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(54) **Title:** CEMENT COMPOSITIONS COMPRISING HIGH ALUMINA CEMENT AND CEMENT KILN DUST AND METHOD OF USING THEM

(57) **Abstract:** The present invention provides cement compositions that comprise water, high alumina cement, a soluble phosphate, and cement kiln dust. The cement compositions optionally may be foamed with a gas. Methods of cementing also are provided that comprise: providing the cement composition; introducing the cement composition into a location to be cemented; and allowing the cement composition to set therein. The location to be cemented may be above ground or in a subterranean formation.



WO 2007/048999 A1

**CEMENT COMPOSITIONS COMPRISING HIGH ALUMINA CEMENT AND
CEMENT KILN DUST AND METHOD OF USING THEM**

BACKGROUND

[0001] The present invention relates to cementing operations and, more particularly, to cement compositions comprising high alumina cement, a soluble phosphate, and cement kiln dust ("CKD"), and associated methods of use.

[0002] Cement compositions may be used in a variety of subterranean applications. An example of a subterranean application that utilizes cement compositions is primary cementing whereby pipe strings, such as casing and liners, are cemented in well bores. In performing primary cementing, a cement composition may be pumped into an annular space between the walls of a well bore and the exterior surface of the pipe string disposed therein. The cement composition sets in the annular space, thereby forming therein an annular sheath of hardened cement (*Le.*, a cement sheath) that supports and positions the pipe string in the well bore and bonds the exterior surface of the pipe string to the walls of the well bore. Cement compositions also may be used in remedial cementing operations, for example, to seal cracks or holes in pipe strings, to seal highly permeable zones or fractures in subterranean formations, and the like. Cement compositions also may be used in surface applications, for example, construction cementing.

[0003] Cement compositions used heretofore in subterranean applications commonly comprise Portland cement. Drawbacks may exist to using Portland cements in certain applications, however, because they are prone to corrosive attacks by carbonic acid. Other hydraulic cements also may be prone to corrosive attacks by carbonic acid. Carbonic acid may be naturally present in a subterranean formation, or it may be produced in the formation by the reaction of water and carbon dioxide when the latter is introduced into the formation, for example, during a carbon dioxide enhanced recovery operation. Carbonic acid is believed to react with calcium hydroxide that is produced by hydration of Portland cement potentially causing the deterioration of the set cement. This may be problematic, for example, because it may increase the permeability of the set cement. In some instances, the degradation of the set cement may cause loss of support for the casing and undesirable interzonal communication of fluids.

[0004] The susceptibility of some hydraulic cements (*e.g.*, Portland cement), to degradation by carbonic acid may be especially problematic in high temperature wells (*e.g.*, geothermal wells). The term "high temperature," as used herein, refers to wells having a static bottom hole temperature above about 200°F. Because the high static well bore temperatures involved often coupled with brines containing carbon dioxide, these hydraulic cements may rapidly deteriorate. In geothermal wells, which typically involve high temperatures, pressures, and carbon dioxide concentrations, set cement failures have occurred in less than five years causing the collapse of well casing.

[0005] It has heretofore been discovered that cement compositions comprising water, high alumina cement, and a soluble phosphate set to form a cement that exhibits improved carbon dioxide resistance when cured in hydrothermal environments as compared to previously used cement compositions comprising Portland cement. As used herein, the term "high alumina cement" refers to cement having an alumina concentration in the range of from about 40% to about 80% by weight of the high alumina cement. The high alumina cement generally is a major component of the cost for these cement compositions. To reduce the cost of such cements compositions, other components may be included in the cement composition in addition to, or in place of, the high alumina cement. Such components may include fly ash, shale, metakaolin, micro-fine cement, and the like. "Fly ash," as that term is used herein, refers to the residue from the combustion of powdered or ground coal, wherein the fly ash carried by the flue gases may be recovered, for example, by electrostatic precipitation.

[0006] During the manufacture of cement, a waste material commonly referred to as "CKD" is generated. "CKD," as that term is used herein, refers to a partially calcined kiln feed which is removed from the gas stream and collected in a dust collector during the manufacture of cement. Usually, large quantities of CKD are collected in the production of cement that are commonly disposed of as waste. Disposal of the waste CKD can add undesirable costs to the manufacture of the cement, as well as the environmental concerns and costs associated with its disposal. The chemical analysis of CKD from various cement manufactures varies depending on a number of factors, including the particular kiln feed, the efficiencies of the cement production operation, and the associated dust collection systems.

CKD generally may comprise a variety of oxides, such as SiO_2 , Al_2O_3 , Fe_2O_3 , $\text{CaO}_3\text{MgO}_5\text{SO}_3$, Na_2O_3 and K_2O .

