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PROCESS OF INCREASING THE STRENGTH OF POROUS STRUCTURES

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The present invention relates to a process of reinforcing and solidifying porous masses, such as porous concrete, rock, masonry, and the like, which includes forcing an improved, flowable or intrusion composition into the void spaces of such porous masses to increase their strength and water-tightness.

This application is a continuation-in-part of my prior applications, Serial No. 321,222, filed February 28, 1940, Patent 2 313.110, granted March 9, 1943, Serial No. 280,141, filed June 20, 1939, Patent 2 313,107, granted March 9, 1943, and 391,543, filed May 2, 1941, now abandoned.

In application Serial No. 280,141 I disclosed a method for densifying and solidifying porous masses of earth, masonry, concrete structures, and the like, which comprises forming an aqueous slurry having an hydraulic cement, such as Portland cement, in suspension, and containing, in suspension, soluble and insoluble ingredients, particularly a finely divided filling material which contains acidic colloidal silica. This suspension or aqueous slurry is then forced under pressure into the voids and interstices of the porous mass.

In the practice of the invention as therein described, the porous structure, which may, for example, be a dam, bridge, pier or the like, is drilled and the intrusion material is forced through a nozzle inserted in the drilled hole. It has been found that it frequently migrates great distances from the nozzle, which distances are often as much as thirty or forty feet, or even more. Even though there is a very substantial pressure applied to the intrusion material passing through the nozzle, this pressure appears to be largely dissipated or used up by friction of the material on the walls of the passageway, so that in the areas substantially removed from the nozzle there is difficulty in forcing the material into many of such remote, finer voids and crevices.

In my application, Ser. No. 391,543, I disclosed a method for facilitating the filling of finer voids at great distance from intrusion nozzle by incorporating a small amount of aluminum powder within the intrusion mixture.

While the above processes greatly improve the strength of the structures and permits the densifying and rejuvenation of dams and the like, it

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is desirable and it is an object of the present invention to provide a process which will readily fill even the relatively fine voids at great distances from the nozzle, with an intrusion material which has an increased compressive and tensile strength even after a long aging period over material heretofore used, so that even greater improvement in density and strength may be obtained.

It is another object of the present invention to provide a method of repairing and filling concrete, masonry structures and the like, as disclosed in my above mentioned applications Serial No. 321,222, in a manner in which the repair material will have low shrinkage and will make a stronger structure than was previously possible.

Another object of the present invention is to provide a hardenable intrusion material containing an hydraulic cement as the principal bonding ingredient which may be pumped through porous concrete having only fine passageways therein with substantially no tendency for settling or plugging of the passageways, and which, when mixed with aggregate and pumped into a completely enclosed space, will form concrete of superior strength.

Other objects and advantages will be apparent from the following detailed description of the invention.

It has been frequently proposed to add chlorides, such as calcium chlorides and the like, to concrete mixtures in order to increase the rate of the hardening and setting of the cement. Such concrete, if the chloride is used in the correct amount, has a high early strength. It has now been found that a suitable small amount of calcium chloride in the slurry of the present invention gives relatively large increases in the strength of the hardened material at later ages.

When suitable amounts, such as about .5% to about 3.5%, and preferably about 1% or 2%, of the weight of the cement, of calcium chloride are incorporated in the intrusion material described above and the mixture is forced into a porous structure or into aggregate held in place, substantial increases in strength after aging for long periods result in the hardened mass. Also, it has most unexpectedly been found that such amounts of calcium chloride in the slurry do not cause plugging of the slurry within the hose lines and fine passageways of the structure but, in

spite of the normal tendency of this chloride to cause rapid setting of the cement, they permit the penetration of the hydraulic intrusion material into the very fine voids of the structure far removed from the intrusion nozzle.

