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(54) Title: METHOD FOR THE TREATMENT OF FLY ASH

(57) Abrégé/Abstract:
Method for treatment of fly ash for preparation of mortars and concretes. The invention is characterized in, that in a first step fly ash is intensively blended with a highly-reactive and dry cement mixture, which mixture have been obtained by mixing Portland cement with a microfiller and possibly a water reducing agent and by grinding said mixture, in that, in a second stage the so obtained blend is intergrinded in a vibratory milling device to achieve the fineness of the final product with a retention on a 45μm sieve which is less than 15 percent by weight.

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(54) Title: METHOD FOR THE TREATMENT OF FLY ASH

(57) Abstract: Method for treatment of fly ash for preparation of mortars and concretes. The invention is characterized in, that in a first step fly ash is intensively blended with a highly-reactive and dry cement mixture, which mixture have been obtained by mixing Portland cement with a microfiller and possibly a water reducing agent and by grinding said mixture, in that, in a second stage the so obtained blend is intergrinded in a vibratory milling device to achieve the fineness of the final product with a retention on a 45μm sieve which is less than 15 percent by weight.

Method for the treatment of fly ash.

The present invention relates to the method for treatment of fly ash which is useful for production of concretes, mortars and other mixtures comprising cement and fly ash. Fly ash manufactured according to the present method significantly improves performance of the concrete and provides higher level of replacement of Standard Portland cement, which leads to significant economical and environmental benefits.

Background

Fly ash is a by-product of a coal burning power plant and is produced worldwide in large quantities each year.

Fly ash usually contains about 85% glassy, amorphous components. According to ASTM C 618 fly ash is classified in two classes, Class C and Class F. The Class F fly ash typically contains more than 70% by weight of silica, alumina, and ferric oxides, while Class C typically contains between 70% and 50%. Class F produced as a by product of the combustion of bituminous coal Class C fly ash has a higher calcium content and is produced as a by product of the combustion of sub-bituminous coal.

In 1988, approximately 84 million tons of coal ash were produced in the U.S. in the form of fly ash (ca 60.7%), bottom ash (ca 16.7%), boiler slag (5.9%), and flue gas desulphurization (16.7%), *see e.g. Tyson, 1990, "Coal Combustion By-Product Utilization", Seminar, Pittsburgh, 15 pp*. Out of the approximately 50 million tons of fly ash generated annually, only about 10 percent is used in concrete , *see e.g. ACI Committee 226. 1987, "Use of Fly Ash In Concrete," ACI*

226.3R-87, ACI J. Proceedings 84:381-409), while the remaining portion is mostly deposited as waste in landfills.

Comprehensive research demonstrated that high volume fly ash concretes showed a higher long term strength development, a lower water and a gas permeability, a high chloride ion resistance, etc. in comparison with Portland cement concretes without fly ash.

At the same time high volume fly ash concrete has significant drawbacks: a very long setting time and a very slow strength development during the period 0 to 28 days, which reduce the level of fly ash used for replacement of Portland cement to an average of 15-20%.

Number of efforts has been made towards improvement of the performance of high volume fly ash concretes; see e.g. *Malhotra, Concrete International J., Vol.21, No5, May 1999, pp. 61-66*. According to Malhotra strength development of such concretes could be improved by significantly increasing the binder content (cement + microfiller) and significantly decreasing the amount of mixed water, but such an approach require increased dosage of water reducing admixtures to keep an acceptable consistency of concrete mixtures, which sharply increases the cost of the concrete.

Number of methods related to grinding fly ash in order to improve it pozzolanic activity by grinding fly ash, which increase the amount of fly ash particles of the size about 11 microns and by simultaneous introduction of calcium oxide have been developed, see U.S. Pat. Nos. 6,038,987; 5,714,002; 5,714,003; 5,383.521, and 5,121,795. All mentioned known methods could not provide significant improvement of the fly ash performance as a concrete component and drastically increase the costs of pozzolan additive.

