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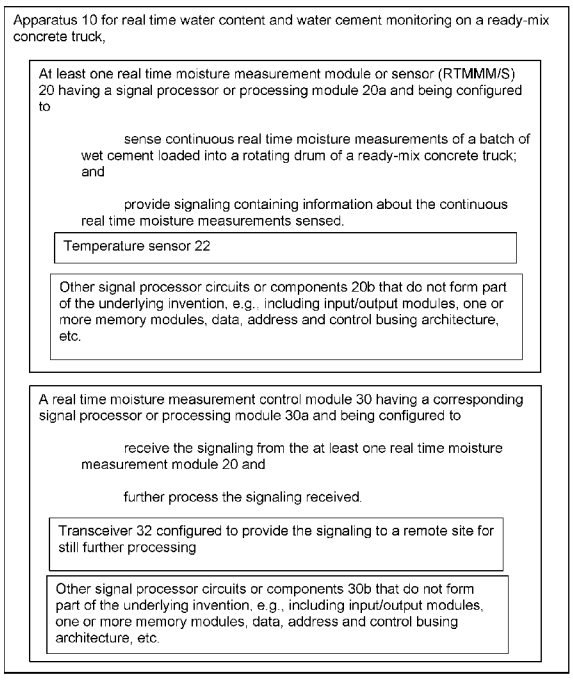

Figure 1: The Apparatus 10

(57) **Abstract:** Apparatus for real time water content and water cement monitoring on a ready-mix concrete truck includes at least one real time moisture measurement module or sensor configured to sense continuous real time moisture measurements of a batch of wet cement loaded into a rotating drum of a ready-mix concrete truck; and provide signaling containing information about the continuous real time moisture measurements sensed. The apparatus may include either a hatch door of the rotating drum of the ready-mix concrete truck, or the rotating drum of the ready-mix concrete truck, or the ready-mix concrete truck itself.

WO 2022/040123 A1

REAL TIME WATER CONTENT AND WATER-CEMENT MONITORING ON A READY-MIX CONCRETE TRUCK

CROSS-REFERENCE TO RELATED APPLICATIONS

This application claims benefit to provisional patent application serial no. 63/066,431 (712-2.467//CCS-0216) filed on 17 August 2020, which is hereby incorporated by reference in their entirety.

This application is related to US Patent no. 10,156,547 (WFMB no. 712-002.365-1-1 (CCS-0075, 67, 104)), which corresponds to PCT/US2012/060822, filed 18 October 2012, claiming benefit to provisional patent application serial nos. 61/548,549 and serial no. 61/548,563, both filed 18 October 2011, which are all incorporated by reference in their entirety.

This application is related to patent application no. 16/638,258 (WFMB no. 712-002.451-1-1 (CCS-0143)), which corresponds to PCT/US2018/047429, filed 22 August 2018, claiming benefit to provisional patent application serial nos. 62/548,638 and 62/548,699, both filed on 22 August 2017, which are all incorporated by reference in their entirety.

This application is related to patent application no. 16/638,237 (WFMB no. 712-002.452-1-1 (CCS-0200)), which corresponds to PCT/US2018/047479, filed 22 August 2018, claiming benefit to provisional patent application serial nos. 62/548,699 and 62/548,712, both filed on 22 August 2017; which are all incorporated by reference in their entirety.

The aforementioned applications were all assigned to the assignee of the present application, which builds on this family of technology.

BACKGROUND OF THE INVENTION

1. Field of Invention

This invention relates to a technique for real time water content and water cement monitoring on a ready-mix concrete truck.

2. Description of Related Art

U.S. Patent no. 10,156,547 (WFMB no. 712-2.365-1-1 (CCS-0075, 67, 104)), assigned to the assignee of the present invention, discloses a technique for measuring entrained air in wet concrete loaded in a rotating drum of a ready-mix concrete truck, which is known in the industry as, AIRtrac™ sensor or AIRtrac Mobile™. The AIRtrac™ sensor may be permanently installed on the rotating container/concrete mixer drum or on the hatch door of a concrete mixer drum. The AIRtrac™ sensor includes an acoustic-based air probe that has an acoustic source that provides an acoustic signal into a mixture of concrete, and an acoustic receiver substantially co-planar with the acoustic source that responds to the acoustic signal, and provides signaling containing information about the acoustic signal injected into the mixture of concrete, which is further processed to determine the air content of the mixture of concrete. The AIRtrac™ sensor does not sensor or measure real time moisture or water content in the wet cement.

Moisture level, and in particular water cement ratio, is a critical parameter that affects the quality of concrete. Excess water in concrete will result in higher porosity, lower strength, and lower durability. Low water cement ratio can also be detrimental to the final concrete strength and can cause difficulty placing and properly consolidating the concrete. If the water to cement ratio is kept below a certain value, the strength of the concrete can be guaranteed to meet specification.