SUMMARY

[0007] The present invention relates to cementing operations and, more particularly, to cement compositions comprising high alumina cement, a soluble phosphate, and CKD_3 and associated methods of use.

[0008] In one embodiment, the present invention provides a cement composition that comprises water, a high alumina cement, a soluble phosphate, and CKD.

[0009] Another embodiment of the present invention provides a cement composition that comprises water, calcium aluminate, sodium polyphosphate, and CKD.

[0010] Another embodiment of the present invention provides a foamed cement composition that comprises water, a high alumina cement, a soluble phosphate, CKD, a gas, and a surfactant.

[0011] In one embodiment, the present invention provides a method of cementing comprising: providing a cement composition that comprises water, a high alumina cement, a soluble phosphate, and CKD.

[0012] Another embodiment of the present invention provides a cement composition into a desired location; and allowing the cement composition to set in the desired location.

[0013] Another embodiment of the present invention provides a method of cementing comprising: providing a foamed cement composition that comprises water, a high alumina cement, a soluble phosphate, CKD_3 , a gas, and a surfactant; introducing the foamed cement composition into a desired location; and allowing the foamed cement composition to set in the desired location.

[0014] Another embodiment of the present invention provides a method of cementing comprising: providing a cement composition comprising water, calcium aluminate, sodium polyphosphate, and CKD; introducing the cement composition into a portion of a subterranean formation; and allowing the cement composition to set therein.

[0015] The features and advantages of the present invention will be apparent to those skilled in the art. While numerous changes may be made by those skilled in the art, such changes are within the spirit of the invention.

DESCRIPTION OF PREFERRED EMBODIMENTS

[0016] The present invention relates to cementing operations and, more particularly, to cement compositions comprising high alumina cement, a soluble phosphate, and CKD, and associated methods of use. While the cement compositions of the present invention may be useful in a variety of subterranean and surface applications, they may be particularly useful in primary and remedial cement operations. Furthermore, in certain embodiments, it is believed that the cement compositions of the present invention also may be useful applications where resistance to carbon dioxide is desired, for example, in high temperature wells (*e.g.*, geothermal wells).

[0017] A cement composition of the present invention generally comprises water, a high alumina cement, a soluble phosphate, and CKD. In some embodiments, a cement composition of the present invention may be foamed, for example, comprising water, a high alumina cement, a soluble phosphate, CKD, a gas, and a surfactant. A foamed cement composition may be used, for example, where it is desired for the cement composition to be lightweight. Other optional additives also may be included in the cement compositions of the present invention as desired, including, but not limited to, hydraulic cement, fly ash, shale, metakaolin, combinations thereof, and the like.

[0018] The cement compositions of the present invention should have a density suitable for a particular application as desired by those of ordinary skill in the art, with the benefit of this disclosure. In some embodiments, the cement compositions of the present invention may have a density in the range of from about 8 pounds per gallon ("ppg") to about 16 ppg. In the foamed embodiments, the foamed cement compositions of the present invention may have a density in the range of from about 8 ppg to about 13 ppg.

[0019] The water used in the cement compositions of the present invention may include freshwater, saltwater (*e.g.*, water containing one or more salts dissolved therein), brine

(*e.g.*, saturated saltwater produced from subterranean formations), seawater, or combinations thereof. Generally, the water may be from any source, provided that it does not contain an excess of compounds that may adversely affect other components in the cement composition. In some embodiments, the water may be included in an amount sufficient to form a pumpable slurry. In some embodiments, the water may be included in the cement compositions of the present invention in an amount in the range of from about 40% to about 200% by weight. As used herein, the term "by weight," when used herein to refer to the percent of a component in the cement composition, means by weight included in the cement compositions of the present invention relative to the weight of the dry components in the cement composition. In some embodiments, the water may be included in an amount in the range of from about 40% to about 150% by weight.

[0020] The cement compositions of the present invention further comprise a high alumina cement. In some embodiments, a high alumina cement that may be suitable for use comprises a calcium aluminate. The calcium aluminate may be any calcium aluminate suitable for use as a cement. A suitable calcium aluminate is SECAR[®] 60 calcium aluminate, commercially available from Lonstar Lafarge Company. Suitable examples of compositions comprising high alumina cements useful in subterranean cementing applications are described in United States Patent Nos. 5,900,053; 6,143,069; 6,244,343; 6,332,921; 6,488,763; 6,488,764; 6,796,378; 6,846,357; 6,835,243; and 6,904,971, the entire disclosures of which are incorporated herein by reference.

