Abstract: High strength, corrosion resistant, low greenhouse gas emission concrete compositions include a geopolymer-based concrete compound and a slag-based concrete compound. The geopolymer component includes a relatively large amount of amorphous silica and is mixed with an aggregate compound such as granite, limestone or sand. The geopolymer based concrete compound can be manufactured by an environmentally friendly process that involves alkali activation of the amorphous silica and thus minimizes the need for lime, which typically involves limestone combustion. The slag-based concrete compound includes slag and an aggregate including limestone, granite and/or sand. The slag-based concrete compound also can include an activator for raising the pH of the compound. Example activators include waterglass and Natron.
Published:
— without international search report and to be republished upon receipt of that report
COMPOSITIONS OF AND METHODS FOR GENERATING CONCRETE COMPOUNDS

CROSS REFERENCE TO RELATED APPLICATIONS

[0001] The present application claims priority to U.S. Provisional Patent Application No. 60/829,629, entitled "COMPOSITIONS AND METHODS FOR MANUFACTURING GEOPOLYMERIC CONCRETE," filed October 16, 2006, which is hereby incorporated by reference in its entirety.

TECHNICAL FIELD

[0002] The technical field is generally related to compositions of concrete and manufacturing concrete. The technical field is more specifically related to alkali-activated concrete and low-greenhouse gas emission earth concrete.

BACKGROUND

[0003] Portland cement has long been an industry standard and is the most common type of cement in general usage. Portland cement is manufactured by sintering raw materials,
primarily limestone, at 1450° C. The hydraulic mixture of lime and clay hardens and sets with the addition of water. Portland cement compositions are subject to corrosion and require long setting times. In addition, large amounts of lime are required to make such cements, which requires significant infrastructure for production and results in undesirable greenhouse gas emissions.

[0004] For each ton of ordinary Portland cement based concrete created, approximately one ton of greenhouse gas is added to the atmosphere. This greenhouse gas is primarily composed of Carbon Dioxide. The creation of greenhouse gas is due to the fuel composition when heating the raw materials to high temperatures as well as to chemical changes that take place during this heating.

SUMMARY

[0005] This Summary is provided to introduce a selection of concepts in a simplified form. This Summary is not intended to be used to limit the scope of the claimed subject matter.

[0006] Novel concrete compounds as described herein are inexpensive to produce, exhibit high strength, are corrosion resistant, and minimize environmental harm during formulation. The concrete compounds do not need to undergo high temperature processing and can set at room temperature, thus minimizing or eliminating the consumption of fuel during its manufacture.

[0007] In a first example configuration, the composition comprises an alkali-activated material made by reaction of amorphous silica with an alkali. The alkali-activated material is subsequently mixed with an aggregate to form a concrete material labeled Earth Concrete. To manufacture the high strength, corrosion resistant concrete compound, amorphous silica is reacted with an alkali and mixed with an aggregate and cured to form the concrete composition. This composition has the advantage that it may be manufactured by an environmentally friendly process that uses an alkali initiator and eliminates or minimizes the need for limestone combustion to produce the lime needed to make many current commercial concrete materials.
The Earth Concrete sets at room temperature and achieves high early strengths. The Earth Concrete does not adhere to steel, cardboard, plastic, or wood. The Earth Concrete is fluid enough to fill complex molds with ease. The Earth Concrete shrinks slightly during setting, which acts as a natural mold release. Thus, due to its fluidity, ability to shrink slightly during setting, and its aversion to sticking to steel, cardboard, plastic, and wood, Earth Concrete is capable of filling complex molds and providing perfect replicas.

