Cementitious Material and Uses Thereof

Technical Field

The present disclosure generally relates to a cementitious composition comprising supplementary cementitious material. The present disclosure further generally relates to a method of producing the cementitious composition.

Background Art

The production process of ordinary Portland Cement (OPC) contributes 8% of total released anthropogenic CO_2 globally and 50-60% of it is due to the calcination of limestone at 1400-1450 °C. It is unlikely that OPC can be completely replaced in the near future. However, the urgency to develop alternate low-carbon binders has not gone unnoticed and in this regard, different locally available materials have investigated as potential supplementary cementitious materials (SCM). The most commonly used SCMs are either industrial waste such as fly ash, ground granulated blast furnace slag (GGBS), silica fume and nano silica which contribute to the properties of hardened concrete through their hydraulic and/or pozzolanic activity to the. In addition to these materials natural pozzolans (of volcanic origin), metakaolin and calcined shale have also been used as SCMs to partially replace OPC. Although the use of metakaolin as SCM in concrete shows promising mechanical performance, its commercial use on a large scale is limited owing to its scant availability and high cost. Hence, there is a need to find other sources of SCMs that can replace OPC.

Summary

The present disclosure provides a cementitious composition comprising:

(a) Portland cement clinker in an amount of from about 70 wt% to 95 wt% by dry weight based on the total dry weight of the cementitious composition; and

(b) supplementary cementitious material in an amount from about 5 wt% to about 30 wt% by dry weight based on the total dry weight of the cementitious composition,

wherein the supplementary cementitious material comprises:

(i) calcined clay material produced from heating a clay material at a maximum temperature of between about 700 °C to about 900 °C;

(ii) carbonate material selected from the group consisting of limestone, calcium magnesium carbonate, and mixtures thereof; and

(iii) sulphate material selected from the group consisting of gypsum, bassanite, anhydrite, and mixtures thereof,

wherein the weight ratio of the calcined clay material to the carbonate material is about 1.5:1 to about 2.1:1.

In one aspect, the present disclosure provides a cementitious composition comprising:

(a) Portland cement clinker in an amount of from 70 wt% to 95 wt% by dry weight based on the total dry weight of the cementitious composition; and
(b) supplementary cementitious material in an amount from 5 wt% to 30 wt% by dry weight based on the total dry weight of the cementitious composition,

wherein the supplementary cementitious material comprises:

(i) calcined clay material produced from heating a marine clay material at a maximum temperature of between 700 °C to 900 °C, whereby the heating converts the kaolinite in the marine clay material to metakaolin;
(ii) carbonate material selected from the group consisting of limestone, calcium magnesium carbonate, and mixtures thereof; and
(iii) sulphate material selected from the group consisting of gypsum, bassanite, anhydrite, and mixtures thereof,

wherein the weight ratio of the calcined clay material to the carbonate material is 1.5:1 to 2.1:1.

Advantageously, the cementitious composition of the present disclosure solves two problems: firstly to validate the use of raw marine clay as Supplementary Cementitious Material (SCM) in replacing Ordinary Portland Cement; as well as finding a new use for raw marine clay which is normally thought of as industrial waste of no value.

Using calcined clay material derived from raw marine clay as SCM also provides for another advantage, it was discovered that calcination of marine clay takes place at 700 ºC to 900 ºC, which is a significantly lower temperature as compared to the calcination temperature of clinker (1450 ºC). This results in lower energy consumption that directly leads to a smaller carbon footprint. Further the carbonate material used in the cementitious composition of the present disclosure does not need prior calcination, further reducing the carbon footprint of the process.

The present disclosure provides a cementitious composition, comprising:

(a) Portland cement clinker in an amount of from about 70 wt% to 80 wt% by dry weight based on the total dry weight of the cementitious composition; and
(b) supplementary cementitious material in an amount from about 20 wt% to about 30 wt% by dry weight based on the total dry weight of the cementitious composition,

wherein the supplementary cementitious material comprises:

(i) calcined clay material produced from heating a clay material at a maximum temperature of about 700 °C to about 900 °C, wherein the clay material contains at least about 25 wt% to about 35 wt% kaolinite;

(ii) limestone; and

(iii) gypsum,

wherein the weight ratio of the calcined clay material to the limestone is about 2:1 to about 2.1:1.

