

CALCIUM ALUMINATE MORTAR FOR USE IN A SHOTCRETE DRY PROCESS

The present invention relates to a mortar composition comprising a calcium aluminate based binder and an aggregate, to a concrete prepared therefrom and to the use thereof, notably in a shotcrete dry process, for example, in the rehabilitation, notably by lining/refining, 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 on sites, 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 the shotcrete dry process, a dry mixture is firstly prepared by mixing a binder (cement), an aggregate in a suitable particle size range, usually crystalline silica sand (siliceous sand), with additives such as hardeners and/or accelerators. This dry mixture is generally displaced pneumatically to a mixing/spraying nozzle whereat it is wetted with mixing water to effect setting of the mixture and the concrete thus obtained is sprayed to the surface to be shotcreted.

Known constraints of such a shotcrete process by the dry mode, to name just a few, are :

- a very limited period of contact time between dry mixture (powder) and mixing water ;
- formulation must contain as few components as possible which are able to rapidly mix together

with water and quickly harden but no plugging of spray nozzles must occur –often there being noted a premature hardening due to localised reactions of mortar components with accelerators or hardeners.

- An exaggerate rebound of the concrete on the support to be rehabilitated usually occurs inevitably causing safety problems for the crew and also cost problems due loss of material impossible to reuse.

Bonded aggregate compositions to be used in a shotcrete dry 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 in use in a shotcrete dry process.

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

Accordingly, the present invention relates in its first aspect to a mortar comprising a calcium aluminate binder comprising about 40 % to about 45 % by weight alumina, and an aggregate of an appropriate selected particle size, characterised in that said aggregate is a calcium aluminate aggregate comprising a first aggregate portion a1, having a grain size of from about 1.4 mm to about 2.8 mm and a second aggregate portion a2, having a grain size smaller than about 1.4 mm, in a a1:a2 ratio of about 2.5 :1.

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 a shotcrete dry process and is inappropriate for use, notably, 10 in the rehabilitating of sewerage systems and associated structures already in place onsites.

Contrary to the present invention mortar, the mortar taught in the EP 0.690.258 document cannot be used in fact in a shotcrete process whether by the dry or wet route, 15 simply because the latter requires the mortar formulation to be in a sufficiently pumpable (flowable) state and still be able to quickly set so as to be easily sprayed and then adhered onto the surface to be concreted.

The mortar formulation according to the present 20 invention is easily pneumatically pumped to the projection nozzle, where water is added. The components comprised in the mortar are mixed with water in a very short time, and a perfect adhesion of the fresh mixture on the support/surface to be concreted as well as a quick setting 25 are achieved, from the starting of the shotcrete process.

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

30 The calcium aluminate binder of the present invention contains at least 1 % of $C_{12}A_7$. This amount is necessary to cause a gelation of the mixture on the support, ensuring its holding in place while allowing, where necessary, a troweling in view of finishing the surface.

(standard nomenclature in the art of high alumina content cements: $C=CaO$; $A=Al_2O_3$)

The combined aggregate of the mortar according to the present invention comprises two types of aggregates of appropriate grain size and in a selected ratio. In use, for example, in a shotcrete dry process, the advantages that such a combined aggregate confers to the mortar formulation are notably the following :

- all support neat surfaces are adhered to
- gain in thickness in a few runs
- cohesiveness is achieved in order to optimise compactness and density of the finished layer
- rebound problem is solved specially in the shotcrete dry process where the courant speeds are always very high.

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

- the mortar has about 96.1 % calcium alumina.
- the mortar has at least one internal strength promoting agent having a grain size smaller than about 900 μm , preferably clay. Clay also limits the rebound to a minimum and promotes adhesion of the coating on the support.
- the mortar is devoid of organic additive, such as a hardener or accelerator thus simplifying the problem of mixing of such admixtures with the other powder components of the mortar. With the prior art mortar mixtures, the presence of an accelerator causes the projected mixture to quickly set on its support. The usual contact time between the water and the powder is thus very limited and mixing only a few components, as is the case in the present invention, is very advantageous.