Disclosure of the invention

The present invention refers to a method for treatment of fly ash for preparation of mortars and concretes,and is characterized in, that in a first step fly ash is intensively blended with a highly-reactive and dry cement mixture, which mixture have been obtained by mixing Portland cement with a microfiller and possibly a water reducing agent and by grinding said mixture, in that, in a second stage the so obtained blend is intergrinded in a vibratory milling device to achieve the fineness of the final product with a retention on a 45µm sieve which is less than 15 percent by weight.

According to a preferred embodiment said milling device has a vibration cycle having an amplitude of from 2 to 30 mm and a frequency of vibration from 800 to 2000 rpm.

The present invention thus refers to a method for treatment of fly ash useful for preparation of mortars and concretes, where firstly the said fly ash is intensively blended with a highly-reactive and dry cement mixture, which mixture has been obtained by thorough mixing of Portland cement with a microfiller and possibly a water reducing agent, and secondly the said blend is interground in a vibratory milling device.

Intergrinding of the fly ash with the highly reactive cement mixture in a milling device with a vibration cycle having an amplitude of from 2 to 30 mm and a frequency of vibration of from 800 to 2000 rpm leads to a several effects.

The effects are firstly, an increase of the fineness of the final product takes place, where a reduction of the average size of fly ash particles is obtained, so that the amount of fly ash retained on a 45μm sieve will be less than 15 percent by weight, secondly, additional amorphisation of the fly ash particle surface takes place, and thirdly, tri- and dicalcium silicates from the highly-reactive cement mixture becomes homogeneously distributed on the surface of fly ash particles. These phenomena improve the pozzolanic activity towards a reaction with calcium hydroxide and in addition also create an inherent hydraulic activity of the treated fly ash.

Another advantage with the present method is that the grinding process appears to release ammonia captured in the surface of the fly ash produced from urea-treated coal, which is used to reduce NOX emissions. The presence of ammonia in fly ash renders it unsuitable for use in concretes or mortars.

This advantage of the present invention is that the proposed treatment of fly ash minimizes the effects of boiler conditions on fly ash properties associated with boiler conditions and the degree of coal pulverization.

By a highly-reactive, dry cement mixture according to the foregoing is meant a cement mixture of the kind obtained by the process described in European Patent Specification No. EP 0696262 and the US Patent 5,804,175 or a cement mixture that has been treated in accordance with a corresponding process so as to obtain a compressive strength corresponding to that recited in EP 0696262 and U.S. Patent No 5, 804,175.

According to one preferred embodiment a water reducing agent in introduced in a powdery form in an amount from about 0.1 to 0.3 percent by weight during said intergrinding.

According to another preferred embodiment said fly ash is caused to replace the cement in the fly ash-cement mixture from about 20 to about 70 percent by weight of the total weight of the mixture.

The European Patent Specification No. EP 0696262 and U.S. Patent No 5,804,175 describe a method of producing cement that can be use to produce a cement that can be used to produce pastes, mortar, concrete and other cement-based materials of high bearing capacity with a reduced water content, a high mechanical strength and a density and a rapid strength development. This method includes the mechanical-chemical treatment of a mixture of cement and at least one component of two components, wherewith the first component is a micro-filler that contains silicon dioxide and the second component is a polymer in the form of water reducing agent. The cement and the first and/or the second component are mixed in the first stage in a dry state, wherewith the particles in the first and/or the second component are adsorbed on the cement particles. The mixture obtained in the first stage is treated in the second stage in a grinder with vibrating grinding media in which the particles in said mixture are subjected to a large number of impact impulses which change directions in a rapid sequence and therewith result in modification of the surface properties of cement particles in the form of considerable increase in surface energy and chemical reactivity. The duration of treatment in the second stage is sufficient for a cement paste cube having the side length of 20 mm and compacted thoroughly under vibration and cured at +20 degrees

C under sealed conditions to obtain a one-day compressive strength equal to at least 60 MPa.