The grout or the intrusion material should contain, besides the calcium chloride or other alkaline earth metal chloride, in the amount of .5% to 3.5%, a very finely divided filling material which contains acidic colloidal silica, a small amount of lubricating agent, and sufficient water to form a slurry of the desired consistency. Preferably, a gas-producing metal powder, such as aluminum powder, and preferably, some powdered limestone are also present in the slurry.

Examples of desirable filling materials are blast furnace slag, fly ash, pumicite, or any finely divided artificial material, as well as certain natural siliceous materials, generally classified as "puzzolanas," which form compounds having considerable cementitious value with lime that may be liberated as a by-product during the setting of the cement. Some types of blast furnace slag are hydraulically active in themselves and are very desirable. The filling material should be ground sufficiently fine so that substantially all of it will pass through a 100-mesh screen, and preferably a 200-mesh screen. Such fineness is especially desirable when there are a number of substantially fine voids in the structure.

The quantity of finely divided siliceous materials or filler used will depend upon the character and qualities desired in the required slurry and hardened cement. Usually the siliceous material and cement may be used advantageously in about equal proportions. The range of proportions of filler to cement may vary widely from approximately 1 part of filler to 2 parts of cement to about 2 parts of filler to 1 part of cement. The greatest strength is obtained in the lower portion of this range, i. e., when the amount of filler is less than the amount of cement. Where the filling of relatively small holes in a structure is of prime consideration, the ratio of filler to cement may be increased to the region of about 2 parts of filler to 1 part of cement. For most purposes about equal proportions are very satisfactory.

The lubricating agent may be any of the oleaginous materials which preferably do not undergo any appreciable reaction with the ingredients of the cement composition or, at least, do not react with the cement at appreciable speed to destroy its oily properties. Examples of lubricants are mineral oils, stearates, or fatty acid salts, such as ammonium stearate, sodium stearate, vegetable oils, particularly sulphonated vegetable oils, such as sulphonated coconut oil or peanut oil, and mixtures of such materials. A particularly desirable lubricating material comprises about 40% to 50% of a light mineral oil, which is preferably lighter than lubricating grades, and 50% to 60% of a solution or emulsion of a stearate, such as an emulsified ammonium stearate containing about two-thirds water and one-third solid ammonium stearate. These materials reduce the friction within the voids or passageways of a structure, or between the particles of the aggregate and to some extent delay and retard the setting of the cement, so that gelling or setting does not take place until the slurry is placed.

The quantity of lubricating agent may be varied considerably and is varied according to the fineness of the voids in the structure. When the cavities in the structures are composed substantially of relatively fine voids, a much larger quantity of lubricating agent should be present than when the structure is composed of relatively coarse voids. Usually, the quantity of lubricant is about 1% of the weight of the cement, but as much as 5% to 10% may be desirable in cases where the structure being repaired contains very fine voids, which have high frictional resistance, and as little as .1% of the cement, by weight, is sometimes satisfactory for porous structures having coarser voids.

Examples of the gas-producing metallic powders that may be used are finely divided iron, zinc or aluminum. Aluminum powder produces the most desirable results and should preferably be present in the amount of about .01% to about .02% or even .025% of the weight of the cement. A sufficient amount of retarder or lubricant should be present in the mix to retard the gas-producing reaction between the metal and the alkali until the slurry has been placed, and to also retard the setting of the cement until the concrete has been placed and the gas-producing reaction is substantially complete.

The above mentioned oleaginous materials have also been found to perform both of these functions, and, in the mixing of the ingredients of the slurry, the aluminum powder is preferably first mixed with the retarder, such as a stearate, mineral oil, etc., before it is mixed with the cement. In this manner the aluminum powder is more readily dispersed and the particles are coated with sufficient of the retarder to prevent the gas reaction from taking place during the mixing.

The following examples illustrate the present invention:

EXAMPLE 1

Slurries having the compositions set forth in the following Table I were prepared.