[0021] The high alumina cement may be included in the cement compositions of the present invention in an amount suitable for a particular application. In some embodiments, the high alumina cement may be present in the cement compositions of the present invention in an amount in the range of from about 20% to about 80% by weight. In some embodiments, the high alumina cement may be present in the cement compositions of the present invention in an amount in the range of from about 30% to about 70% by weight.

[0022] The cement compositions of the present invention further comprise a soluble phosphate. Among other things, it is believed that the soluble phosphate should react with the high alumina cement to form a set cement that may be resistant to carbon dioxide. For example, calcium aluminate should react with sodium polyphosphate to form a calcium

phosphate cement. Any type of soluble phosphate may be included in the cement compositions of the present invention, but not limited to, vitreous sodium phosphates, sodium hexametaphosphates, sodium polyphosphates, sodium dihydrogen phosphates, sodium monohydrogen phosphates, and combinations thereof. Other soluble alkali phosphates also may be suitable for use. A suitable soluble phosphate is commercially available from Astaris LLC, St. Louis, Missouri. In some embodiments, the soluble phosphate may be present in the cement compositions of the present invention in an amount in the range of from about 1% to about 20% by weight. In some embodiments, the soluble phosphate may be present in the cement compositions of the present invention in an amount in the range of from about 1% to about 10% by weight.

[0023] The cement compositions of the present invention further comprise CKD. The CKD should be included in the cement compositions in an amount sufficient to provide the desired compressive strength, density, and/or cost reduction. In some embodiments, the CKD may be present in the cement compositions of the present invention in an amount in the range of from about 5% to 80% by weight. In some embodiments, the CKD may be present in the cement compositions of the present invention in an amount in the range of from about 10% to about 50% by weight.

[0024] The cement compositions of the present invention may optionally comprise a hydraulic cement. A variety of hydraulic cements may be utilized in accordance with the present invention, including, but not limited to, those comprising calcium, aluminum, silicon, oxygen, iron, and/or sulfur, which set and harden by reaction with water. Suitable hydraulic cements include, but are not limited to, Portland cements, pozzolana cements, gypsum cements, slag cements, silica cements, and combinations thereof. In certain embodiments, the hydraulic cement may comprise a Portland cement. In some embodiments, the Portland cements that are suited for use in the present invention are classified as Classes A, C, H, and G cements according to American Petroleum Institute, *API Specification for Materials and Testing for Well Cements*, API Specification 10, Fifth Ed., July 1, 1990.

[0025] Where present, the hydraulic cement generally may be included in the cement compositions in an amount sufficient to provide the desired compressive strength, density, and/or cost. In some embodiments, the hydraulic cement may be present in the cement

compositions of the present invention in an amount in the range of from 1% to about 50% by weight. In some embodiments, the hydraulic cement may be present in the cement compositions of the present invention in an amount in the range of from about 5% to about 47.5% by weight.

[0026] In some embodiments, a pozzolana cement that may be suitable for use comprises fly ash. A variety of fly ashes may be suitable, including fly ash classified as Class C and Class F fly ash according to American Petroleum Institute, *API Specification for Materials and Testing for Well Cements*, API Specification 10, Fifth Ed., July 1, 1990. Class C fly ash comprises both silica and lime so that, when mixed with water, it sets to form a hardened mass. Class F fly ash generally does not contain sufficient lime, so an additional source of calcium ions is required for the Class F fly ash to form a cement composition with water. In some embodiments, lime may be mixed with Class F fly ash in an amount in the range of from about 0.1% to about 25% by weight of the fly ash. In some instances, the lime may be hydrated lime. Suitable examples of fly ash include, but are not limited to, POZMDC[®] A cement additive, commercially available from Halliburton Energy Services, Inc., Duncan, Oklahoma.

[0027] Where present, the fly ash generally may be included in the cement compositions in an amount sufficient to provide the desired compressive strength, density, and/or cost. In some embodiments, the fly ash may be present in the cement compositions of the present invention in an amount in the range of from about 5% to about 60% by weight. In some embodiments, the fly ash may be present in the cement compositions of the present invention in an amount in the range of from about 10% to about 50% by weight.

[0028] In certain embodiments, the cement compositions of the present invention further may comprise metakaolin. Generally, metakaolin is a white pozzolan that may be prepared by heating kaolin clay, for example, to temperatures in the range of from about 600°C to about 800°C. In some embodiments, the metakaolin may be present in the cement compositions of the present invention in an amount in the range of from about 5% to about 50% by weight. In some embodiments, the metakaolin may be present in an amount in the range of from about 10% to about 20% by weight.

