concrete mix is sufficiently workable for its intended use, and the carbonated wash water is of an age that the same mix made with the wash water of the same age in the same proportions would not be sufficiently workable for its intended use. In certain embodiments, the mix water comprises carbonated wash water in an amount that results in a concrete mix that is at least 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 12, 15, 20, 25, 30, 40, or 50%, for example 5%, stronger at a time after pouring—e.g., 1 day, 7 days, 28 days, or any combination thereof--than the same concrete mix made without carbonated wash water. In certain embodiments, the mix water comprises carbonated wash water in an amount that allows the concrete mix to contain at least 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 22, 25, 30, 40, or 50%, for example at least 5%, less cement than, and retain a compressive strength after pouring of within 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 12, 15, 20, 25, 30, 40, or 50%, for example at least 5%, of the same concrete mix made without carbonated wash water and with the extra (normal mix) percentage cement.

[0005] In another aspect, the invention provides apparatus.

[0005a] In another aspect, the invention provides an apparatus for carbonating wash water produced in the production of concrete in a wash water operation wherein the wash water comprises cement and/or supplementary cementitious materials (SCM), comprising (i) a source of carbon dioxide; (ii) a first conduit operably connected to the source of carbon dioxide that runs to a wash water container, a carbonation loop, or both, wherein (a) the wash water container contains wash water from a concrete production site; (b) the conduit is configured to deliver carbon dioxide to the wash water in the container, the wash water in the carbonation loop, or both, to produce carbonated wash water, and (c) the conduit comprises one or more actuators to adjust the flow of carbon dioxide to the wash water in the container, the wash water in the carbonation loop, or both; (iii) a system to transport the carbonated wash water to a concrete mix operation where the carbonated wash water is used as mix water in a concrete mix; and (iv) a control system comprising at least two sensors configured to send information connected to a controller, wherein the controller is configured to process the information from the sensors and to modulate carbon dioxide flow by sending a signal to the one or more actuators based on the information, wherein the sensors are configured to monitor at least two of (a) pH of the wash water, (b) rate of delivery of carbon dioxide to the wash water, (c) total amount of wash water in the wash water container, (d) temperature of the wash water, (e) specific gravity of the wash water, (f) concentration of one or more ions in the wash water, (g) age of the wash water, (h) circulation rate of the wash water, (i) timing of circulation of the wash water, (j) appearance of bubbles at surface of the wash water, (k) carbon dioxide concentration of the air above the wash water, (l) electrical conductivity of the wash water, (m) optical characteristics of the wash water.

[0006] In certain embodiments, the invention provides an apparatus for carbonating wash water produced in the production of concrete in a wash water operation wherein the wash water comprises cement and/or supplementary cementitious materials (SCM), comprising (i) a source of carbon dioxide; (ii) a first conduit operably connected to the source of carbon dioxide that runs to a wash water container, wherein (a) the wash water container contains wash water from a concrete production site; (b) the conduit has one or more openings positioned to deliver carbon dioxide at or under the surface of the wash water in the container to produce carbonated wash water; (iii) a system to transport the carbonated wash water to a concrete mix operation where the carbonated wash water is used as mix water in a concrete mix. The apparatus can further include (iv) a controller that determines whether or not, and/or how, to modify delivery of carbon dioxide to the wash water, or another characteristic of the wash water operation, or both, based on the one or more characteristics of the wash water or wash water operation. The characteristic can be, e.g., at least one, at least two, at least three, at least four, at least five, or at least six, of pH of the wash water, rate of delivery of carbon dioxide to the wash water, total amount of wash water in the wash water container, temperature of the wash water, specific gravity of the wash water, concentration of one or

CLAIMS

What is claimed is

1. An apparatus for carbonating wash water produced in the production of concrete in a wash water operation wherein the wash water comprises cement and/or supplementary cementitious materials (SCM), comprising

(i) a source of carbon dioxide;

(ii) a first conduit operably connected to the source of carbon dioxide that runs to a wash water container, a carbonation loop, or both, wherein

(a) the wash water container contains wash water from a concrete production site;

(b) the conduit is configured to deliver carbon dioxide to the wash water in the container, the wash water in the carbonation loop, or both, to produce carbonated wash water, and

(c) the conduit comprises one or more actuators to adjust the flow of carbon dioxide to the wash water in the container, the wash water in the carbonation loop, or both;

(iii) a system to transport the carbonated wash water to a concrete mix operation where the carbonated wash water is used as mix water in a concrete mix; and

(iv) a control system comprising at least two sensors configured to send information connected to a controller, wherein the controller is configured to process the information from the sensors and to modulate carbon dioxide flow by sending a signal to the one or more actuators based on the information, wherein the sensors are configured to monitor at least two of

(a) pH of the wash water,

(b) rate of delivery of carbon dioxide to the wash water,

(c) total amount of wash water in the wash water container,

(d) temperature of the wash water,

(e) specific gravity of the wash water,

(f) concentration of one or more ions in the wash water,

(g) age of the wash water,

(h) circulation rate of the wash water,

(i) timing of circulation of the wash water,

(j) appearance of bubbles at surface of the wash water,

(k) carbon dioxide concentration of the air above the wash water,

(l) electrical conductivity of the wash water,

(m) optical characteristics of the wash water.