In another aspect, the present disclosure provides a cementitious composition, comprising:

(a) Portland cement clinker in an amount of from 70 wt% to 80 wt% by dry weight based on the total dry weight of the cementitious composition; and

(b) supplementary cementitious material in an amount from 20 wt% to 30 wt% by dry weight based on the total dry weight of the cementitious composition,

wherein the supplementary cementitious material comprises:

(i) calcined clay material produced from heating a marine clay material at a maximum temperature of 700 °C to 900 °C, whereby the heating converts the kaolinite in the marine clay material to metakaolin, wherein the marine clay material contains 25 wt% to 35 wt% kaolinite;

(ii) limestone; and

(iii) gypsum,

wherein the weight ratio of the calcined clay material to the limestone is 2:1 to 2.1:1.

The present disclosure provides a method of producing a cementitious composition, comprising:

(a) heating a clay material at a maximum temperature of about 700 °C to about 900 °C to form a calcined clay material;

(b) mixing the calcined clay material with a carbonate material selected from the group consisting of limestone, calcium magnesium carbonate, and mixtures thereof, and a sulphate material selected from the group consisting of gypsum, bassanite, anhydrite, and mixtures thereof to form a supplementary cementitious mixture;

(c) blending the supplementary cementitious mixture with Portland cement clinker,

wherein:

the Portland cement clinker is in an amount of from about 70 wt% to 95 wt% by dry weight based on the total dry weight of the cementitious composition;

the supplementary cementitious material in an amount from about 5 wt% to about 30 wt% by dry weight based on the total dry weight of the cementitious composition;

the weight ratio of the calcined clay material to the carbonate material is about 1.5:1 to about 2.1:1.

In another aspect, the present disclosure provides a method of producing a cementitious composition, comprising:

(a) heating a marine clay material at a maximum temperature of 700 °C to 900 °C to form a calcined clay material;
(b) mixing the calcined clay material with a carbonate material selected from the group consisting of limestone, calcium magnesium carbonate, and mixtures thereof, and a sulphate material selected from the group consisting of gypsum, bassanite, anhydrite, and mixtures thereof to form a supplementary cementitious mixture;
(c) blending the supplementary cementitious mixture with Portland cement clinker,

wherein:

the Portland cement clinker is in an amount of from 70 wt% to 95 wt% by dry weight based on the total dry weight of the cementitious composition;

the supplementary cementitious material in an amount from 5 wt% to 30 wt% by dry weight based on the total dry weight of the cementitious composition;

the weight ratio of the calcined clay material to the carbonate material is 1.5:1 to 2.1:1.

Definitions

Unless otherwise defined herein, scientific and technical terms used in this application shall have the meanings that are commonly understood by those of ordinary skill in the art. Generally, nomenclature used in connection with, and techniques of, chemistry described herein, are those well-known and commonly used in the art.

Unless the context requires otherwise or specifically stated to the contrary, integers, steps, or elements of the invention recited herein as singular integers, steps or elements clearly encompass both singular and plural forms of the recited integers, steps or elements.

As used herein, the term “clinker” refers to the solid intermediate material produced from the sintering of limestone and aluminosilicate materials during the calcination stage. The same clinker also refers to the intermediate material prior to the formation of the final Portland cement.

As used herein, the term “supplementary cementitious material” refers to any material that may be used to replace cement clinker in any cement product.

As used herein, the term “marine clay” refers to clay material that are found in coastal regions around the world. They may also be found as a waste by-product from dredging, construction, and reclamation processes.

As used herein, the term “calcination” refers to the thermal treatment of a material at high temperatures in absence or limited supply of oxygen, to either remove impurities, volatile substances, or to induce thermal decomposition. Accordingly, the term “calcined” refers to the final state of the material that has undergone the process.

As used herein, the term “cementitious” refers to any material that possess the property akin to cement, i.e. any material that sets, hardens and adheres to other materials.

Claims

1. A cementitious composition comprising:

(a) Portland cement clinker in an amount of from 70 wt% to 95 wt% by dry weight based on the total dry weight of the cementitious composition; and

(b) supplementary cementitious material in an amount from 5 wt% to 30 wt% by dry weight based on the total dry weight of the cementitious composition,

wherein the supplementary cementitious material comprises:

(i) calcined clay material produced from heating a marine clay material at a maximum temperature of between 700 °C to 900 °C, whereby the heating converts the kaolinite in the marine clay material to metakaolin;

(ii) carbonate material selected from the group consisting of limestone, calcium magnesium carbonate, and mixtures thereof; and

(iii) sulphate material selected from the group consisting of gypsum, bassanite, anhydrite, and mixtures thereof,

wherein the weight ratio of the calcined clay material to the carbonate material is 1.5:1 to 2.1:1.