[0029] In certain embodiments, the cement compositions of the present invention further may comprise shale. Among other things, shale included in the cement compositions

may react with excess lime to form a suitable cementing material, for example, calcium silicate hydrate. A variety of shales are suitable, including those comprising silicon, aluminum, calcium, and/or magnesium. An example of a suitable shale comprises vitrified shale. Suitable examples of vitrified shale include, but are not limited to, PRESSUR-SEAL[®] Fine LCM and PRESSUR-SEAL[®] Coarse LCM, which are commercially available from TXI Energy Services, Inc., Houston, Texas. Generally, the shale may have any particle size distribution as desired for a particular application. In certain embodiments, the shale may have a particle size distribution in the range of from about 37 micrometers to about 4,750 micrometers.

[0030] Where present, the shale may be included in the cement compositions of the present invention in an amount sufficient to provide the desired compressive strength, density, and/or cost. In some embodiments, the shale may be present in an amount in the range of from about 5% to about 75% by weight. In some embodiments, the shale may be present in an amount in the range of from about 10% to about 35% by weight. One of ordinary skill in the art, with the benefit of this disclosure, will recognize the appropriate amount of the shale to include for a chosen application.

[0031] In certain embodiments, the cement compositions of the present invention further may comprise a set retarding additive. As used herein, the term "set retarding additive" refers to an additive that retards the setting of the cement compositions of the present invention. Suitable set retarding additives may comprise water-soluble hydroxycarboxylic acids, synthetic retarders, lignosulfonates, and combinations thereof. In some embodiments, for example, in high temperature wells, water-soluble hydroxycarboxylic acids may be used alone or in combination with another set retarding additive. Examples of suitable water-soluble hydroxycarboxylic acids include, but are not limited to, gluconic acid, lactic acid, tartaric acid, citric acid, and combinations thereof. An example of a suitable water-soluble hydroxycarboxylic acid is HR[®]-25 retarder, commercially available from Halliburton Energy Services, Inc., Duncan, Oklahoma. Examples of suitable synthetic retarders, include, but are not limited to, copolymers of 2-acrylamido-2-methylpropane sulfonic acid and acrylic acid, and copolymers of 2-acrylamido-2-methylpropane sulfonic acid and maleic anhydride. Examples of suitable synthetic retarders are SCR[®]-100 retarder and SCR[®]-500 retarder, commercially available from Halliburton Energy Services, Duncan, Oklahoma. In some embodiments, the set

retarding additive may be present in an amount in the range of from about 0.1% to about 5% by weight.

[0032] Optionally, other additional additives may be added to the cement compositions of the present invention as deemed appropriate by one skilled in the art, with the benefit of this disclosure. Examples of such additives include, but are not limited to, accelerators, weight reducing additives, heavyweight additives, lost circulation materials, fluid loss control additives, dispersants, and combinations thereof. Suitable examples of these additives include crystalline silica compounds, amorphous silica, salts, fibers, hydratable clays, microspheres, pozzolan lime, latex cement, thixotropic additives, combinations thereof and the like.

[0033] An example of a cement composition of the present invention may comprise water, a high alumina cement, a soluble phosphate, and CKD. Another example of a cement composition of the present invention may comprise water, a high alumina cement, a soluble phosphate, CKD, and an additive comprising at least one of the following group: fly ash; shale; metakaolin; and combinations thereof. As desired by one of ordinary skill in the art, with the benefit of this disclosure, the cement compositions of the present invention further may comprise any of the above-listed additives, as well any of a variety of other additives suitable for use in subterranean applications.

[0034] As mentioned previously, in certain embodiments, the cement compositions of the present invention may be foamed with a gas. In some embodiments, foamed cement compositions of the present invention may comprise water, a high alumina cement, a soluble phosphate, CKD, a gas, and a surfactant. Other suitable additives, such as those discussed previously, also may be included in the foamed cement compositions of the present invention as desired by those of ordinary skill in the art, with the benefit of this disclosure.

[0035] The gas used in the foamed cement compositions of the present invention may be any gas suitable for foaming a cement composition, including, but not limited to, air, nitrogen, or combinations thereof. Generally, the gas should be present in the foamed cement compositions of the present invention in an amount sufficient to form the desired foam. In certain embodiments, the gas may be present in the foamed cement compositions of the present

invention in an amount in the range of from about 10% to about 80% by volume of the cement composition.

