

CALCIUM ALUMINATE MORTAR FOR USE IN A SHOTCRETE WET PROCESS

The present invention relates to a mortar composition comprising a calcium aluminate based binder and an aggregate, to a concrete composition prepared therefrom and to the use thereof, notably in a shotcrete wet process, for example, in the rehabilitation, notably by lining/relining, of sewerage and drainage systems, pipes, manholes, and associated structures.

At regular intervals it is necessary to rehabilitate pipes, manholes and associated structures in sewerage and drainage systems. The water loaded with organic matter circulating in these pipes causes via biological actions the formation of very aggressive acids. Generally such equipment as pipes are made of cast or concrete, sometimes optionally coated with a protective material such as for example PVC (polyvinylchloride), HDPE (high density polyethylene), epoxy resin, etc but such equipment as pipes may also be made of PVC – thus problems arise for their replacement, which sometimes remain unsolved). These pipes have in general a small diameter, in contrast to the sewerage systems with higher diameters - higher than 500 mm - which are rather made of cast or concrete. Most of the tanks, accumulation chambers, manholes are out of concrete and therefore must be often rehabilitated due to corrosion by city supply waters and factory waste waters.

A successful way of rehabilitating the sewerage systems is to use mortars, having numerous known advantages. They are generally of low cost, simple to handle, allow recovering the initial geometry of the pipes, and improving the structure resistance. Furthermore, if needed, after several years of restarting, new rehabilitation may be achieved with a new mortar. Mortars allowing a quick restarting, such as Portland cement or in particular calcium aluminate cementitious mortar, are preferred for evident reasons.

In fact, there remain problems to be solved when dealing with formulations of quick setting mortars as the main process generally chosen for the rehabilitation is the so-called shotcrete process, which is preferred to cast, for example, when framework conditions are difficult due to the geometry of the constructions.

The choice of shotcrete process mode, dry or wet, depends on different factors such as the need to avoid formation of dust in a confined atmosphere, a long time of transfer in function of the distance, the type of works tools available onsites, mechanical performances of the projected material, productivity linked economic considerations, etc. The type of process is finally determined after considering the general worksite constraints.

Other important problems encountered when formulating a mortar for shotcrete applications, to name a few, are the absences of sufficient cohesion of the projected mortar. A poor paste/aggregate binding is also one of the prerequisites for good resistance to corrosion.

In a shotcrete wet process a mixture is generally firstly formed by mixing binder (cement), aggregate (granulates, generally crystalline silica (siliceous) sand, mixing water and additives. This mixture is then usually displaced by a pump in a pipe towards a spraying nozzle whereat an additive such as a setting accelerator is generally added. The thus obtained mixture is sprayed from the nozzle by means of compressed air onto the surface to be concreted.

The known problems encountered in such a shotcrete wet process, to name just a few, are the following :

- mortar formulation must be in a pumpable (flowable) and sprayable state while ensuring an efficient adhesion to the surface to be concreted ; premature setting often cause the mortar to block

the pipe conveying the formulation to the spraying nozzle ; and

- presence of excess water in the initial mortar mixture causes the latter to segregate and insufficient mixture compactness is achieved ; moreover water not consumed during hydration results in reduction of thickness of the layer sprayed in one run.

Bonded aggregate compositions to be used in a shotcrete wet process generally comprise a suitable, generally calcium silicate based aggregate, bound by a binder(cement). Conventional rapid hardening cements for bonding aggregates include aluminous binders, generally containing at least 30 % to 35 % alumina or Portland cements, containing generally less than 5 % alumina.

According to the present inventors, no mortars obtained by mixing such conventional binders and aggregates have proven satisfactory to prepare a concrete composition for use in a shotcrete wet process.

Therefore applicant identified the need of an improved mortar over the prior art mortars, a new concrete composition prepared therefrom and a shotcrete dry process making use thereof.

