon and ability to be electrically oriented and in part of grains that do not manifest such phenomenon nor such ability, which consists in subjecting the mass to the influence of an electro-magnetic field, and repeatedly varying the magnetic effect of the field and producing in the mass piezo-electrical-vibration-producing stresses.

4. The method herein described of increasing the density of a mass of granular material which consists in subjecting the mass to polarizing stresses, and repeatedly varying the intensity of such stresses.

5. The method herein described of filling a mold with slip, which consists in subjecting the slip as it comes to place in the mold to polarizing stresses, and repeatedly varying the intensity of such stresses.

6. The method herein described of increasing the density of a mass of size-graded granular materials including in part grains that manifest the piezo-electrical phenomenon and in part grains that do not manifest such phenomenon, which method consists in subjecting the mass to differently directed electrical forces and producing in the mass piezo-electrical vibration-producing stresses.

7. The method herein described of increasing the density of a mass of size-graded granular materials including in part grains that manifest the piezo-electrical phenomenon and in part grains that do not manifest such phenomenon, which method consists in subjecting the mass to electrical forces, repeatedly varying the intensity of such forces and producing in the mass piezo-electrical vibration-producing stresses.