[0008] In a second example configuration, a concrete-like substance uses simple, naturally available materials in combination with waste products (e.g., blast furnace slag) from the ore processing industries. This new substance, referred to herein as Slag Concrete, is simple to manufacture and results in the emission of 10% or less of the amount of greenhouse gases that would be emitted by a similar quantity of Portland cement-based concrete. Various embodiments of the Slag Concrete formula comprise additives introduced during mixing. Example additives include silica, clay, and aluminum oxide containing powders. The additives change the ratios of silicon or aluminum to other elements. Additionally, salts or acids can be added as plasticizers. The Slag Concrete sets at room temperature and achieves high early strengths. The Slag Concrete does not adhere to steel, cardboard, plastic, or wood. The Slag Concrete is fluid enough to fill complex molds with ease. The Slag Concrete shrinks slightly during setting, which acts as a natural mold release. Thus, due to its fluidity, ability to shrink slightly during setting, and its aversion to sticking to steel, cardboard, plastic, and wood, Slag Concrete is capable of filling complex molds and providing perfect replicas.

BRIEF DESCRIPTION OF THE DRAWINGS

[0009] The foregoing summary, as well as the following detailed description, is better understood when read in conjunction with the appended drawings.

[0010] Figure 1 is an illustration of an example alkali-activated concrete compound.

[0011] Figure 2 is a flow diagram of an example process for making a alkali-activated concrete composition.
[0012] Figure 3 is a graph illustrating the compressive strengths of various alkali-activated concrete samples having different amounts of aggregate.

[0013] Figure 4 is a graph illustrating the compressive strengths of various alkali-activated concrete samples prepared using different curing times.

[0014] Figure 5 is a graph illustrating compressive strengths of various alkali-activated concrete samples having varying amounts of sodium hydroxide.

[0015] Figure 6 is a graph illustrating compressive strengths of various alkali-activated concrete samples that were cured at 90° C, prior to, and after soaking in water.

[0016] Figure 7 is another graph illustrating compressive strengths of various alkali-activated concrete samples that were cured at 90° C, prior to, and after soaking in water.

[0017] Figure 8 is yet another graph illustrating compressive strengths of various alkali-activated concrete samples that were cured at 90° C, prior to, and after soaking in water.

[0018] Figure 9 too is a graph illustrating compressive strengths of various alkali-activated concrete samples that were cured at 90° C, prior to, and after soaking in water.

[0019] Figure 10 illustrates compressive strength versus strain for various alkali-activated concrete samples.

[0020] Figure 11 an illustration of an example slag-based concrete compound.

[0021] Figure 12 is a flow diagram of an example process for making a slag-based concrete compound.
DETAILED DESCRIPTION OF ILLUSTRATIVE EMBODIMENTS

Akali Activated Concrete Composition

[0022] In a first example embodiment, a concrete compound comprises a alkali-activated concrete composition that exhibits high strength, corrosion resistance, thermal resistance and durability. In various embodiments, the concrete compositions include at least one aggregate and at least one alkali-activated component. These compositions have properties that are at least comparable to standard concrete compositions based on Portland concrete that are typically used for residential and commercial construction projects.

[0023] As illustrated in Figure 1, the alkali-activated concrete compound comprises three components: an alkali-activated component, an aggregate component, and a liquid component, such as water. The aggregate component can comprise any inert granular material including sand, granite, limestone, other minerals such as carbonates, including barium and magnesium carbonates, and mixtures thereof, for example. The aggregate can be fine or coarse granular material or any combination thereof. Example particle sizes of aggregate can range from approximately 50 µm to 10 cm in size. In an example configuration, larger particle sizes are utilized in order to minimize the surface area of the aggregate material. The compressive strength of the concrete compound generally increases with the particle size of the aggregate. In example configuration, the aggregate has particle sizes on the order of 1-8 mm to 1-8 cm.

[0024] The aggregate can constitute any appropriate portion of the concrete compound. In an example configuration, the aggregate constitutes about 40-95% by volume of the concrete compound. In another example configuration, the aggregate constitutes 50-85% by volume of the concrete compound. In yet another example configuration, the aggregate constitutes 60-80% by volume of the concrete compound. In an example embodiment, the aggregate comprises limestone and constitutes about 60-80% by volume of the concrete material. By preheating the aggregate or ensuring that sufficient heat is imparted to the aggregate/alkali-activated mixture during mixing, it is possible to increase the percent by volume of aggregate that can be used in the concrete material. In an example configuration, the aggregate comprises carbonate material...
such as calcium carbonate, barium carbonate and magnesium carbonate (MgCO₃). In another example configuration, the aggregate comprises limestone.