The European Patent No 0 696 262 is hereby incorporated in the present application.

According to a preferred embodiment the blend of fly ash and the highly reactive cement mixture contains fly ash from about 99 to about 90 percent by weight.

Further the invention refers to a process for producing concrete mixtures useful for preparing a shaped concrete elements or structures which comprises the steps of firstly producing a treated fly ash according to the above said method and secondly mixing the said blended cement with sand and/or aggregate of grater dimensions and water, and thirdly casting a shaped element or the structure and hardening of the subject.

In this respect it is preferred that said fly ash is caused to replace the cement in the fly ash-cement mixture from about 20 to about 70 percent by weight of the total weight of the mixture.

The present invention will be described more in detail in the following, partly in connection with Tables, where

Table 1 and 2 respectively show the strength development of the mortar with a reference of Portland cement, and with 20 and 40 percent by weight of Portland cement replacement by fly ash Class F and Class C treated according to the present method.

The said tables contain data for the mortars with similar levels of Portland cement replacement, where fly ash has been introduced by only intermixing with other ingredients of the mortar in a traditional way. Tests have been performed according to ASTM C 109, ASTM C-311 and ASTM C-192.

According to the obtained results mortars prepared with 20 and 40% replacement of Portland cement with fly ash Class F showed a significant increase of the strength, both early-age and long- term, in comparison with traditional blends. The mortar with 20 % replacement reached a strength level of the pure Portland cement about 3 days after hardening and demonstrates about an 11% higher strength after 28 days of curing. The mortar with 40% replacement almost reached the strength of the pure Portland cement mortar after 28 days of curing.

Mortars prepared with fly ash Class C treated according to the presented method showed a similar tendency of strength development improvement. The strength of the mortar with 20% replacement of Portland cement showed a superior strength compared to pure Portland cement mortar already after 3 days and about a 12% higher strength after 28 days of hardening.

Measurement of setting time of binders containing treated fly ash and reference Portland cement paste using the Gilmore apparatus have been made according to ASTM C 266. Data showed that the cement pastes with treated fly ash demonstrated a setting time in line with reference Portland cement: initial setting time 2:20 - 2:40 hours and final setting time 3:40 - 3:55 hours.

It was discovered that fly ash Class F and Class C intergrinded with a highly-reactive cement mixture in a vibratory milling device, where the milling device has a vibration cycle having amplitude of from 2 to 30 mm and a frequency of vibration of from 800 to 2000 rpm, resulted in a fineness of the final product where the retention on a 45μm sieve is less than 5 percent by weight. This leads to a significant modification of the surface of the said fly ash resulting in additional amorphisation and adsorption of the particles of the highly-reactive cement mixture. This modification leads to an improvement of the chemical reactivity of the fly ash and improvement of the performance of the fly ash containing composites.

According to a first embodiment said fly ash consists essentially of Class F fly ash.

According to a second embodiment said fly ash consists essentially of Class C fly ash.

According to a third embodiment said fly ash consists essentially of the blend of Class F and Class C fly ash.

According to a fourth embodiment said fly ash consists essentially of a blend of Class F, Class C fly ash and/or lignite fly ash.

Examples

The following materials have been used in the experiments described below:
Standard Portland cement CEM I 42.5 according to EN-197 or Type I according to ASTM C 150, fly ash Class F and Class C.

The fineness of the fly ash Class F and Class C are characterized by the retention on the 45 microns sieve of 21 and 19.5 percent by weight, respectively.

The said fly ash was mixed in a dry state with a highly reactive dry cement mixture produced according to European Patent Specification No. EP 0696262 and containing 99% of Portland Cement (PC) and 2% of fly ash Class F. The mixing of the said components was performed with a mixer "Tonimix" (Made in Germany) having a rotation speed of 280 rpm during 3 min to obtain a homogeneous blend. The content of fly ash and highly reactive cement mixture were 95 percent by weight and 5 percent by weight, respectively.