[0036] Where foamed, the cement compositions of the present invention further comprise a surfactant. In some embodiments, the surfactant comprises a foaming and stabilizing surfactant composition. As used herein, a "foaming and stabilizing surfactant composition" refers to a composition that comprises one or more surfactants and, among other things, may be used to facilitate the foaming of a cement composition and also may stabilize the resultant foamed cement composition formed therewith. Any suitable foaming and stabilizing surfactant composition may be used in the cement compositions of the present invention. Suitable foaming and stabilizing surfactant compositions may include, but are not limited to: mixtures of an ammonium salt of an alkyl ether sulfate, a cocoamidopropyl betaine surfactant, a cocoamidopropyl dimethylamine oxide surfactant, sodium chloride, and water; mixtures of an ammonium salt of an alkyl ether sulfate surfactant, a cocoamidopropyl hydroxysultaine surfactant, a cocoamidopropyl dimethylamine oxide surfactant, sodium chloride, and water; hydrolyzed keratin; mixtures of an ethoxylated alcohol ether sulfate surfactant, an alkyl or alkene amidopropyl betaine surfactant, and an alkyl or alkene dimethylamine oxide surfactant; aqueous solutions of an alpha-olefinic sulfonate surfactant and a betaine surfactant; and combinations thereof. In one certain embodiment, the foaming and stabilizing surfactant composition comprises a mixture of an ammonium salt of an alkyl ether sulfate, a cocoamidopropyl betaine surfactant, a cocoamidopropyl dimethylamine oxide surfactant, sodium chloride, and water. A suitable example of such a mixture is ZONESEAL[®] 2000 foaming additive, commercially available from Halliburton Energy Services, Inc., Duncan, Oklahoma. Suitable foaming and stabilizing surfactant compositions are described in United States Patent Nos. 6,797,054, 6,547,871, 6,367,550, 6,063,738, and 5,897,699, the entire disclosures of which are incorporated herein by reference.

[0037] Generally, the surfactant may be present in the foamed cement compositions of the present invention in an amount sufficient to provide a suitable foam. In some embodiments, the surfactant may be present in an amount in the range of from about 0.8% and about 5% by volume of the water ("bvow")-

[0038] The cement compositions of the present invention may be used in a variety of subterranean applications, including, but not limited to, primary cementing and remedial cementing operations. The cement compositions of the present invention also may be used in surface applications, for example, construction cementing.

[0039] An example of a method of the present invention comprises providing a cement composition of the present invention comprising water, a high alumina cement, a soluble phosphate, and CKD; placing the cement composition in a location to be cemented; and allowing the cement composition to set therein. In some embodiments, the location to be cemented may be above ground, for example, in construction cementing. In some embodiments, the location to be cemented may be in a subterranean formation, for example, in subterranean applications. In some embodiments, the cement compositions of the present invention may be foamed. As desired by one of ordinary skill in the art, with the benefit of this disclosure, the cement compositions of the present invention useful in this method further may comprise any of the above-listed additives, as well any of a variety of other additives suitable for use in subterranean applications.

[0040] Another example of a method of the present invention is a method of cementing in a subterranean formation. An example of such a method may comprise providing a cement composition of the present invention comprising water, a high alumina cement, a soluble phosphate, and CKD; introducing the cement composition into a portion of the subterranean formation; and allowing the cement composition to set therein. In some embodiments, the portion of the subterranean formation may be a high temperature subterranean formation. In some embodiments, the portion of the subterranean formation may have a temperature in the range of from about 200°F to about 800°F. In some embodiments, the portion of the subterranean formation may have a temperature in the range of from about 300°F to about 800°F. In some embodiments, the cement compositions of the present invention may be foamed. As desired by one of ordinary skill in the art, with the benefit of this disclosure, the cement compositions of the present invention useful in this method further may comprise any of the above-listed additives, as well any of a variety of other additives suitable for use in subterranean application.

[0041] To facilitate a better understanding of the present invention, the following examples of certain aspects of some embodiments are given. In no way should the following examples be read to limit, or define, the scope of the invention.

EXAMPLE 1

[0042] A series of sample cement compositions were prepared at room temperature and subjected to 72-hour compressive strength tests at 190⁰F in accordance with API Specification 10. Sample No. 1 was a comparative sample that did not comprise CKD.

[0043] The results of the compressive strength tests are set forth in the table below.