[0025] The alkali-activated composition contains, in an example composition, amorphous silica, alkali, and water. The amorphous silica can be obtained in the form of, for example, amorphous diatomaceous earth and/or fumed silica. The amorphous silica makes up about 20 to about 50 weight percent of the components of the alkali-activated composition. In another example configuration, the amorphous silica makes up about 25 - 45 weight percent of the components of the alkali-activated composition. In yet another example configuration, the amorphous silica makes up about 30 - 40 weight percent of the components of the alkali-activated composition. In comparison to the expensive and complex preparations necessary for other geopolymers that use as a main reactant, aluminosilicate clay and amorphous silica fumes, and contain only about 5-10% by weight of amorphous silica, the herein described alkali-activated concrete compound contains significantly more amorphous silica.

[0026] Figure 2 is a flow diagram of an example process for making a alkali-activated concrete composition. At step 12, a high pH alkali solution is prepared. The alkali solution is composed of at least one alkali material in an aqueous solution. The high-pH solution can comprise any appropriate material. For example, a high-pH material that can be used for the high-pH solution is Natron. Various configurations of Natron comprise Soda Ash (Na₂CO₃) or Sodium Carbonate-Soda Ash and Water (Na₂CO₃ 10 H₂O). Natron also can comprise various amounts of sodium chloride and/or sodium sulfate. In an example configuration, the pH of the aqueous solution is at least 11.5. The pH can be slightly decreased if the amount of heat used in the reaction to form the alkali-activated component is increased. In another example configuration, the alkali solution has a pH of at least about 12.

[0027] The alkali material can be selected from alkali metal salts, alkaline earth metal salts, or mixtures thereof. In an example embodiment, the cation is selected from sodium, potassium, calcium, and ammonium. In one example embodiment, the alkali material is sodium hydroxide. Sodium hydroxide is inexpensive, has low volatility, and is a strong base. In various
configurations, the mole ratio of monovalent alkali metal cation to amorphous silica is from about 0.5 - 2.0, from about 0.7 - 1.4, or, from about 0.8 - 1.1.

[0028] In another example embodiment, the alkali material additionally includes one or more alkaline earth metal salts, such as calcium salts, for example, calcium oxide (lime). It has been found that the addition of alkaline earth metal ions to the alkali-activated component minimizes the tendency of the concrete material to dissolve in water. In such an embodiment, about one mole of divalent alkaline earth metal cation can be used for every 2 - 8 total moles of silica and alumina used to make the alkali-activated component. In an example configuration, about one mole of divalent alkaline earth metal cation is employed for each 3 - 6 total moles of silica and alumina. In an example embodiment, the alkali-activated concrete composition contains at least 90 percent by weight of calcium, oxygen, silicon, carbon, and hydrogen.

[0029] When the alkali-activated material contains both monovalent and divalent cationic materials, an aqueous solution of the monovalent cation-containing salts is first made, and this aqueous solution is reacted with the amorphous silica. A second aqueous solution of the divalent cation-containing salts is prepared and added to the resultant alkali-activated material after the reaction between the monovalent alkali material and the amorphous silica, but prior to addition of the aggregate. At step 14, once the alkali-activated component is formed, the aggregate is added to the composition with thorough mixing and the composition is cured to form a concrete composition.

[0030] The alkali-activated component of the concrete compound advantageously has a high tolerance for the inclusion of other materials therein. For example, the alkali-activated component can be combined with optional additives such as aluminosilicate clays, such as metakaolinite (Al₂O₃(SiO₂)₂). The aluminosilicate clays have been found to be useful to prevent dissolution of alkali-activated components in the aqueous solutions. Thus, in an example embodiment, sufficient aluminosilicate is employed to provide sufficient alumina to prevent dissolution of alkali-activated components in the aqueous solution. In an example configuration, aluminosilicate clays constitute no more than about 15 weight percent of the alkali-activated components, no more than about 10 weight percent of the alkali-activated components, or, no
more than about 8 weight percent of the alkali-activated components. The amount of aluminosilicate clay employed will depend upon the amount of alumina present in the particular clay employed.

