

IMPROVED POZZOLANIC COMPOSITIONS

The invention relates to improved silica fume compositions and to a method for the production of such improved compositions. Such compositions are useful as admixtures for cementitious compositions.

According to ASTM C 618 a pozzolan is defined as a "siliceous or siliceous and aluminous material which in itself possesses little or no cementitious value but will, in finely divided form and in the presence of moisture, chemically react with calcium hydroxide at ordinary temperature to form compounds possessing cementitious properties." Besides natural pozzolans, many industrial byproducts are rapidly becoming the primary source of artificial pozzolans in use today. Power plants using rice husks or coal as fuel, and metallurgical furnaces producing iron, silicon and ferrosilicon alloys are the main source of artificial pozzolans like fly ash, rice husk ash, blast furnace slag, silica fume, etc.

Silica fume, sometimes known as volatilized silica or condensed silica fume, is manufactured by electric arc furnaces as a byproduct of the production of metallic silicon or ferrosilicon alloys. In the transformation of quartz to silicon at temperatures of about 2000°C, a gaseous SiO oxidises to SiO₂ and condenses in the form of special fine particles consisting of amorphous silica. Silica fume is removed by filtering the outgoing gases in a bag filter. The pozzolanic activity of silica fume, that is the chemical reactivity with calcium hydroxide, is substantially due to the non crystalline character of silica and the very high specific surface area (10 to 30 m²/g), which in turn depends on the very small particle size (much lower than 1 μm). For the same reason, however, silica fume has a relatively low bulk gravity (about 0.2 to 0.3 tonne/m³), so that shipping and storing

costs are relatively high. Moreover, silica fume forms a lot of dust product and is difficult to cause to flow. It cannot be moved into storage silos by pneumatic lines, bucket elevator or screen conveyor as easily as cement can be.

According to the invention there is provided a method for humidifying to increase the flowability of pozzolanic compositions comprising:

- spraying from 2 to 25% by weight of water on pozzolanic compositions containing silica fume; and
- stirring the material by a mechanical mixer until a uniformly humidified powder results. All weights are by weight of the pozzolanic compositions.

Pozzolanic compositions treated according to the present invention having a small amount of water are uniform humidified powders which have a higher bulk gravity, are virtually dustless, flow easily, can be stored in ordinary cement silos and transported in bulk cement tankers. Moreover, such pozzolanic compositions can be dispensed through the same systems as used for cement.

The water used to humidify the pozzolanic compositions containing silica fume is optionally an aqueous solution of well known chemical admixtures, generally utilized in cement mortars or concrete mixes, such as accelerators, retarders, air-entraining agents, water reducers, plasticisers and superplasticizers.

Pozzolanic compositions according to the invention are mixtures of silica fume with natural pozzolan or other artificial pozzolans such as fly ash, rice husk ash, blast furnace slag, etc. Preferably the pozzolanic compositions according to the invention contain at least 50% by weight of silica fume. The preferred material treated according

to the invention is a mixture of silica fume with fly ash containing 80% by weight of silica fume and 20% by weight of fly ash.

The amount of water used in the method of the invention is critical in order to obtain a uniformly humidified powder with the recited advantages. If an amount below 2% is used, no particular effect can be observed. If an amount above 25% is used, the obtained powder will rather be a slurry with all the disadvantages well known in the art. Preferably the amount of water used is from 10% to 20% by weight.

An especially preferred pozzolanic composition according to the invention comprises from 66-84% by weight of a pozzolanic material comprising silica fume and fly ash, from 10-20% by weight of water and from 6-14% by weight of a superplasticizer and/or plasticizer.

The time required for the treatment according to the invention depends on the amount of pozzolanic composition containing silica fume and of water being mixed and on the effectiveness of the mechanical mixing equipment. Generally, when using an ordinary laboratory mixer, a few minutes of mixing will suffice for an even distribution of the preferred 10 to 20% of water.

In order to have some quantitative indication about the improvement of the bulk gravity two different tests have been developed: one consists in measuring the weight of loose material in a container of a given volume and calculating the weight/volume ratio in kg/l or tonne/m³; the other is the so called slide test: a brass ring placed on a smooth plastic (PMMA) horizontal plate is filled with the loose powder material; the brass ring is removed so that a powder disc (100 mm in diameter and 20 mm thick) is obtained; the slope of the plastic table (420 mm in length) is increased until all material has slipped down into a container; the angle at which the material flows down is the "angle of slide" which is an indication for the powder flowability.

