

AGGREGATE CONTAINING HYDRATION WATER IN SPRAY APPLIED
FIREPROOFING

BACKGROUND OF THE INVENTION

It is well known to spray apply hydraulic cementitious slurries to metal structural members in order to provide a heat resistant coating thereon. U.S. Patent Nos. 3,719,513 and 3,839,059, the disclosures of which are hereby incorporated by reference, disclose gypsum-based formulations which contain, in addition to the gypsum binder, a lightweight inorganic aggregate such as vermiculite, a fibrous substance such as cellulose and an air entraining agent. Such slurries are generally prepared at ground level and are pumped to the point of application, where they are spray applied to the substrate. Often the point of application exceeds 20 or 30 stories where high rise construction is involved. Accordingly, pumpability of the slurries is an important criteria in their formulation and preparation. Thus, they must be able to hold the large quantity of water that renders them capable of being pumped easily and to great heights, yet they must retain a consistency sufficient to prevent segregation or settling of ingredients and permit adequate yield or coverage of the substrate at a given thickness. The coating mixes must adhere to the substrate both in the slurried state and in the dry state. Also, the mix must set without undue expansion or shrinkage which could result in the formation of cracks that would seriously deter from the insulative value of the dry coating.

U.S. patent No. 4,751,024, the disclosure of which is incorporated herein by reference, teaches sprayable cementitious compositions containing shredded polystyrene as a lightweight

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aggregate in fireproofing compositions. The cementitious binder is preferably gypsum, but may instead be Portland cement. Indeed, Portland cement is typically used as the binder in applications involving high traffic areas, since the cement tends to be stronger than gypsum.

High density (40-42 pcf [pounds per cubic foot]), high durable, cement-based structural steel fireproofing compositions are primarily used for industrial and/or exterior applications, i.e., applications in which preventing the physical failure of the composition is of the utmost importance. Accordingly, the high density product typically includes, as the hard aggregate, sand, which allows for excellent in-place and application performance. However, the sand does not contribute to the thermal characteristics of the product, and, as a result, a thicker coating is required to obtain the same hourly fireproofing protection as a product that does not include sand aggregate. That is, the sand aggregate provides physical strength to the product, but does not contribute thermally.

Reference to Figure 1 illustrates the sacrifice in thermal performance when using a cementitious fireproofing composition that includes sand as the hard aggregate. Compositions A, B, C and D are high density (43.8 pcf, 42.2 pcf, 54.7 pcf and 48.5 pcf, respectively) compositions that include sand. Composition B is Carboline 241, available commercially from Carboline Fireproofing Products Division of RPM Company. Carboline 241 is a Portland cement based (35% by weight) product which includes muscovite (35% by weight) and aluminum hydroxide (15% by weight) as the major ingredients. It does not include sand, and has a



density of 49.4 pcf. The graph in Figure 1 illustrates the superior thermal performance of Composition E compared to the compositions utilizing sand as the hard aggregate.

It therefore would be desirable to improve the thermal performance of these and other sprayable cementitious compositions without substantially deleteriously influencing the application and physical properties thereof. The present invention is directed towards such an improvement.

SUMMARY OF THE INVENTION

The problems of the prior art have been overcome by the present invention, which provides a sprayable fireproofing material which exhibits improved thermal performance. In general, an aggregate that contains hydration water is added to the cementitious compositions, thereby not only performing the function of a typical aggregate, but also enhancing the thermal performance of the composition. In high-density cementitious fireproofing compositions, the aggregate containing hydration water partially or completely replaces the sand aggregate.

In its method aspects, the present invention is directed towards a method of spray applying the disclosed cementitious compositions onto a substrate, such as a structural steel member.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a graph showing the thermal performance of various cementitious compositions;

Figure 2 is a graph showing the thermal performance of various cementitious compositions;



Figure 3 is a graph showing the thermal performance of various cementitious compositions; and

Figure 4 is a diagram indicating the experimental set-up used in carrying out the Examples set forth below.

DETAILED DESCRIPTION OF THE INVENTION

Any suitable hydraulic cement binder can be used in accordance with the present invention, such as gypsum (both non-hydrated and hydrated Plaster of Paris), Portland cement, aluminous cement and pozzolanic cement. The preferred binders are gypsum and Portland cement. Preferably the binder is used in an amount of about 10 to about 60% by weight, more preferably about 40 to about 50% by weight.