[0031] The alkali-activated concrete composition has a good compressive strength and superior corrosion resistance and thermal stability in comparison to Portland cement-based concretes. The alkali-activated concrete compositions exhibit compressive strengths of about 15-43 MPa. The physical properties of the alkali-activated concrete composition are comparable to medium strength Portland cement-based concretes. In all other respects, the alkali-activated concrete composition is mechanically comparable to commercially available cement-based concretes. Because of the alkali-activated concrete composition’s superior corrosion resistance and thermal stability, the alkali-activated concrete composition may require less maintenance, repair, and/or less frequent replacement than currently available Portland cement-based concretes.

[0032] The resultant alkali-activated concrete compositions can be used for various applications including, but not limited to, roadways, bridges, sidewalks, walls, docks, and building foundations; ancillary products, including but not limited to blast barriers, bollards, and highway dividers; objects of art, including but not limited to statues, sculptures, monuments, and tombstones; consumer products, including but not limited to garden and landscaping products, countertops, and large-gauge jewelry; and/or any application for which Portland cement is used.

[0033] An aspect of the herein described alkali-activated concrete composition is utilizing an effective amount of alkali initiator to activate the amorphous silica, in comparison to standard means for concrete production which require heat-treatment, high purities of reactants, or long reaction periods that may persist for days, the present method eliminates any need for large batch curing in excess water or curing in general by utilizing an alkali initiator. For some applications, however, a modest curing regime for short periods of time may be employed to initiate the reaction to form the alkali-activated component.
In one example embodiment, only naturally occurring reactants are utilized to prepare the alkali-activated concrete composition, simplifying manufacturing and minimizing environmental greenhouse emissions. Standard methods for producing cement often employ large amounts of lime, produced by burning limestone (CaCO$_3$), which releases carbon dioxide (CO$_2$) into the atmosphere in addition to other gases created by the consumption of fuel during the burning process itself. Because lime (CaO) and metakaolinite are not major components of the alkali-activated concrete compositions, the attendant release of harmful greenhouse gases is minimized. Additionally, the above described method of preparing the alkali-activated concrete composition is inexpensive and does not involve specialized or complex processing. The alkali-activated concrete composition can be formed using a simple mixer and may optionally be cured at relatively low temperatures of room temperature (20° C) to about 90° C. Further, the alkali-activated concrete composition is composed of naturally abundant materials available worldwide, that are substantially less expensive than other materials frequently used to make geopolymers. This simple manufacturing process facilitates inexpensive, large-scale production and may be particularly practical for rural or developing areas lacking the facilities and infrastructure required for the calcination of limestone required in standard concrete production.

An example formulation, the alkali-activated concrete composition comprises 105 g of diatomaceous earth, 140 g of water (2 batches of 70 g each for preparing separate aqueous solutions of NaOH and CaO), 23.5 g of lime (CaO), 60 g of sodium hydroxide (NaOH), 25 g of metakaolinite, and 800 grams of limestone aggregate. In various formulations, the alkali-activated concrete composition provides a compressive strength, after soaking in water, as high as 29.8 MPa.

Figure 3 is a graph illustrating the compressive strengths of various alkali-activated concrete samples having different amounts of aggregate. The samples depicted in Figure 2 comprised a 1:1 molar ratio of sodium hydroxide and water amorphous diatomaceous earth and sand. A sample comprising 20% sand by volume exhibited a compressive strength of slightly above 10 MPa. A sample comprising 40% sand by volume exhibited a compressive strength of approximately 24 MPa. A sample comprising 60% sand by volume exhibited a
compressive strength of approximately 15 MPa. A sample comprising 80% sand by volume exhibited a compressive strength of approximately 12 MPa.