TABLE 1
Unfoamed Compressive Strength Tests

Sample	Density (ppg)	SECAR [®] 60 calcium aluminate (by wt)	CKD Class A (by wt)	POZMIX [®] A Cement Additive (by wt)	Soluble Phosphate ¹ (by wt)	Hydrated Lime (by wt)	HR [®] -25 Retarder (by wt)	Citric Acid (by wt)	72-Hour Compressive Strength at 190°F (psi)
No. 1	15.2	46.57	--	46.57	4.9	--	.98	.98	3,650
No. 2	13	46.57	46.57	--	4.9	--	.98	.98	734
No. 3	12.5	46.57	46.57	--	4.9	--	.98	.98	186.4
No. 4	13	46.57	23.29	23.29	4.9	--	.98	.98	Not Set
No. 5	12.97	46.57	19.61	23.29	4.9	3.67	.98	.98	158
No. 6	14.5	46.57	46.57	--	4.9	--	.98	.98	919

¹ The soluble phosphate included in the samples comprised sodium hexametaphosphate.

EXAMPLE 2

[0044] Sample Compositions No. 7 and No. 8 were prepared at room temperature and subjected to 72-hour compressive strength tests at 190°F in accordance with API Specification 10.

[0045] Sample Composition No. 7 was a comparative sample that did not comprise CKD. Sample Composition No. 7 comprised 46.57% by weight of SECAR® 60 calcium aluminate, 46.57% by weight of POZMIX® cement additive, 4.9% by weight of sodium hexametaphosphate, 0.9% by weight of HR®-25 retarder, 0.9% by weight of citric acid, and 2% bvow of ZONESEAL® 2000 foaming additive. Sample Composition No. 7 was foamed down to a density of about 12 ppg.

[0046] Sample Composition No. 8 comprised 46.57% by weight of SECAR® 60 calcium aluminate, 46.57% by weight of Class A CKD, 4.9% by weight of sodium hexametaphosphate, 0.9% by weight of HR®-25 retarder, 0.9% by weight of citric acid, and 2% bvow of ZONESEAL® 2000 foaming additive. Sample Composition No. 8 was foamed down to a density of about 12 ppg.

[0047] The results of the compressive strength tests are set forth in the table below.

TABLE 2
Foamed Compressive Strength Tests

Sample	Base Density (ppg)	Foam Density (ppg)	SECAR® 60 calcium aluminate (by weight)	CKD Class A (by weight)	POZMIX® A Cement Additive (by weight)	Soluble Phosphate ¹ (by weight)	72-Hour Compressive Strength at 190°F (psi)
No. 7	15.2	12	46.57	--	46.57	4.9	803
No. 8	13.05	12	46.57	46.57	--	4.9	34.5 ²
No. 8	13.05	12	46.57	46.57	--	4.9	140

¹ The soluble phosphate included in the samples comprised sodium hexametaphosphate.

² It is believed that this compressive strength test was terminated early due to the inadvertent shut off of the hot water bath.

[0048] Accordingly, the above examples indicate that foamed and imfoamed cement compositions comprising water, a high alumina cement, a soluble phosphate, and CKD may provide suitable compressive strengths for a particular application.

[0049] Therefore, the present invention is well adapted to attain the ends and advantages mentioned as well as those that are inherent therein. The particular embodiments disclosed above are illustrative only, as the present invention may be modified and practiced in different but equivalent manners apparent to those skilled in the art having the benefit of the teachings herein. Furthermore, no limitations are intended to the details of construction or design herein shown, other than as described in the claims below. It is therefore evident that the particular illustrative embodiments disclosed above may be altered or modified and all such variations are considered within the scope and spirit of the present invention. In particular, every range of values (of the form, "from about a to about b," or, equivalently, "from approximately a to b," or, equivalently, "from approximately a-b") disclosed herein is to be understood as referring to the power set (the set of all subsets) of the respective range of values, and set forth every range encompassed within the broader range of values. Also, the terms in the claims have their plain, ordinary meaning unless otherwise explicitly and clearly defined by the patentee.

CLAIMS:

1. A cement composition comprising:
water;
a high alumina cement;
a soluble phosphate; and
cement kiln dust.
2. The cement composition of claim 1 wherein the water comprises at least one of the following group: freshwater; saltwater; a brine; seawater; and combinations thereof.
3. The cement composition of claim 1 wherein the high alumina content cement comprises a calcium aluminate.
4. The cement composition of claim 1 wherein the high alumina content cement is present in the cement composition in an amount in the range of from about 20% to about 80% by weight.
5. The cement composition of claim 1 wherein the soluble phosphate comprises at least one of the following group: a vitreous sodium phosphate; a sodium hexametaphosphate; a sodium polyphosphate; a sodium dihydrogen phosphate; a sodium monohydrogen phosphate; and combinations thereof.
6. The cement composition of claim 1 wherein the soluble phosphate is present in the cement composition in an amount in the range of from about 1% to about 20% by weight.
7. The cement composition of claim 1 wherein the cement kiln dust is present in the cement composition in an amount of about 5% to 80% by weight.
8. The cement composition of claim 1 wherein the cement composition further comprises fly ash.
9. The cement composition of claim 8 wherein the cement composition further comprises a hydrated lime.