In a further aspect, the present invention relates to a concrete composition comprising a mixture of a mortar and

water, wherein a binder and an aggregate, as defined above, are present in a ratio of about 1 :1.9 and wherein there is a water:binder ratio of about 0.37.

5 In still a further aspect, the present invention relates to a concrete composition obtainable by a process consisting of mixing a mortar, as defined above, with water wherein preferably from about 8 % to about 10 % water, by weight of dry components of the concrete composition, is added whereby an appropriate amount of $C_{12}A_7$ is formed.

10 In still another aspect, the present invention relates to a shotcrete dry process making use of the concrete as defined above, preferably for the rehabilitation, notably by lining/relining, of sewerage and drainage systems, pipes, manholes, and associated structures.

15 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.

20 Example 1 : Preparation of a mortar according to the invention

25 A calcium aluminate binder having about 43 % by weight of alumina, namely Secar 41[®], 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. Clay, namely Raymond Hill clay from Cedar Heights is added. The proportions of the different components and the sieve sizes (grain diameter $\varnothing$, in mm) of the granulates are shown in Table 1.

Table 1

Components	%
Binder Secar 41 [®]	24.6
Granulates Alag [®] , 1.4 mm < $\varnothing$ < 2.4 mm Alag [®] , $\varnothing$ < 1.4 mm Raymond Hill Clay, $\varnothing$ < 900 μ m	50.8 20.7 3.9

5 Example 2 : Shotcrete dry process according to the invention

The formulation obtained in Example 1, incorporating only three components in the form of a powder, is pneumatically pumped to the spraying nozzle of a shotcrete dry apparatus, where is added about 8 % to 10 % diluting water by weight of dry components.

The formulation of Example 1 is able to rapidly mix with water and to set in a very short time. Therefore this formulation is perfectly suited for a shotcrete dry process.

15 When used, for instance, in the relining of a support this formulation confers to the coating a prolonged life time and limits to a minimum the periods of rehabilitation, compared to prior art formulations, as will be shown in the next example.

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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 usual

aggregates, 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 on sites.

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Table 2

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

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 m³ ; temperature is adjusted to 30°C and relative humidity kept between about 95 % and about 97 %. In order to have a 15-20 ppm H₂S 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.

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.

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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 of the invention formulation allow a quick setting of the concrete and thus a
5 very rapid restarting of the rehabilitated sewerage system while ensuring a prolonged life to the restored system.

CLAIMS

1. Repair mortar for use in a shotcrete dry process comprising a calcium aluminate binder, comprising about
5 40 % to about 45 % by weight alumina, and an aggregate of an appropriate selected particle size, characterised in that said aggregate is a calcium aluminate aggregate comprising a first aggregate portion a1, having a grain size of from about 1.4 mm to about 2.8 mm and a second
10 aggregate portion a2, having a grain size smaller than about 1.4 mm, in a a1:a2 ratio of about 2.5 :1.

2. Mortar according to claim 1 having about 96.1 % by weight of calcium alumina.

3. Mortar according to claim 1 or 2 wherein the
15 calcium aluminate binder has an amount of C₁₂ A₇ superior to 1 %.

4. Mortar according to claim 1 or 2 further comprising at least one internal strength promoting agent having a grain size smaller than about 900 µm.

20 5. Mortar according to claim 3, wherein said agent is clay.

6. Mortar according to anyone of claims 1 to 4, characterised in that it is devoid of organic additive, such as a hardener or accelerator.

25 7. oncrete composition comprising a mortar as defined in anyone of the preceding claims, and water wherein binder:aggregate ratio is about 1 :1.9 and water:binder ratio is about 0.37.

8. Concrete composition obtainable by a process
30 consisting of mixing a mortar, according to anyone of claims 1 to 5, with water wherein about 8 % to about 10 WT % water, by weight of dry components of the concrete composition, is added.

9. Concrete composition according to claim 7,
35 obtainable by mixing about 24.6 WT % of an about

43 WT % alumina containing binder, about 71.5 WT % aggregate as defined in claim 1, about 3.9 WT % clay as defined in claim 4, with about 8 WT % to about 10 WT % water by weight of dry components of the concrete composition.

10. Shotcrete dry process making use of a concrete composition according to anyone of claims 6 to 8.

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