[0037] Figure 4 is a graph illustrating the compressive strengths of various alkali-activated concrete samples prepared using different curing times. The samples comprise a 1:1 molar ratio of sodium hydroxide and water, amorphous diatomaceous earth and about 40% by volume of sand. A sample cured for two hours exhibited a compressive strength of about 13.5 MPa. A sample cured for three hours exhibited a compressive strength of about 19 MPa. A sample cured for four hours exhibited a compressive strength of about 30 MPa. A sample cured for five hours exhibited a compressive strength of about 32 MPa. A sample cured for six hours exhibited a compressive strength of about 34 MPa.

[0038] Figure 5 is a graph illustrating compressive strengths of various alkali-activated concrete samples having varying amounts of sodium hydroxide. They samples comprise sodium hydroxide, water, amorphous diatomaceous earth, and about 40% by volume of sand. A sample comprising 0.9 moles of sodium hydroxide exhibited the compressive strength of approximately 42 MPa. A sample comprising 1.0 moles of sodium hydroxide exhibited a compressive strength of approximately 37 MPa. A sample comprising 1.1 moles of sodium hydroxide exhibited a compressive strength of approximately 29 MPa.

[0039] Figure 6 is a graph illustrating compressive strengths of various alkali-activated concrete samples that were cured at 90° C., prior to, and after soaking in water. As depicted in Figure 6, samples that were not soaked in water are labeled as pre-soaked, and samples that were soaked in water are labeled a post-soaked. The samples were made using the above example composition, i.e., 105 g of diatomaceous earth, 140 g of water (2 batches of 70 g each for preparing separate aqueous solutions of NaOH and CaO), 23.5 g of lime (CaO), 63.5 g of sodium hydroxide (NaOH), and 800 grams of limestone aggregate. No metakaolinite was used. As depicted in Figure 6, the darker shaded bars on the graph are indicative of samples that were post-soaked, and the lighter shaded bars on the graph indicate samples that were pre-soaked. Pre-soaked samples that were cured for two hours exhibited a compressive strength of approximately 14 MPa, and post soaked samples that were cure for two hours exhibited a
compressive strength of approximately 3 MPa. Pre-soaked samples that were cured for six hours exhibited a compressive strength of approximately 17 MPa, and post soaked samples that were cure for six hours exhibited a compressive strength of approximately 22 MPa. Pre-soaked samples that were cured for 24 hours exhibited a compressive strength of approximately 21 MPa, and post soaked samples that were cure for 24 hours exhibited a compressive strength of approximately 22 MPa. Pre-soaked samples that were cured for 48 hours exhibited a compressive strength of approximately 25 MPa, and post soaked samples that were cure for 48 hours exhibited a compressive strength of approximately 17 MPa.