Because of this, there is a need in the industry for measuring and monitoring real time water content in a batch of cement in a ready-mix concrete truck.

SUMMARY OF THE INVENTION

In summary, the present invention provides a new technique for using real time measurement of physical and electrical properties to determine the moisture content of concrete on a ready-mix concrete truck. The innovation of the present invention is the application of real time moisture measurements to a mobile ready-mix concrete truck. The moisture content when combined with the batch weight of cement can be used to calculate the water-cement ratio. Even without knowing the batch weight of cement, just monitoring the moisture content of fresh concrete on a ready-mix truck is advantageous because it allows a remote quality control person to know if and when water is added to the load.

Electrical impedance measurements of a medium are currently used to measure water content in various field including soil analysis, mining, and concrete plants. Frequency/Time domain reflectometry, complex impedance, and conductivity measurements have all been shown to be an accurate indication of water content in fresh and hydrating concrete with various technical tradeoffs.

Electrical conductivity and complex electrical impedance as a function of frequency can be used to determine the water content of fresh concrete. The present invention extends that measurement specifically to be used on a ready mix concrete truck to monitor the water content of fresh concrete from the moment of batching all the way to the job site pour.

The present invention provides for electrical impedance measurement that can be adapted into a hardened sensor element such as the assignee's

Smarthatch™ so that moisture level in fresh concrete is monitored continuously from the time concrete is first loaded into the drum at the batch plant until it is finally discharged at the job site. The novelty of the idea is that with the present invention the concrete producer would have the ability to know when water was added. The concrete producer would also be able to calculate how much water was added. Ultimately, the water/cement ratio could be calculated using the measured moisture level, and the total weight of cementitious material determined from the batching system.

Previously, the water/cement ratio has been calculated using a tracking system, that solely relies on the amount of water and cementitious material added initially to the concrete at the batch plant, and any subsequent water added to the truck before the final pour. This calculation has a number of error sources which include the amount of moisture absorbed by the aggregate as well as any evaporation that has occurred before the concrete was poured. True water/cement ratio is the ratio of the free water and the amount of cementitious material, as this most accurately describes the glue that holds concrete together and exhibits the properties described earlier. The only accurate way to know the true water content is a direct real-time measurement as the amount of water absorbed by aggregate and the evaporative amount can vary widely from a number of factors. The techniques described herein will not be subject to these errors due to the direct moisture measurement technique.

Hot days – combination of outside temperature and the increased temperature due to the chemical reaction within the concrete.

Temperature can be used to monitor changes in the water content. Water that's added to a batch of concrete is rarely at the same temperature as the concrete

itself. Monitor average temperature of concrete, when water is added the concrete temperature changes rapidly (different from the slow increase in temperature cause by the hydration process). If the amount of concrete and the temperature of the water added is known, then the amount of water added can be determined by the heat capacity and thermal mass of the concrete.

Moisture is measured at multiple points during the rotation of the drum. By knowing the orientation of the drum simultaneously with the moisture measurement measurements while the moisture sensor is out of the concrete can be ignored, and the multiple measurements while the sensor is in the concrete can be averaged to form a more accurate determination of the entire load. Multiple averages over multiple rotations can be combined to further refine the moisture measurement.

A further benefit is that the variability of individual measurements for each rotation and aggregated over multiple rotation can be used to determine the homogeneity of the mix.

The real time moisture measurement over time from the batch plant to the job site can be used in several ways. The initial reading of moisture shortly after loading the truck can be used to validate the batching system expected water content. This initial reading of moisture content along with information about the amount of cement batched sets a starting point to monitor the water cement ratio in real time. The moisture reading and the entrance angle can be used before batching to measure the amount of water left in the drum – this can be used to pre-adjust the water add during batching. After the initial reading, the real-time moisture measurement is an indication of several critical factors. When no additional water is added, the state of hydration is monitored. The slow downward trend of the moisture indicates that hydration is taking place and the concrete is aging. An upward spike in the real-time

water content measurement is an indication that water has been added to the mix. This could be from the onboard water tanks on the truck but could also be from another unknown source such as the job site. Integration of the water content over time can be used to quantify the amount of water added.

The present invention utilizes the use of a real-time impedance measurement to determine the moisture content and calculation of cement/water ratio in ready-mix concrete as this currently represents the most practical approach for this measurement. However, various other methods could be used as a substitute for the real-time moisture measurement including nuclear high energy particle a

Specific Embodiment

In its broadest sense, the present invention provides new and unique apparatus for real time water content and water cement monitoring on a ready-mix concrete truck, which may include, or take the form of:

at least one real time moisture measurement module or sensor configured to:

sense continuous real time moisture measurements of a batch of wet cement loaded into a rotating drum of a ready-mix concrete truck; and

provide signaling containing information about the continuous real time moisture measurements sensed.