10. The cement composition of claim 1 wherein the cement composition further comprises at least one of the following group: hydraulic cement; fly ash; metakaolin; shale; and combinations thereof.

11. The cement composition of claim 1 wherein the cement composition further comprises vitrified shale.

12. The cement composition of claim 1 wherein the cement composition further comprises at least one of the following group: a set retarding additive; an accelerator; a weight reducing additive; a heavyweight additive; a lost circulation material; a fluid loss control additives; a dispersant; and combinations thereof.

13. The cement composition of claim 1 wherein the cement composition further comprises at least one of the following group: a crystalline silica compound; amorphous silica; a salt; a fiber; a hydratable clay; a microsphere; pozzolan lime; a latex cement; a thixotropic additive; and combinations thereof.

14. A cement composition comprising:
water;
calcium aluminate;
sodium polyphosphate; and
cement kiln dust.

15. The cement composition of claim 13:
wherein the calcium aluminate is present in the cement composition in an amount in the range of from about 20% to about 80% by weight;
wherein the sodium polyphosphate is present in the cement composition in an amount in the range of from about 1% to about 20% by weight; and
wherein the cement kiln dust is present in the cement composition in an amount of about 5% to 80% by weight.

16. A foamed cement composition comprising:
water;
a high alumina cement;

a soluble phosphate;
cement kiln dust;
a gas; and
a surfactant.

17. The foamed cement composition of claim 16 wherein the high alumina content cement comprises a calcium aluminate.

18. The foamed cement composition of claim 16 wherein the soluble phosphate comprises at least one of the following group: a vitreous sodium phosphate; a sodium hexametaphosphate; a sodium polyphosphate; a sodium dihydrogen phosphate; a sodium monohydrogen phosphate; and combinations thereof.

19. The foamed cement composition of claim 16:
wherein the high alumina content cement is present in the cement composition in an amount in the range of from about 20% to about 80% by weight;
wherein the soluble phosphate is present in the cement composition in an amount in the range of from about 1% to about 20% by weight; and
wherein the cement kiln dust is present in the cement composition in an amount of about 5% to 80% by weight.

20. The foamed cement composition of claim 16 wherein the gas comprises at least one of the following group: air; nitrogen; and combinations thereof.

21. The foamed cement composition of claim 16 wherein the surfactant comprises a foaming and stabilizing surfactant composition.

22. The foamed cement composition of claim 16 wherein the surfactant comprises at least one of the following group: a mixture of an ammonium salt of an alkyl ether sulfate, a cocoamidopropyl betaine surfactant, a cocoamidopropyl dimethylamine oxide surfactant, sodium chloride, and water; a mixture of an ammonium salt of an alkyl ether sulfate surfactant, a cocoamidopropyl hydroxysultaine surfactant, a cocoamidopropyl dimethylamine oxide surfactant, sodium chloride, and water; a hydrolyzed keratin; a mixture of an ethoxylated alcohol ether sulfate surfactant, an alkyl or alkene amidopropyl betaine surfactant, and an alkyl

or alkene dimethylamine oxide surfactant; an aqueous solution of an alpha-olefinic sulfonate surfactant and a betaine surfactant; and combinations thereof.

23. A method of cementing comprising:
providing a cement composition comprising water, a high alumina cement, a soluble phosphate, and cement kiln dust;
introducing the cement composition into a desired location; and
allowing the cement composition to set in the desired location.
24. The method of claim 23 wherein the water comprises at least one of the following group: freshwater; saltwater; a brine; seawater; and combinations thereof.
25. The method of claim 23 wherein the high alumina content cement comprises a calcium aluminate.
26. The method of claim 23 wherein the high alumina content cement is present in the cement composition in an amount in the range of from about 20% to about 80% by weight.
27. The method of claim 23 wherein the soluble phosphate comprises at least one of the following group: a vitreous sodium phosphate; a sodium hexametaphosphate; a sodium polyphosphate; a sodium dihydrogen phosphate; a sodium monohydrogen phosphate; and combinations thereof.
28. The method of claim 23 wherein the soluble phosphate is present in the cement composition in an amount in the range of from about 1% to about 20% by weight.
29. The method of claim 23 wherein the cement kiln dust is present in the cement composition in an amount of about 5% to 80% by weight.
30. The method of claim 23 wherein the cement composition further comprises fly ash.
31. The method of claim 30 wherein the cement composition further comprises a hydrated lime.