2. The apparatus of claim 1 wherein the controller comprises at least three sensors, wherein the sensors are configured to monitor at least three of

(a) pH of the wash water,

(b) rate of delivery of carbon dioxide to the wash water,

(c) total amount of wash water in the wash water container,

(d) temperature of the wash water,

(e) specific gravity of the wash water,

(f) concentration of one or more ions in the wash water,

(g) age of the wash water,

(h) circulation rate of the wash water,

(i) timing of circulation of the wash water,

(j) appearance of bubbles at surface of the wash water,

(k) carbon dioxide concentration of the air above the wash water,

(l) electrical conductivity of the wash water,

(m) optical characteristics of the wash water.

3. The apparatus of claim 1 wherein the controller comprises at least four sensors, wherein the sensors are configured to monitor at least four of

(a) pH of the wash water,

(b) rate of delivery of carbon dioxide to the wash water,

(c) total amount of wash water in the wash water container,

(d) temperature of the wash water,

(e) specific gravity of the wash water,

(f) concentration of one or more ions in the wash water,

(g) age of the wash water,

(h) circulation rate of the wash water,

(i) timing of circulation of the wash water,

(j) appearance of bubbles at surface of the wash water,

(k) carbon dioxide concentration of the air above the wash water,

(l) electrical conductivity of the wash water,

(m) optical characteristics of the wash water.

4. The apparatus of claim 1 wherein the controller comprises at least five sensors, wherein the sensors are configured to monitor at least five of

(a) pH of the wash water,

(b) rate of delivery of carbon dioxide to the wash water,

(c) total amount of wash water in the wash water container,

(d) temperature of the wash water,

(e) specific gravity of the wash water,

(f) concentration of one or more ions in the wash water,

(g) age of the wash water,

(h) circulation rate of the wash water,

(i) timing of circulation of the wash water,

(j) appearance of bubbles at surface of the wash water,

(k) carbon dioxide concentration of the air above the wash water,

(l) electrical conductivity of the wash water,

(m) optical characteristics of the wash water.

5. The apparatus of claim 1 wherein the controller comprises at least six sensors, wherein the sensors are configured to monitor at least six of

(a) pH of the wash water,

(b) rate of delivery of carbon dioxide to the wash water,

(c) total amount of wash water in the wash water container,

(d) temperature of the wash water,

(e) specific gravity of the wash water,

(f) concentration of one or more ions in the wash water,

(g) age of the wash water,

(h) circulation rate of the wash water,

(i) timing of circulation of the wash water,

(j) appearance of bubbles at surface of the wash water,

(k) carbon dioxide concentration of the air above the wash water,

(l) electrical conductivity of the wash water,

(m) optical characteristics of the wash water.

6. The apparatus of claim 1 wherein the controller comprises at least seven sensors, wherein the sensors are configured to monitor at least seven of

(a) pH of the wash water,

(b) rate of delivery of carbon dioxide to the wash water,

(c) total amount of wash water in the wash water container,

(d) temperature of the wash water,

(e) specific gravity of the wash water,

(f) concentration of one or more ions in the wash water,

(g) age of the wash water,

(h) circulation rate of the wash water,

(i) timing of circulation of the wash water,

(j) appearance of bubbles at surface of the wash water,

(k) carbon dioxide concentration of the air above the wash water,

(l) electrical conductivity of the wash water,

(m) optical characteristics of the wash water.

7. The apparatus of claim 1 wherein the controller comprises two sensors, wherein the sensors are configured to monitor specific gravity of the wash water and temperature of the wash water.

8. The apparatus of claim 7 wherein the controller further comprises a sensor configured to monitor total amount of wash water in the container.

9. The apparatus of claim 8 wherein the controller further comprises a sensor configured to monitor rate of delivery of carbon dioxide to the wash water.

10. The apparatus of claim 7 wherein the controller further comprises a sensor configured to monitor rate of delivery of carbon dioxide to the wash water.

11. The apparatus of claim 7 wherein the controller further comprises a sensor configured to monitor circulation rate of the wash water.

12. The apparatus of claim 1 wherein the first conduit runs to a carbonation loop and is configured to deliver carbon dioxide to the wash water in the carbonation loop to produce carbonated wash water.

13. The apparatus of claim 12 wherein the controller comprises two sensors, wherein the sensors are configured to monitor specific gravity of the wash water and temperature of the wash water.

14. The apparatus of claim 13 wherein the controller further comprises a sensor configured to monitor total amount of wash water in the container.

15. The apparatus of claim 13 wherein the controller further comprises a sensor configured to monitor rate of delivery of carbon dioxide to the wash water.

16. The apparatus of claim 12 wherein the controller further comprises a sensor configured to monitor rate of delivery of carbon dioxide to the wash water.

17. The apparatus of claim 12 wherein the controller further comprises a sensor configured to monitor circulation rate of the wash water.