The apparatus may include one or more of the following features:

The real time moisture measurement module or sensor may be mounted on a hatch door of the rotating container or a wall of the drum, as well as other parts of the rotating container or drum.

The at least one real time moisture measurement module or sensor may be configured as, or forms part of, at least one hardened sensor element arranged in or on the hatch door, or on the wall of the rotating drum, to sense the continuous real time moisture measurements.

The continuous real time moisture measurements may include:

an initial real time moisture measurement of the batch of wet cement loaded into the rotating drum of the ready-mix concrete truck; and

subsequent real time moisture measurements sensed after the initial real time moisture measurement of the batch of wet cement in the rotating drum, including as the ready-mix concrete truck travels from a patch plant to a pour site, or as the ready-mix concrete truck sits at the pour site.

The continuous real time moisture measurements may be measured using a real time impedance measurement technique. Alternatively, the continuous real time moisture measurements may be measured using a real time nuclear high energy particle absorption measurement technique or a near infrared optical reflectance measurement technique.

The apparatus may include a real time moisture measurement control module configured to receive the signaling sensed from the at least one real time moisture measurement module or sensor and further processing the signaling received.

The real time moisture measurement control module may be arranged in some part of the ready-mix truck, including its cab, or at a remote site for operating by a remote quality control person.

The real time moisture measurement control module may include a transceiver configured to provide the signaling from the ready-mix truck to the

remote site for still further processing, e.g., by the remote quality control person. The signaling may also be sent via the Internet, e.g., using a WIFI network.

The real time moisture measurement control module may be configured to determine if and when water was added to the batch of wet cement in the rotating drum, e.g., based upon the continuous real time moisture measurements received.

The real time moisture measurement control module may be configured to determine an amount of water added to the batch of wet cement in the rotating drum, e.g., based upon the continuous real time moisture measurements received.

The real time moisture measurement control module may be configured to receive associated signaling containing information about a known total weight of cementitious material of the batch of wet cement in the rotating drum; and determine a water/cement ratio using a real time moisture level measurement and the known total weight of cementitious material of the batch of wet cement in the rotating drum, e.g., based upon the continuous real time moisture measurements received.

The real time moisture measurement control module may be configured to determine and monitor changes in the real time water content of the batch of wet cement using a temperature-based technique.

The real time moisture measurement control module may be configured to receive associated signaling containing information about a known amount of cement added and a known temperature of the water added and determine a heat capacity and a thermal mass of the batch of wet cement using the temperature-based technique based upon the associated signaling received.

The real time moisture measurement module or sensor may include a temperature sensor configured to determine the temperature of the batch of wet cement in the rotating drum.

The at least one real time moisture measurement module or sensor may include multiple real time moisture measurement modules arranged at multiple points in the rotating drum; and each of the real time moisture measurement modules may be configured to

sense corresponding continuous real time moisture measurements of the batch of wet cement at the multiple points of the ready-mix concrete truck; and

provide corresponding signaling containing information about the corresponding continuous real time moisture measurements sensed.

The real time moisture measurement control module may be configured to average the corresponding continuous real time moisture measurements determined of the batch of wet cement at the multiple points in the rotating drum.

The real time moisture measurement control module may be configured to average the corresponding continuous real time moisture measurements determined at the multiple points over multiple rotations of the rotating drum, and provide an averaged corresponding continuous real time moisture measurement for further processing.

The real time moisture measurement control module may be configured to determine a homogeneity of the batch of wet cement based upon the averaged corresponding continuous real time moisture measurement.

The continuous real time measurements may include an initial real time moisture measurement sensed after loading the batch of wet cement into the rotating drum of the ready-mix concrete truck; and the real time moisture measurement control module may be configured to receive associated signaling containing information about an expected water content of after the batch of wet cement is

loaded into the rotating drum of the ready-mix concrete truck, and validate the expected water content based upon a comparison of the expected water content received and the initial real time moisture measurement.

The real time moisture measurement control module may be configured to receive associated signaling containing information about additional water added to the batch of cement loaded into the rotating drum and monitor a state of hydration of the batch of cement based upon the associated signaling received.

The associated signaling may contain information about no additional water being added to the batch of cement loaded into the rotating drum; and the real time moisture measurement control module may be configured to receive the continuous real time moisture measurements and determine a downward trend of real moisture content of the batch of cement, e.g., based upon the continuous real time moisture measurements received.