32. The method of claim 23 wherein the cement composition further comprises at least one of the following group: hydraulic cement; fly ash; metakaolin; shale; and combinations thereof.

33. The method of claim 23 wherein the cement composition further comprises vitrified shale.

34. The method of claim 23 wherein the cement composition further comprises at least one of the following group: a set retarding additive; an accelerator; a weight reducing additive; a heavyweight additive; a lost circulation material; a fluid loss control additives; a dispersant; and combinations thereof.

35. The method of claim 23 wherein the cement composition further comprises at least one of the following group: a crystalline silica compound; amorphous silica; a salt; a fiber; a hydratable clay; a microsphere; pozzolan lime; a latex cement; a thixotropic additive; and combinations thereof.

36. The method of claim 23 wherein the desired location is above ground or in a subterranean formation.

37. The method of claim 23 wherein the desired location is a high temperature well or a geothermal well.

38. A method of cementing comprising:
providing a foamed cement composition comprising water, a high alumina cement, a soluble phosphate, cement kiln dust, a gas, and a surfactant;
introducing the foamed cement composition into a desired location; and
allowing the foamed cement composition to set in the desired location.

39. The method of claim 38 wherein the high alumina content cement comprises a calcium aluminate.

40. The method of claim 38 wherein the soluble phosphate comprises at least one of the following group: a vitreous sodium phosphate; a sodium hexametaphosphate; a sodium polyphosphate; a sodium dihydrogen phosphate; a sodium monohydrogen phosphate; and combinations thereof.

41. The method of claim 38:
wherein the high alumina content cement is present in the cement composition in an amount in the range of from about 20% to about 80% by weight;
wherein the soluble phosphate is present in the cement composition in an amount in the range of from about 1% to about 20% by weight; and
wherein the cement kiln dust is present in the cement composition in an amount of about 5% to 80% by weight.
42. The method of claim 38 wherein the gas comprises at least one of the following group: air; nitrogen; and combinations thereof.
43. The method of claim 38 wherein the surfactant comprises a foaming and stabilizing surfactant composition.
44. The method of claim 38 wherein the surfactant comprises at least one of the following group: a mixture of an ammonium salt of an alkyl ether sulfate, a cocoamidopropyl betaine surfactant, a cocoamidopropyl dimethylamine oxide surfactant, sodium chloride, and water; a mixture of an ammonium salt of an alkyl ether sulfate surfactant, a cocoamidopropyl hydroxysultaine surfactant, a cocoamidopropyl dimethylamine oxide surfactant, sodium chloride, and water; a hydrolyzed keratin; a mixture of an ethoxylated alcohol ether sulfate surfactant, an alkyl or alkene amidopropyl betaine surfactant, and an alkyl or alkene dimethylamine oxide surfactant; an aqueous solution of an alpha-olefinic sulfonate surfactant and a betaine surfactant; and combinations thereof.
45. A method of cementing comprising:
providing a cement composition comprising water, calcium aluminate, sodium polyphosphate, and cement kiln dust;
introducing the cement composition into a portion of a subterranean formation; and
allowing the cement composition to set therein.
46. The method of claim 45:
wherein the calcium aluminate is present in the cement composition in an amount in the range of from about 20% to about 80% by weight;

wherein the sodium polyphosphate is present in the cement composition in an amount in the range of from about 1% to about 20% by weight; and

wherein the cement kiln dust is present in the cement composition in an amount of about 5% to 80% by weight.

INTERNATIONAL SEARCH REPORT

International Application No
PCT/GB2006/003730

A. CLASSIFICATION OF SUBJECT MATTER INV. C04B28/06 C04B22/16 C09K8/467		
According to International Patent Classification (IPC) or to both national classification and IPC		
B. FIELDS SEARCHED Minimum documentation searched (classification system followed by classification symbols) C04B C09K		
Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched		
Electronic data base consulted during the international search (name of data base and, where practical, search terms used) EPO-Internal , WPI Data		
C. DOCUMENTS CONSIDERED TO BE RELEVANT		
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<input type="checkbox"/> Further documents are listed in the continuation of Box C		
<input checked="" type="checkbox"/> See patent family annex		
* Special categories of cited documents		
"A" document defining the general state of the art which is not considered to be of particular relevance "E" earlier document but published on or after the international filing date "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified) "O" document referring to an oral disclosure, use, exhibition or other means "P" document published prior to the international filing date but later than the priority date claimed	"T" later document published after the International filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention "X" document of particular relevance, the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone "Y" document of particular relevance, the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art "&" document member of the same patent family	
Date of the actual completion of the International search	Date of mailing of the international search report	
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