The humidified silica fume containing powder according to the invention can be used in a conventional way to improve the properties of cement mortars and of concrete mixes and it has been observed that, in comparison to cement mortars or concrete mixes containing known silica fume dust and superplasticizer, an improved fluidity is obtained with silica fume containing powder which has been humidified with an aqueous solution of superplasticizer. Flow table tests according to ASTM C 230 have been carried out to evaluate these effects.

The invention is illustrated by the following examples in which all percentages are by weight and temperatures are in centigrade.

Example 1

Silica fume samples from the Norwegian firm Elkem ($\text{SiO}_2 = 97\%$, specific surface area according to BET method is $16\text{m}^2/\text{g}$) are mixed with fly ash in a ratio of 4:1 and treated with varying amounts of water by spraying with a laboratory sprayer into an ordinary laboratory mixer of the "Hobart" (trademark) type. The mixing time is 2 minutes for all the samples and the amounts of water vary from 0.1, 1, 2, 5, 10, 20, to 25% based on the weight of the silica fume containing powder. The bulk gravity of the obtained powders is determined by the bulk gravity test and by the slide test. It is observed that with amounts of water above 2% the bulk gravity increases from 0.3 kg/l (for the untreated powder) to a value of 0.6 kg/l (for the powder treated with 20% of water) and that the angle of slide for untreated powder is about 38° , whereas angles below 30° are sufficient for the humidified samples. When the water content is higher than 25% the powder is transformed into a water slurry so that the measurement is no longer meaningful. Similar results have been obtained by using silica fume of different origin (from companies in Italy, France and Germany).

Example 2

Dry untreated silica fume containing powders (80% by weight silica fume and 20% by weight fly ash) and water treated powders are used to manufacture cement mortar mixes including ordinary Portland cement, Torre del Lago (Italy) sand used in standard Italian tests for mortars, mixing water and superplasticizer ("Rheobuild" 1000 (trademark)). The cement/sand weight ratio is $1/3$. The amount of superplasticizer is 3% by weight of cement. The water/cement weight ratio is 2:5. In calculating the water/cement ratio the amount of water includes both batched water and water coming from the superplasticizer (40% solution) and/or humidified powder, i.e. all the mortar mixes are manufactured with the same amount of total water independently of the water content in the treated powders. Whereas the fluidity of the-----

mixes with untreated powder is 110% according to ASTM C 230, the mixes with water treated powder show a fluidity of 125 to 150% when the powder has been treated with water amounts of 5 to 20%.

Example 3

The same tests as described in Example 2 are carried out with a mixture of silica fume (60% by weight) and fly ash (40% by weight). The fluidity of the cement mortar with the untreated silica fume/fly ash mixture is 130% according to ASTM C 230, whereas the mortars with the treated silica fume/fly ash mixture show a fluidity of 140 to 170%, when this mixture has been treated with water amounts of 5, 10, 15 and 20%.



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1. A method of humidifying pozzolanic compositions as hereinabove defined containing silica fume, comprising:

- spraying from 2% to 25 % by weight of water on the pozzolanic composition containing silica fume whilst stirring the material by a mechanical mixer until a uniformly humidified powder is obtained.

2. A method according to claim 1 in which the amount of water used is from 10% to 20% of water.

3. A method according to claim 1 or 2 in which the pozzolanic composition containing silica fume is treated with an aqueous solution containing admixtures selected from accelerators, retarders, air-entraining agents, water reducers, plasticizers and superplasticizers.

4. A method according to claim 3 in which the pozzolanic composition containing silica fume is treated with an aqueous solution of a superplasticizer.

5. A uniformly humidified, powdered pozzolanic composition as hereinabove defined, comprising silica fume and fly ash and 2% to 25% by weight of water.

6. A pozzolanic composition according to claim 5 in which the pozzolanic material contains at least 50% by weight of silica fume.

7. A pozzolanic composition according to claim 6 in which the pozzolanic material contains 60% by weight of silica fume and 40% by weight of fly ash.



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8. A pozzolanic composition according to any one of claims 5 to 7 containing from 10% to 20% by weight of water.
 9. A pozzolanic composition according to any one of claims 5 to 8 containing a superplasticizer.
 10. A pozzolanic composition comprising:
 - 1) 66 to 84% of a pozzolanic material comprising silica fume and fly ash;
 - 2) 10 to 20% of water; and
 - 3) 6 to 14% of a superplasticizer.
 11. A process for the manufacture of a cement mortar or a concrete mix characterized in that pozzolanic compositions containing silica fume according to any one of claims 5 to 10 are used.
 12. A pozzolanic composition according to claim 5 substantially as herein described with reference to any one of Examples 1 to 3.
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