Accordingly, the main objects of the present invention are to provide an improved mortar over the prior art mortars, the concrete composition prepared therefrom and uses thereof specially in a shotcrete wet process.

Thus the present invention relates in its first aspect to a mortar comprising a mixture of a calcium aluminate binder having more than about 40% by weight alumina and an aggregate of appropriate grain size characterised in that said aggregate is a calcium aluminate aggregate having a grain size lower than 1.4 mm and at least about 35 % by weight of said mixture presents a grain size smaller than about 100 μ m.

Yet it is known from document EP 0.690.258 a calcium aluminate based mortar. Such a mortar is applied to the interior surface of pipes which are then rotated at about 500 to 700 rpm for about 8 to about 40 seconds. 5 After centrifuging, this mortar is subjected to a drying at about 60°C. The centrifuge effect combined to the drying ensures an adhesion of the mortar to a cast or iron pipe.

However, such a mortar is not at all suited for the preparation of a concrete composition to be used in a shotcrete wet process and is inappropriate for use notably 10 in the rehabilitating of sewerage systems and associated structures already in place on sites.

Contrary to the present invention mortar, the mortar taught in the EP 0.690.258 document cannot be used in fact for the preparation of a concrete to be used in a shotcrete process whether by the dry or wet route, simply because the latter require the formulation to be in a sufficiently pumpable (flowable) state and still be able to quickly set so as to be easily sprayed while ensuring an 20 efficient adhesion on the surface to be concreted.

In use, for example, in a shotcrete wet process, the advantages of the invention formulation are, notably, the following :

- all support neat surfaces are adhered to
- 25 - gain in thickness in a few runs
- cohesiveness is achieved in order to optimise compactness and density of the finished layer.

The fact that both binder and aggregate of the mortar according to the present invention are chemically 30 of the same nature improves the aggregate-binder bond and thus the overall resistance to corrosion of the material.

Moreover, the calcium aluminate binder of the present invention contains low quantity of $C_{12}A_7$. The 35 amount is less than 0,6 %. This avoids stiffening of the

mortar, to keep it pumpable, but is sufficient for its holding in place and where necessary, a troweling in view of finishing the surface.

Further or alternatives preferred features of the mortar according to the invention are as follows :

- Mortar binder has a Blaine specific surface area from about 2950 cm²/g to about 4600 cm²/g, preferably .of about 4500 cm²/g.
- Mortar binder has about 53 % by weight of alumina.
- Mortar binder is obtainable by melting in a reverbatory furnace, just like the so-called FONDU®, well known in the art.
- Mortar aggregate passes a sieve of about 1.4 mm.
- Mortar has about 97.7 % calcium aluminate.
- Mortar further comprises one or more additives selected in the group consisting of leak resistance promoting agents, anti-shrinkage agents, internal strength promoting agents/anti-segregation agents, and flowability promoting agents.

In another aspect the present invention relates to a concrete composition wherein a binder and an aggregate, as defined above, are present in a binder:aggregate ratio of about 1:1.9 and wherein the water:binder ratio is about 0.37.

In still another aspect, the present invention relates to a concrete composition obtainable by a process consisting of mixing a mortar, as defined above, with water wherein about 14 % water, by weight of dry components of the concrete composition, is added whereby a sufficiently low content of C₁₂A₇ phase is achieved. (standard nomenclature in the art of high alumina cements: C=CaO ; A=Al₂O₃).

In a further aspect the present invention relates to a shotcrete wet process making use of a concrete

composition as defined above, preferably for the rehabilitation by lining/relining of sewerage and drainage systems, pipes, manholes, and associated.

Other features and complementary advantages of the present invention will now be described in further details in the following illustrating, but in no way limiting, examples.

Example 1 : Preparation of a mortar according to the invention

A calcium aluminate binder having about 53 % by weight of alumina, namely Secar 51[®], sold by Lafarge Aluminates is mixed with an aggregate of the same mineralogy, so-called Alag[®], which is a calcium aluminate clinker based granulate produced by Lafarge Aluminates.