2. The cementitious composition of claim 1, wherein the marine clay material contains at least 25 wt% kaolinite.

3. The cementitious composition of claim 1 or 2, wherein the marine clay material contains 25 wt% to 35 wt% kaolinite.

4. The cementitious composition of any one of claims 1 to 3, wherein the calcined clay material is produced by heating the marine clay material at a maximum temperature of about 900 °C.

5. The cementitious composition of any one of claims 1 to 4, wherein the calcined clay material is produced from heating the marine clay material at a rate of 5 °C to 15 °C per minute up to the maximum temperature, and the maximum temperature is maintained for at least 1 hour.

6. The cementitious composition of any one of claims 1 to 5, wherein the calcined clay material is produced from heating the marine clay material at a rate of about 10 °C per minute up to the maximum temperature, and the maximum temperature is maintained for at least 1 hour.

7. The cementitious composition of any one of claims 1 to 6, wherein the maximum temperature is maintained for at least 2 hours.

8. The cementitious composition of any one of claims 1 to 7, wherein the weight ratio of the calcined clay material to the carbonate material is 2:1 to 2.1:1.

9. The cementitious composition of any one of claims 1 to 8, wherein the weight ratio of the calcined clay material to the carbonate material is about 2.067:1.

10. The cementitious composition of any one of claims 1 to 9, wherein the weight ratio of the calcined clay material to the sulphate material is 7:1 to 8:1.

11. The cementitious composition of any one of claims 1 to 10, wherein the weight ratio of the calcined clay material to the sulphate material is about 7.75:1.

12. The cementitious composition of any one of claims 1 to 11, wherein the sulphate material is present in the range of 1 wt% to 10 wt% by dry weight based on the total dry weight of supplementary cementitious material.

13. The cementitious composition of any one of claims 1 to 12, wherein the supplementary cementitious material in an amount from 5 wt% to 30 wt% by dry weight based on the total dry weight of the cementitious composition.

14. The cementitious composition of any one of claims 1 to 13, wherein the carbonate material is limestone.

15. The cementitious composition of any one of claims 1 to 14, wherein the sulphate material is gypsum.

16. The cementitious composition of any one of claims 1 to 15, wherein the calcined clay material contains 24 wt% to 33 wt% metakaolin.

17. A cementitious composition, comprising:

(a) Portland cement clinker in an amount of from 70 wt% to 80 wt% by dry weight based on the total dry weight of the cementitious composition; and

(b) supplementary cementitious material in an amount from 20 wt% to 30 wt% by dry weight based on the total dry weight of the cementitious composition,

wherein the supplementary cementitious material comprises:

(i) calcined clay material produced from heating a marine clay material at a maximum temperature of 700 °C to 900 °C, whereby the heating converts the kaolinite in the marine clay material to metakaolin, wherein the marine clay material contains 25 wt% to 35 wt% kaolinite;

(ii) limestone; and

(iii) gypsum,

wherein the weight ratio of the calcined clay material to the limestone is 2:1 to 2.1:1.

18. The cementitious composition of claim 17, wherein the calcined clay material contains 24 wt% to 33 wt% metakaolin.

19. A method of producing a cementitious composition, comprising:

(a) heating a marine clay material at a maximum temperature of 700 °C to 900 °C to form a calcined clay material;

(b) mixing the calcined clay material with a carbonate material selected from the group consisting of limestone, calcium magnesium carbonate, and mixtures thereof, and a sulphate material selected from the group consisting of gypsum, bassanite, anhydrite, and mixtures thereof to form a supplementary cementitious mixture;

(c) blending the supplementary cementitious mixture with Portland cement clinker,

wherein:

the Portland cement clinker is in an amount of from 70 wt% to 95 wt% by dry weight based on the total dry weight of the cementitious composition;

the supplementary cementitious material in an amount from 5 wt% to 30 wt% by dry weight based on the total dry weight of the cementitious composition;

the weight ratio of the calcined clay material to the carbonate material is 1.5:1 to 2.1:1.

20. The method of claim 19, wherein:

(i) step (a) is performed at a maximum temperature of 700 °C to 900 °C, wherein the marine clay material is heated at a rate of 5 °C to 15 °C per minute up to the maximum temperature, and the maximum temperature is maintained for at least 1 hour,

(ii) step (a) is performed at a maximum temperature of 700 °C to 900 °C, wherein the marine clay material is heated at a rate of about 10 °C per minute up to the maximum temperature, and the maximum temperature is maintained for at least 1 hour, or

(iii) step (a) is performed at a maximum temperature of 700 °C to 900 °C, wherein the marine clay material is heated at a rate of about 10 °C per minute up to the maximum temperature, and the maximum temperature is maintained for at least 2 hours.