[0040] Figure 7 is a graph illustrating compressive strengths of various alkali-activated concrete samples that were cured at 90° C, prior to, and after soaking in water. As depicted in Figure 7, samples that were not soaked in water are labeled as pre-soaked, and samples that were soaked in water are labeled a post-soaked. The samples were made using the example composition of Figure 6, with the exception that 53 grams of sodium hydroxide was used instead of 60 grams of sodium hydroxide. Thus, the composition used for Figure 7 was 105 g of diatomaceous earth, 140 g of water (2 batches of 70g each for preparing separate aqueous solutions of NaOH and CaO), 23.5 g of lime (CaO), 50 g of sodium hydroxide (NaOH), 25 g of metakaolinite, and 800 grams of limestone aggregate. As depicted in Figure 7, the darker shaded bars on the graph are indicative of samples that were post-soaked, and the lighter shaded bars on the graph indicate samples that were pre-soaked. Pre-soaked samples that were cured for two hours exhibited a compressive strength of approximately 10 MPa, and post soaked samples that were cure for two hours exhibited a compressive strength of approximately 14 MPa. Pre-soaked samples that were cured for six hours exhibited a compressive strength of approximately 18 MPa, and post soaked samples that were cure for six hours exhibited a compressive strength of approximately 20 MPa. Pre-soaked samples that were cured for 24 hours exhibited a compressive strength of approximately 21 MPa, and post soaked samples that were cure for 24 hours exhibited a compressive strength of approximately 16 MPa. Pre-soaked samples that were cured for 48 hours exhibited a compressive strength of approximately 22 MPa, and post soaked samples that were cure for 48 hours exhibited a compressive strength of approximately 17 MPa.
Figure 8 is a graph illustrating compressive strengths of various alkali-activated concrete samples that were cured at 90° C, prior to, and after soaking in water. As depicted in Figure 8, samples that were not soaked in water are labeled as pre-soaked, and samples that were soaked in water are labeled a post-soaked. The samples were made using the example composition of Figure 6 with the exception that metakaolin was used. Thus, the composition used for Figure 8 was 105 g of diatomaceous earth, 140 g of water (2 batches of 70g each for preparing separate aqueous solutions of NaOH and CaO), 23.5 g of lime (CaO), 63 g of sodium hydroxide (NaOH), 25 g of metakaolinite, and 800 grams of limestone aggregate. As depicted in Figure 8, the darker shaded bars on the graph are indicative of samples that were post-soaked, and the lighter shaded bars on the graph indicate samples that were pre-soaked. Pre-soaked samples that were cured for two hours exhibited a compressive strength of approximately 7.5 MPa, and post soaked samples that were cure for two hours exhibited a compressive strength of approximately 7 MPa. Pre-soaked samples that were cured for six hours exhibited a compressive strength of approximately 10 MPa, and post soaked samples that were cured for six hours exhibited a compressive strength of approximately 11.5 MPa. Pre-soaked samples that were cured for 24 hours exhibited a compressive strength of approximately 24 MPa, and post soaked samples that were cure for 24 hours exhibited a compressive strength of approximately 12.5 MPa. Pre-soaked samples that were cured for 48 hours exhibited a compressive strength of approximately 17.5 MPa, and post soaked samples that were cure for 48 hours exhibited a compressive strength of approximately 15 MPa.

Figure 9 is a graph illustrating compressive strengths of various alkali-activated concrete samples that were cured at 90° C, prior to, and after soaking in water. As depicted in Figure 9, samples that were not soaked in water are labeled as pre-soaked, and samples that were soaked in water are labeled a post-soaked. The samples were made using the example composition of Figure 8, with the exception that metakaolinite also was used, i.e., 105 g of diatomaceous earth, 140 g of water (2 batches of 70g each for preparing separate aqueous solutions of NaOH and CaO), 23.5 g of lime (CaO), 50 g of sodium hydroxide (NaOH), 25 g of metakaolinite, and 800 grams of limestone aggregate. As depicted in Figure 9, the darker shaded bars on the graph are indicative of samples that were post-soaked, and the lighter shaded bars on
the graph indicate samples that were pre-soaked. Pre-soaked samples that were cured for two hours exhibited a compressive strength of approximately 17 MPa, and post soaked samples that were cured for two hours exhibited a compressive strength of approximately 18 MPa. Pre-soaked samples that were cured for six hours exhibited a compressive strength of approximately 18 MPa, and post soaked samples that were cured for six hours exhibited a compressive strength of approximately 28 MPa. Pre-soaked samples that were cured for 24 hours exhibited a compressive strength of approximately 18 MPa, and post soaked samples that were cured for 24 hours exhibited a compressive strength of approximately 22 MPa. Pre-soaked samples that were cured for 48 hours exhibited a compressive strength of approximately 24.5 MPa, and post soaked samples that were cured for 48 hours exhibited a compressive strength of approximately 20 MPa.

[0043] Figure 10 illustrates compressive strength versus strain for various alkali-activated concrete samples. Graph 20 and graph 22 shows compressive strength versus strain for an example composition comprising 1.00 moles Silicon Dioxide (SiO₂), 1.10 moles Sodium Hydroxide (NaOH), 1.65 moles Water (H₂O), 0.20 moles Calcium Carbonate (CaCO₃), and 40% by volume sand. Graph 20 illustrates compressive strength versus strain for a sample cured for 4 hours and 70° C. Graph 22 illustrates compressive strength versus strain for a sample cured for 24 hours and 24° C.