As a binder to include in a mortar according to the present invention, Secar 51[®] may be replaced by Calcoat[®], another type of calcium aluminate sold by Lafarge Aluminates, the composition thereof equally allows to achieve the same performances as Secar 51. Secar 51 confers to the mortar a high resistance to corrosion induced by the sulphuric acid contained in waters circulating in the sewerage system. The life time of the lining thus obtained is prolonged and repair periods are limited to a minimum.

The Alag[®] aggregate has a particle size, which allows to incorporate a high level of fines in the formulation and as an advantageous consequence the formulation is easily pumped. Its mineralogy is perfectly suited to that of the binder, therefore adherence between them is at best.

Polypropylene fibres are a means for limiting the segregation and shrinkage phenomena.

Fly ash promotes cohesion of the shotcrete and allows where appropriate to spray layers of a more important thickness without the risk of collapsing of the projected layer.

- 5 Trisodium citrate is a well known water reducing additive in the art of aluminous cement. It permits to control the water:binder ratio to a pumpable state of the mortar and indirectly allows to reduce segregation.

10 Methylcellulose J5MS is an anti-segregation agent that also promotes pumping.

Slick Pack2 renders the formulation easier to pump.

The proportions (WT%) of the different components, of the mortar according to the present invention, including different additives, and the sieve sizes (grain diameter $\varnothing$, in mm) of the aggregate (granulates) are
15 shown in Table 1.

Table 1

Binder Secar 51®	33.7
Granulates Alag®, Ø<1.4 mm	64
Fibres Polypropylene fibres, L=12 mm	0.2
Powder additives Fly ash, Elkem 940 U	1.8
Redispersable polymer Elotex WSA45	0.3
Other powder components by WT% of binder	0.05
Trisodium citrate	0.06
Methylcellulose J5MS Dow Chemical	0.01
Slick Pak II Fritz-Pak Corporation	

5 Example 2 : Shotcrete wet process according to the invention.

To a formulation as obtained in Example 1, incorporating the components in the form of a powder, is added about 12 % to about 16 %, preferably about 14 % diluting water by weight of dry components, which is
10 measured in a mixer. Said mixer is a concrete mixing machine with open vessel or of the type with appropriately

sized blades, over which is connected a measuring water tank (precision is $\pm 1\%$).

The shotcrete wet process or "wet gunning", calls for a special equipment comprising a mixer, a concrete pump, an additive pump. Usually this type of equipment is available onsites and thus it allows to limit the operating costs of such a process. The concrete pump is a commonly used pump in the shotcrete wet process art and may be one of so-called P11, P13 or P38 pump from the Putzmeister company.

The shotcrete wet process comprises the steps consisting of

- (i) mixing the flowable mortar, as obtained in Example 1, with an amount of water measured in the mixer ;
- (ii) delivering the mixture to the loading hopper of a concrete pump ;
- (iii) pumping the mixture through pipes to the spraying nozzle ;
- (iv) injecting compressed air and additive into said nozzle, in order to achieve the spraying ; and
- (v) spraying until the desired layer thickness is achieved.

Example 3 : Comparison of the performances of a mortar according to the invention and of a prior art mortar.

Other aluminous mortar available on the market, comprised of aluminous binders blended with conventional aggregates, such as calcium silica or siliceous sand (control mortar, as shown in Table 2), do not perform as well as the mortar according to the present invention and thus might cause damages onsites.

Moreover the invention formulation is of a reasonable cost.

Table 2

Control Mortar (prior art)	Aluminate binder Calcoat® Siliceous sand Water:binder ratio = 0.32	1 part by weight 1.5 part by weight
Mortar according to the invention	Aluminate binder Calcoat® Alag® granulates Water:binder ratio = 0.37	1 part by weight 1.9 part by weight

5 24 cubes are produced from each of these mortars and are placed in a simulation chamber where they are kept in an atmosphere supplied with Hydrogen sulphur gas. The chamber volume is about 1 m^3 ; temperature is adjusted to 30°C and relative humidity kept between about 10 95 % and about 97 %. In order to have a 15-20 ppm H_2S concentration, the gas is injected by means of a 10 l bottle. Every 30 min., a bacteriological mixture is sprayed which function is to accelerate the corrosion phenomena.