Table I

Composition of Slurries

Slurry No.	Portland Cement, lbs.	Fine-ground Slag, lbs.	Fly Ash, lbs.	Pumicite, lbs.	$CaCl_2$, lbs.	Ratio Water/Cement plus filler by wt.	Amm.[1] Stearate Emulsion, lbs.
1	100	82	------	----------	--------	0.43	1
2	100	150	------	----------	--------	0.43	1
3	100	150	------	----------	2	0.40	1
4	100	--------	43	----------	--------	0.43	1
5	100	--------	43	----------	2	0.46	1
6	100	--------	------	43	--------	0.55	1
7	100	--------	------	43	2	0.53	1

[1] Contains 33% of ammonium stearate.

Slurries of Table I were mixed with equal weights of a sand, all passing a screen having 28 meshes to the inch, and the mix was allowed to

harden and cure. 2" x 4" test cylinders had the characteristics indicated in the following Table II.

Table II

Slurry No.	Compressive Strength, p. s. i.				Tensile Strength		
	7 days	28 days	3 Mo.	1 Yr.	7 days	28 days	3 Mo.
1	3,210	6,650	9,350	10,740	430	695	695
2	2,870	6,730	8,780	10,360	380	636	710
3	5,310	9,590	11,030	12,590	605	750	745
4	3,310	5,630	8,120	10,650	485	580	690
5	4,400	7,010	10,040	13,140	400	460	550
6	2,220	3,960	6,390	9,270	315	495	570
7	2,830	5,120	7,630	10,620	395	605	635

EXAMPLE 2

Slurries Nos. 2 and 3 of Table I were forced into porous structures in the manner disclosed in my application Serial No. 280,141. Core samples removed from the structure repaired with slurry No. 3 showed a compressive strength substantially higher than that of cores removed from the same relative positions of the structure repaired with slurry No. 2. No noticeable difference in the penetration at great distances from the nozzle was observed in the two cases. Although a lubricating agent such as a soap or oil be present in the grout, the calcium chloride as seen from the above, substantially increases the strength of the hardened grout, as well as imparting increased flowability to the grout. As pointed out in my aforementioned parent application, Serial No. 321,222, when sand is used in the grouting composition it tends to decrease shrinkage. The increase in flowability of such a grout obtained with calcium chloride even in the presence of the lubricant and filling material, makes the grout particularly valuable for solidifying porous masses or structures.

The composition of my invention may be used for the solidification of earth, rock, gravel, strata, concrete, such as are present at dams or building sites, as well as for the patching and repairing of concrete structures.

It has been found in accordance with the present invention that superior results are obtained when a slurry containing calcium chloride also contains some powdered limestone. The limestone should preferably be present in an amount equal to about 1% or 2% to about 10% of the total mineral filling material above described, which filling material contains the acidic colloidal silica. With much more than 10% of the powdered limestone in the inert filling material, strength of the hardened material is adversely affected. When about 5% of the mineral filler in the above example is substituted by an equal weight of limestone powder, an increase of about 10% in the compressive strength may be expected. Further increase in strength may also be had with a small amount of metal powder.

It is to be understood that the particular product shown and described, and the particular procedure set forth, are presented for purposes of explanation and illustration, and that various modifications can be made without departing from my invention as defined in the appended claims.

What I claim is:

1. A process for filling voids and interstices in porous masses, which comprises intimately mixing with water, to form a slurry, a finely divided, hydraulic cement, a finely divided filling material containing acidic colloidal silica and capable of retarding gelation of the slurry, an oleaginous lubricating agent to increase flowability of the slurry, aluminum powder in an amount up to .02% of the weight of the cement, and an alkaline metal chloride in an amount of about .5% to 3.5% of the weight of the cement, forcing the aqueous slurry containing the above finely divided solids into the voids and interstices of a porous mass, and allowing the slurry to gel and set within the porous mass, whereby the porous mass is substantially strengthened and solidified.