The instant fireproofing compositions preferably contain shredded expanded polystyrene as a soft or lightweight aggregate. The "shreddedness" of the expanded polystyrene preferably conforms to a particular particle size distribution expressed in terms of the amount of particles retained on a standard #12 sieve (having 0.0661 inch holes), and the amount of particles passing through a standard #30 sieve and retained on a #325 sieve, as determined in accordance with the method described in U.S. Patent No. 4,989,464 (the disclosure of which is hereby incorporated by reference). Suitable amounts of particles retained on the #12 sieve, expressed as a weight percent, are from about 0 to about 20%, with from about 0 to about 10% being preferred, and less than about 8% being especially preferred. Suitable amounts of particles passing through a #30 sieve (having 0.0594cm [0.0234 inch] holes) and retained on a #325 sieve (having 0.0043cm [0.0017 inch] holes) are less



than about 40% by weight, preferably less than about 30%, with about 14-20% being especially preferred. The desired amount of particles retained by the #12 sieve depends in part on the amount of particles passing through the #30 sieve and retained by the #325 sieve. Where the amount of particles retained by the #12 sieve is less than about 8% by weight, it is preferred that the amount of particles passing through the #30 sieve and retained by the #325 sieve be less than about 30% by weight. The amount of polystyrene present in the cementitious formulations in accordance with the present invention is from about 0.5 to about 3.5 percent, preferably about 1.0%.

Since the instant fireproofing compositions are typically transported to the building site as dry mixtures, and are formed into slurries upon the addition of an appropriate amount of water, the preparation and application processes may span many hours and thus the setting time of the mix is generally heavily retarded to provide an acceptable field pot life. This retarding in the mixer contradicts the desired quick setting time upon spray application, and thus a delicate balance of retarding and accelerating is difficult to achieve. Obviously, were the mixture to stiffen substantially in the hopper, it would be rendered non-pumpable and therefore would be useless for the intended application. Any set accelerating agent capable of satisfactorily offsetting the retardation of the slurry without deleteriously effecting the same or the substrate which is the subject of the application can be used. Examples of useful accelerators include aluminum sulfate, aluminum nitrate, ferric nitrate, ferric sulfate, potassium sulfate, sulfuric acid, sodium.



carbonate, sodium bicarbonate and acetic acid, with alum being especially preferred. Preferably aluminum sulfate set accelerator is used as a 37% solution and is injected into the slurry at the spray nozzle at a level up to 3%.

The present invention is applicable to Portland cement types 1 through 5, although type 1 is especially preferred. For a mid-density product, the dry mix of such compositions has a bulk density in the 10 to 18 pcf range, preferably in the 12 to 15 pcf range, and the final dry density of the product is in the 15 to 30 pcf range, preferably the 22 to 26 pcf range. The dry material is mixed with water at a ratio of 1.3:1 - 1.6:1 (water:solids). For the high density product, the final density is preferably about 40-42 pcf. Additional optional additives and ingredients may be added, such as glass fibers (chopped fiberglass) in amount of about 0.5 to 2.5%, preferably about 1.0%, to control shrinkage; methyl cellulose or other suitable thickeners known to those skilled in the art in an amount of from about 2 to about 5%, preferably about 2.1%; air stabilizers such as hydroxypropyl methyl cellulose (THEM) in an amount of from about 0.1 to about 3%; air entrainers, such as alcohol sulfate sodium salt in an amount of from about 0.1 to about 3%; polyvinyl acetate in an amount from 0 to about 5%; clay in an amount of from about 3 to about 6%; and a biocide to inhibit bacterial formation.

The present invention is also applicable to lighter weight fireproofing compositions (16-18 pcf) in which gypsum is the cementitious binder. For such applications, low density aggregates having hydration water are preferable.



In the preferred embodiment of the present invention, the aggregate having hydration water is used in cementitious fireproofing compositions having a density in the 40-42 pcf range.

Suitable aggregates having hydration water include coarse ground gypsum, bauxite, cement clinker, brucite and granular aluminum hydroxide. Bauxite is preferred for its excellent thermal effectiveness. The aggregates can be used alone or in combination. The aggregates contribute to the effectiveness of a structural steel fireproofing by enhancing its ability to act as an insulating barrier between the fire and the steel, and by absorbing energy via an endothermic reaction. The endothermic reaction takes place when the chemically bound water within the aggregate is driven off during heating. The aggregate should be preferably used in an amount of 10 to about 60% by weight, more preferably about 40% by weight, and should preferably have the following sieve analysis:

<u>Screen #</u>	<u>% Retained-Cumulative</u>
+40	1% maximum
-40, +60	0-35%
-60, +100	65% minimum
-100, +200	95% minimum

The aggregate can replace some or all of the sand aggregate, and/or some of the cementitious binder.

EXAMPLES

In the following examples, the effectiveness of aggregates



containing hydration water when used in structural steel fireproofing was determined by the following method. The fireproofing formulations were mixed with water, pumped and sprayed with field-typical equipment directly into a cube mold. Upon curing, the cube 10 was removed from the mold and oven dried at 120°F until a constant weight was obtained.

The cube 10 was then suspended, using a suspension rod 15 and suspension wires 16 in a 1' x 2' oven having a Duraboard frame 17 and surrounded by insulation 18 as shown in Figure 4. One thermocouple 12 was positioned in the centre of the cube in order to measure the heat transmission through the material. Two additional thermocouples 13, 14 were placed in the oven on either side of the cube 10 in order to monitor the oven temperature.