The intergrinding of the above mentioned mixtures was carried out in a Humboldt Palla 20U (Humboldt, Germany) vibrating mill with amplitude 10 mm and a frequency of vibration of from 1500 rpm to achieve the fineness of the final product where the 45 micron fraction was about 2.5 percent by weight.

According to the tests results, see tables 1- 2, the fly ash Class C and F treated according to the present method demonstrated a significant improvement in performance. This can lead to an increase in utilisation of the fly ash in concrete and also by an increased level of replacement of Portland cement by fly ash in concrete. This will have a significant impact on the environmental profile of cement and concrete industry.

Table 1. Mortar test with fly ash Class F

Cement type	**Compressive strength, MPa Curing time, days**			
	1	**3**	**7**	**28**
Reference Portland cement	10.2	26.5	30.0	38.6
80% PC + 20% fly ash*	8.5	25.0	32.5	43.1
60% PC + 40% fly ash*	6.4	19.5	24.1	36.2
80% PC+20% fly ash**	6.5	20.0	23.6	35.8
60% PC+40% fly ash**	3.8	15.0	17.7	29.6

*) Fly ash treated according to presented method

**) Fly ash traditionally introduced in mixer

Table 2. Mortar test with fly ash Class C

Cement type	**Compressive strength, MPa Curing time, days**			
	1	**3**	**7**	**28**
Reference Portland cement	10.2	26.5	30.0	38.6
80% PC + 20% fly ash*	9.5	27.0	35.3	46.2
60% PC + 40% fly ash*	7.4	21.5	27.2	38.2
80% PC+20% fly ash**	7.5	22.0	28.3	39.8
60% PC+40% fly ash**	4.8	17.0	19.7	32.6

*) Fly ash treated according to presented method

**) Fly ash traditionally introduced in mixer

Due to a significant reduction of Portland clinker content implementation of such blended cements could significantly reduce the level of carbon dioxide and other "green house" gases emissions, where the reduction could be more than 50%, and the amount of energy required for Portland clinker production.

Claims

1. Method for treatment of fly ash for preparation of mortars and concretes, characterized in, that in a first step fly ash is intensively blended with a highly-reactive and dry cement mixture, which mixture have been obtained by mixing Portland cement with a microfiller and possibly a water reducing agent and by grinding said mixture, in that, in a second stage the so obtained blend is intergrinded in a vibratory milling device to achieve the fineness of the final product with a retention on a 45μm sieve which is less than 15 percent by weight.

2. Method according to claim 1, characterized in, that said milling device has a vibration cycle having an amplitude of from 2 to 30 mm and a frequency of vibration from 800 to 2000 rpm.

3. Method according to claim 1 or 2, characterized in, that the blend of fly ash and the highly reactive cement mixture contains fly ash from about 99 to about 90 percent by weight.

4. Method according to claim 1, 2 or 3, characterized in, that said fly ash consists essentially of Class F fly ash.

5. Method according to claim 1, 2 or 3, characterized in, that said fly ash consists essentially of Class C fly ash.

6. Method according to claim 1, 2 or 3, characterized in, that said fly ash consists essentially of the blend of Class F and Class C fly ash.

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7. Method 1, 2 or 3, characterized in, that said fly ash consists essentially of a blend of Class F, Class C fly ash and/or lignite fly ash.

8. Method according to claim 1, 2, 3, 4, 5, 6 or 7, characterized in, that during said intergrinding a water reducing agent in introduced in a powdery form in an amount from about 0.1 to 0.3 percent by weight.

9. Method for producing a mixture according to claim 7, characterized in, that said fly ash is caused to replace the cement in the fly ash-cement mixture from about 20 to about 70 percent by weight of the total weight of the mixture.

10. Method for producing a concrete mixture for preparing concrete structures and elements, characterized in, that it comprises the steps of any of claims of 1 to 6 and secondly mixing said fly ash and cement mixture with sand and/or aggregates of greater dimensions and water, and possibly air entraining and water reducing admixtures.