**Slag-Based Concrete** Composition

[0044] In a second example configuration, as illustrated in Figure 11, a concrete compound comprises a waste product (e.g., slag) from any of the ore processing industries, an aggregate and a liquid. This slag-based concrete compound, referred to herein as Slag Concrete, is also alkali-activated. It is simple to manufacture and results in the emission of 10% or less of the amount of greenhouse gases that would be emitted by a similar quantity of Portland cement-based concrete. Various embodiments of the slag-based concrete compound comprise additives introduced during mixing. Example additives include silica, clay, and aluminum containing powders. The additives change the ratios of silicon or aluminum to other elements. Additionally, salts or acids can be added as plasticizers. The slag-based concrete compound sets at room temperature and achieves high early strengths. The slag-based concrete compound does
not adhere to steel, cardboard, plastic, or wood. The slag-based concrete compound shrinks slightly during setting, which acts as a natural mold release.

[0045] In an example embodiment, formulation of the slag-based concrete compound comprises activating aluminosilicate minerals with a high-pH solution. In this example embodiment, the slag-based concrete compound comprises slag, a by-product of the pre refining process, and crushed limestone aggregate. The slag component can comprise any appropriate slag compound. For example, the slag component can comprise slag resulting from ferrous and/or non-ferrous smelting processes. The slag component can comprise calcium, magnesium, aluminum, or a combination thereof.

[0046] The aggregate component can comprise any appropriate aggregate. In example embodiments, the aggregate component comprises limestone, granite (e.g., powdered granite), sand, or a combination thereof.

[0047] The liquid component can comprise any appropriate liquid component, such as water for example. The liquid component can have combined therewith a high-pH activator to form a high-pH solution. In an example embodiment, high-pH is a pH greater than or equal to 14. In another example embodiment, high-pH is a pH greater than or equal to 10. The high-pH solution can comprise any appropriate material. Example materials that can be used for the high-pH solution include a waterglass (Sodium Silicate) and Sodium Hydroxide (NaOH) solution, and a waterglass and Potassium Hydroxide (KOH) solution. In another example embodiment, the high-pH material comprises Natron. Various configurations of Natron comprise Soda Ash (Na₂CO₃) or Sodium Carbonate-Soda Ash and Water (Na₂CO₃ 10 H₂O). Natron also can comprise various amounts of sodium chloride and/or sodium sulfate.

[0048] Figure 12 is a flow diagram of an example process for making a slag-based alkali-activated concrete compound. Slag is mixed with aggregate at step 24. As described above the slag can comprise any appropriate slag, such as slag resulting from ferrous and/or non-ferrous smelting processes. The aggregate can comprise any appropriate aggregate, such as limestone, granite, sand, or a combination thereof. Liquid is added to the mixture of slag and
aggregate at step 24. In an example embodiment, the liquid comprises a high-pH activator such as, waterglass or Natron solution. In an example embodiment, the compound comprising the combination of the mixture and liquid is cured at room temperature at step 28. The reaction will occur at any temperature above the freezing temperature of water. The reaction occurs more quickly at warmer temperatures. Thus, the compound does not require curing above room temperature. Curing at room temperature implies that no external heating is required. In an example embodiment, room temperature comprises a temperature ranging from about 0°C (32°F) to about 23°C (73°F).

[0049] In an example formulation, the slag-based concrete composition comprises 480 g of limestone, 400 g of slag, and 144 g of waterglass. This formulation has exhibits a compressive strength of 70 MPa. In another example formulation, the slag-based concrete composition comprises 480 g of limestone, 400 g of slag, 124.8 g of water, 144 g of waterglass, and 41.6 g of Sodium Hydroxide (NaOH). In another example formation comprising no waterglass, the slag-based concrete composition comprises 480 g of limestone, 400 g of slag, 32 g of Natron, and 124.8 g of water. In another example formation comprising no waterglass, the slag-based concrete composition comprises 480 g of limestone, 400 g of slag, 32 g of Natron, 100 g of water, and 35 g of diatomaceous earth.