The oven was then heated using the standard ASTM E-119 time temperature curve. The testing was maintained until the thermocouple 12 inside the cube measured 1000°F. The output from the three thermocouples was recorded using a standard electronic data collection device.

The fireproofing compositions in accordance with the present invention that were tested in the examples had the following formulation:

25	<u>Component</u>	<u>Formulation Tested (%)</u>
	Aggregate	35-45
	Portland cement	40-50
	Shredded polystyrene	0.5-1.5
	Chopped fibreglass strand	1-3
30	Pulverized cellulose	1.5-3
	Hydroxypropyl methyl cellulose	0.1-0.5
	Alcohol sulfate sodium salt	0.1-0.5
	Polyvinyl acetate	1.5-3
	Attapulgite/Sepiolite clay	3-6

35 The aggregate was a hydration-water containing hard aggregate having the following sieve analysis:



	<u>Screen #</u>	<u>% Retained (cumulative)</u>
	+20	14.1
	-20, +40	40.2 minimum
	-40, +60	54.2 minimum
5	-60, +100	67.7 minimum
	+100	100

Compositions A to D are representative of the prior art, as is composition K which is based on Carbolite 241 and contains no sand or hydration water-containing aggregate. Prior art composition O contains sand as aggregate. Compositions F to J, M, N, P and Q are compositions of the invention and contain as the aggregate the following, with total density of composition in parentheses:

15	F	:	Zeolite (42.3 pcf)
	G	:	Coarse Aluminium hydroxide (43.8 pcf)
	H	:	Bauxite (46.0 pcf)
	I	:	Clinker (47.2 pcf)
	J	:	Un-X Perlite (48.6 pcf)
20	M	:	Gypsum sand (44 pcf)
	N	:	Cement clinker (48 pcf)
	P	:	Bauxite (40 pcf)
	Q	:	Dolomite (40 pcf)

Figure 1 illustrates the thermal performance of a high density fireproofing compositions A-D (densities of 43.8, 42.2, 48.5 and 54.7 pcf, respectively) having sand aggregate, versus a fireproofing composition based on Carbolite 241 having a density of 49.4 pcf but no sand aggregate (E). The graph demonstrates the improved thermal performance achieved when sand is not used as the hard aggregate.

Figure 2 is a graphical comparison of the thermal performance of fireproofing compositions according to the present invention (F-J) versus a fireproofing composition based on Carbolite 241 containing no sand aggregate and no aggregate having water of hydration (K). The thermal performance of compositions G and H were superior to



composition K, while compositions F and I were comparable to composition K.

Figure 3 is a graphical illustration of various fireproofing compositions including aggregates having water of hydration, versus the prior art composition (O) having sand as the only hard aggregate. Compositions M, N and P exhibited good to excellent thermal performance.

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CLAIMS

1. A sprayable fireproofing composition, comprising a cementitious binder and a hydration water-containing hard aggregate.
- 5 2. The sprayable fireproofing composition of claim 1, further comprising shredded polystyrene.
3. A dry composition comprising a hydraulic cementitious binder and an aggregate containing water of hydration; said composition providing, upon the addition of water, a
- 10 settable slurry which is capable of spray application to a steel substrate and which, after spray application, is adherent to said substrate in the slurried state and after setting.
4. The dry composition of claim 3, wherein said aggregate
- 15 is a hydration water-containing hard aggregate.
5. The dry composition of claim 3 or claim 4 or the sprayable fireproofing composition of claim 1 or claim 2, further comprising shredded polystyrene aggregate.
6. The sprayable fireproofing composition of claim 1, 2
- 20 or 5, or the dry composition of claim 4, wherein said hydration water-containing hard aggregate is selected from the group consisting of coarse ground gypsum, bauxite, cement clinker, brucite and granular aluminum hydroxide.
7. The composition of claim 6, wherein said hydration
- 25 water-containing hard aggregate is bauxite.
8. The sprayable fireproofing composition of claim 1 or the dry composition of claim 4 wherein the hydration water-containing hard aggregate has the following sieve analysis:
- | <u>Screen #</u> | <u>% Retained-Cumulative</u> |
|-----------------|------------------------------|
| 30 -60, +100 | 65 minimum |
| -100, +200 | 95 minimum. |
9. A method of applying a sprayable fireproofing composition to a steel substrate comprising dry blending a mixture comprising a hydraulic cementitious binder and an
- 35 aggregate containing water of hydration; adding water thereto to form a sprayable slurry; conveying said slurry to a spray nozzle; introducing a set accelerating agent





into said slurry in close proximity to said nozzle; and spraying said slurry onto said substrate.

10. The method of claim 9 wherein the aggregate has any of the additional features set out in claims 2 and 5 to 8.