15 The cubes are regularly weighed every 8 weeks till 48 weeks and losses of weight thus obtained are compared. The results are shown in Table 3.

Table 3

Control Mortar	Age (weeks)	8	16	24	32	40	48
	Weight loss (%)	5	10	15	32	42	43
Invention Mortar	Age (weeks)	8	16	24	32	40	48
	Weight loss (%)	0	1	10	18	21	30

5 As can be seen from Table 3, these results illustrate the excellent and surprising performances of the invention mortar, and specially the remarkable effect of the combination aluminous binder-aluminous aggregate according to the invention, which confers to the invention
 10 mortar a loss of weight due to corrosion which is 30 % smaller than the one achieved with a control mortar, at the end of the test period.

The particularly advantageous mortar according to the invention is in pumpable and sprayable state while
 15 ensuring an efficient adhesion on supports to be rehabilitated. Moreover a minimum amount of water is used to allow on one hand the absence of segregation of the formulation and on the other it confers a sufficient compactness to the mixture. Such an improved mortar
 20 guaranties both excellent mechanical resistance and corrosion resistance properties, especially in the presence of sulphuric acid containing waters circulating in sewerage systems. Furthermore it is well adapted to worksite conditions with variable ambiances (temperature,
 25 humidity...) and is robust. Finally, the mixture, prepared

according to the invention, has a fluidity, which does not fluctuate, and the mortar has constant set and hardening.

Altogether, these performances allow a quick setting of the invention mortar and thus a very rapid restarting of the rehabilitated sewerage system while ensuring a high
5 level of corrosion resistance due to waste waters, thus prolonging the life of the restored system.

CLAIMS

1. Repair mortar for use in a shotcrete wet process comprising a mixture of a calcium aluminate binder having more than about 40% by weight alumina and an aggregate
5 of appropriate grain size characterised in that said aggregate is a calcium aluminate aggregate having a grain size lower than 1.4 mm and at least about 35 % by weight of said mixture presents a grain size smaller than about 100 μm .

10 2. Mortar according to claim 1, characterised in that the binder has a Blaine specific surface area from about 2950 cm^2/g to about 4600 cm^2/g , preferably about 4500 cm^2/g .

15 3. Mortar according to claim 2, wherein the binder has about 53 % by weight of alumina.

4. Mortar according to claim 3, wherein the binder has an amount of C_{12}A_7 less than 0,6 %.

20 5. Mortar according to anyone of claims 1 to 3, wherein the binder is obtainable by melting in a reverbatory furnace.

6. Mortar according to anyone of claims 1 to 4, having about 97.7 % calcium aluminate.

25 7. Mortar according to anyone of claims 1 to 5, further comprising one or more additives selected in the group consisting of leak resistance promoting agents, anti-schrinkage agents, internal strength promoting agents/anti-segregation agents, and flowability promoting agents.

30 8. Concrete composition comprised of a mortar, as defined in anyone of the preceding claims, having a binder:aggregate ratio of about 1:1.9 and wherein the water:binder ratio is about 0.37.

35 9. Concrete composition obtainable by a process consisting of mixing a mortar having about 33.7 WT % of an about 53 WT % alumina containing binder, about 64 WT % aggregate, and about 2.3 WT % of one or more

additives as defined in claim 6, with water wherein about 14 WT% water, by weight of dry components of the concrete composition.

5 10. Shotcrete wet process making use of a concrete composition according to claim 7 or 8.

11. Shotcrete wet process according to claim 9 for the rehabilitation by lining/relining of sewerage and drainage systems, pipes, manholes, and associated structures.