[0050] While illustrative embodiments have various figures, it is to be understood that other similar embodiments can be used or modifications and additions can be made to the described embodiments of alkali-activated and/or slag-based concrete compositions without deviating therefrom. Therefore, alkali-activated Earth or Slag concrete compositions should not be limited to any single embodiment, but rather should be construed in breadth and scope in accordance with the appended claims.
What is Claimed:

1. An alkali-activated concrete composition comprising at least one alkali-activated component and at least one aggregate, wherein the alkali-activated component comprises 20 to 50 percent by weight of amorphous silica.

2. The composition in accordance with claim 1, wherein said amorphous silica comprises amorphous diatomaceous earth.

3. The composition in accordance with claim 1, wherein the aggregate comprises limestone.

4. The composition in accordance with claim 1, wherein said aggregate comprises at least one of sand, granite, limestone, carbonates, or aluminosilicate.

5. The composition in accordance with claim 1, further comprising an amount of an aluminosilicate clay to prevent dissolution of the alkali-activated component in a water.

6. The composition in accordance with claim 1, wherein:

   the aggregate comprises limestone;

   the amorphous silica comprises diatomaceous earth; and

   the composition comprises at least 90 percent by weight of calcium, oxygen, silicon, carbon, and hydrogen.

7. The composition in accordance with claim 1, further comprising an amount of a divalent cation to prevent dissolution of the concrete composition in water.
8. A method for generating an alkali-activated concrete composition comprising:

reacting amorphous silica with an alkali in a high pH aqueous solution to form an alkali-activated component;

mixing the formed alkali-activated component with an aggregate to form a mixture; and

curing the mixture, wherein the amorphous silica comprises 20 to 50 percent by weight of components employed to make the alkali-activated component.

9. A method in accordance with claim 8, further comprising adding an amount of a divalent cation to the alkali-activated component, prior to addition of the aggregate, to prevent dissolution of the alkali-activated concrete in water.

10. The method in accordance with claim 8, wherein the amorphous silica comprises diatomaceous earth.

11. The method in accordance with claim 8, wherein aluminosilicate clay is also reacted with the alkali to form the alkali-activated component.

12. The method in accordance with claim 8, wherein the aggregate comprises limestone.

13. The method in accordance with claim 8, wherein:

the amorphous silica comprises diatomaceous earth;

the high pH aqueous solution is obtained by using lime;

and the aggregate comprises limestone.

14. The method in accordance with claim 8, wherein:
the amorphous silica comprises diatomaceous earth; the high pH aqueous solution is obtained by using Natron; and the aggregate comprises limestone.

15. An alkali-activated component slag-based concrete composition comprising:
   a first component comprising alkali-activated slag; and
   a second component comprising an aggregate.

16. The composition in accordance with claim 15, wherein the aggregate comprises limestone.

17. The composition in accordance with claim 15, wherein the aggregate comprises powdered granite.

18. The composition in accordance with claim 15, wherein the aggregate comprises sand.

19. The composition in accordance with claim 15, further comprising waterglass.

20. The composition in accordance with claim 15, further comprising Natron.

21. A method for making an alkali-activated slag based concrete composition comprising:
   mixing an alkali-activated slag component with an aggregate to form a mixture;
   combining a liquid component with the mixture; and
   curing the mixture at temperature in a range of about 18° C to about 23° C.
22. The method in accordance with claim 21, wherein the aggregate comprises limestone.

23. The method in accordance with claim 21, wherein the aggregate comprises one of powdered granite or sand.

24. The method in accordance with claim 21, further comprising combining waterglass with the mixture to form the mixture.

25. The method in accordance with claim 21, further comprising combining Natron with the mixture to form the mixture.
Water + Aggregate + Alkali Activated Component = Concrete Compound

FIGURE 1
FIGURE 2

React Amorphous Silica With An Alkali in High pH Aqueous Solution To Form Alkali Activated Component

Mix Resultant Alkali Activated Component With Aggregate

Cure Mixture

12

14

16
Concrete Compound = Slag + Aggregate + Liquid/High-pH

FIGURE 11