2. A process for filling voids and interstices in porous masses, which comprises intimately mixing with water, to form a slurry, a finely divided, Portland cement, an oleaginous lubricating agent to increase flowability of the slurry, and aluminum powder in an amount up to .02% of the weight of the cement, a finely divided filler material containing acidic colloidal silica and capable of retarding gelation of the slurry, finely divided limestone, and calcium chloride in an amount of about .5% to 3.5% of the weight of the cement, forcing the aqueous slurry containing the above finely divided solids into the voids and interstices of a porous mass, and allowing the slurry to gel and set within the porous mass, whereby the porous mass is substantially strengthened and solidified.

3. A process for filling voids and interstices in porous masses, which comprises intimately mixing with water, to form a slurry, a finely divided, hydraulic cement, a finely divided filling material containing acidic colloidal silica and capable of retarding gelation of the slurry, an oleaginous lubricating agent which increases the flowability of the mixture, and an alkaline earth metal chloride in an amount of about .5% to 3.5% of the weight of the cement, forcing the aqueous slurry containing the above finely divided solids into the voids and interstices of a porous mass, and allowing the slurry to gel and set within the porous mass, whereby the porous mass is substantially strengthened and solidified.

4. A process for filling voids and interstices in porous masses, which comprises intimately mixing with water, to form a slurry, a finely divided, hydraulic cement, a finely divided filler material containing acidic colloidal silica and capable of retarding gelation of the slurry, a fatty acid salt, calcium chloride in an amount of about .5% to about 3.5% of the weight of the cement, forcing the aqueous slurry containing the above finely divided solids into the voids and interstices of a porous mass, and allowing the slurry to gel and set within the porous mass, whereby the porous mass is substantially strengthened and solidified.

5. A process for filling voids and interstices in porous masses, which comprises intimately mixing with water, to form a slurry, a finely divided, hydraulic cement, a finely divided filler material containing acidic colloidal silica and capable of retarding gelation of the slurry, mineral oil, and calcium chloride in an amount of about .5% to about 3.5% of the weight of the cement, forcing the aqueous slurry containing the above finely divided solids into the voids and interstices of a porous mass, and allowing the slurry to gel and set within the porous mass, whereby the porous mass is substantially strengthened and solidified.

6. A process for filling voids and interstices in porous masses, which comprises intimately mixing with water, to form a slurry, a finely divided, hydraulic cement, a finely divided filler material containing acidic colloidal silica and capable of retarding gelation of the slurry, a fatty acid salt, mineral oil, calcium chloride in an amount of about .5% to 3.5%, and a gas-producing metal

powder in an amount of about .005% to .05% of the weight of the cement, forcing the aqueous slurry containing the above finely divided solids into the voids and interstices of a porous mass, and allowing the slurry to gel and set within the porous mass, whereby the porous mass is substantially strengthened and solidified.

7. A process for filling voids and interstices in porous masses, which comprises intimately mixing with water, to form a slurry, a finely divided, hydraulic cement, a finely divided filler material containing acidic colloidal silica and capable of retarding gelation of the slurry, calcium chloride in an amount of about .5% to about 3.5% of the weight of the cement, and an oleaginous lubricant in an amount up to 5% of the weight of the cement, forcing the aqueous slurry containing the above finely divided solids into the voids and interstices of a porous mass and allowing the slurry to gel and set, under pressure, within the porous mass, whereby the porous mass is substantially strengthened and solidified.

8. A process for filling voids and interstices in porous masses which comprises forming a readily flowable aqueous slurry containing in suspension Portland cement, acidic colloidal silica to retard gelation of the cement, an oleaginous lubricating agent which increases flowability of the slurry, calcium chloride in the amount of .5% to about 3.5%, based on the weight of the cement, and .005% to .05% of finely divided aluminum, based on the weight of the cement, forcing the aqueous slurry into the voids and interstices of the porous masses, and allowing the slurry to gel and set therein, whereby the porous masses are substantially strengthened and solidified.

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