The real time moisture measurement control module may be configured to receive the continuous real time moisture measurements and determine an upward spike of real moisture content of the batch of cement, which indicates that water has been added to the batch of cement, e.g., based upon the continuous real time moisture measurements received.

According to some embodiments, the apparatus may include, or take the form of, the hatch door of the rotating drum of the ready-mix concrete truck.

According to some embodiments, the apparatus may include, or take the form of, the rotating drum of the ready-mix concrete truck.

According to some embodiments, the apparatus may include, or take the form of, the ready-mix concrete truck.

The Method

According to some embodiments, the present invention may take the form of a method for real time water content and water cement monitoring on a ready-mix concrete truck, featuring:

sensing with at least one real time moisture measurement module or sensor continuous real time moisture measurements of a batch of wet cement loaded into a rotating drum of a ready-mix concrete truck; and

providing with the at least one real time moisture measurement module or sensor signaling containing information about the continuous real time moisture measurements sensed.

The method may also include one or more of the features set forth above and herein.

BRIEF DESCRIPTION OF THE DRAWING

The drawing includes Figures 1 - 4, which are not necessarily drawn to scale, as follows:

Figure 1 is a block diagram of apparatus having a sensor and a signal processor or signal processing module for implementing the present invention.

Figure 2 shows a ready-mix truck with an arrow pointing to a hatch door indicating a potential location of a real time moisture measurement module or sensor (RTMMM/S) installation.

Figure 3 shows a hatch door with a real time moisture measurement module or sensor (RTMMM/S) installed.

Figure 4 shows the mounting of a real time moisture measurement module or sensor (RTMMM/S) on an interior surface of a mixing drum wall.

DETAILED DESCRIPTION OF BEST MODE OF THE INVENTION

Figure 1: The Apparatus 10

Figure 1 shows apparatus 10 for real time water content and water cement monitoring on a ready-mix concrete truck (Fig. 2) that may include at least one real time moisture measurement module or sensor 20, as well as a real time moisture measurement control module 30.

The Real Time Moisture Measurement Module or Sensor 20

By way of example, the real time moisture measurement module or sensor 20 may form part of the rotating drum of the ready-mix concrete truck that is loaded with the batch of wet cement having an amount of water and cementitious material, e.g., consistent with that shown in Figures 2-4. For example, the real time moisture measurement module or sensor 20 may be arranged in or on a hatch door (Fig. 3) of the rotating drum, arranged on the drum wall inside the rotating drum, as well as mounted in or on other parts of the rotating container or drum, or some combination thereof. The real time moisture measurement module or sensor 20 may be configured as, or forms part of, at least one hardened sensor element arranged in or on the hatch door or on the rotating drum to sense the continuous real time moisture measurements, e.g., consistent with that shown in Figure 4.

For example, the real time moisture measurement module or sensor 20 may be configured to:

sense continuous real time moisture measurements of a batch of wet cement loaded into a rotating drum of a ready-mix concrete truck, e.g., as shown in Figures 2-4; and

provide signaling containing information about the continuous real time moisture measurements sensed, e.g., consistent with that disclosed herein.

In particular, and by way of example, the continuous real time moisture measurements may include:

an initial real time moisture measurement of the batch of wet cement loaded into the rotating drum of the ready-mix concrete truck; and

subsequent real time moisture measurements sensed after the initial real time moisture measurement of the batch of wet cement in the rotating drum, including where the subsequent real time moisture measurements are sensed as the ready-mix concrete truck travels from a patch plant to a pour site, or as the ready-mix concrete truck sits at the pour site.

The real time moisture measurement module or sensor 20 may include a signal processor or signal processing module 20a configured to process and provide the signaling sensed accordingly, e.g., including providing the signaling sensed to the real time moisture measurement control module 30.

The Real Time Moisture Measurement Control Module 30

By way of example, the real time moisture measurement control module 30 may be configured to receive the signaling from the real time moisture measurement module or sensor 20 and further process the signaling received. The real time moisture measurement control module 30 may be arranged or configured in the ready-mix truck, including in its cab, or at a remote site. The scope of the invention is not intended to be limited to where the real time moisture measurement control module 30 is arranged or configured in relation to the ready-mix truck or the remote site.

The real time moisture measurement control module 30 may include a transceiver 32, e.g., configured to provide the signaling from the cab of the ready-mix truck to the remote site for still further processing. In effect, the real time moisture measurement control module 30 may be configured to process the signaling consistent with that disclosed herein, in the cab of the ready-mix truck at the remote site. The scope of the invention is not intended to be limited to where the real time moisture measurement control module 30 is located. Moreover, the transceiver 32 may receive control signal from the remote site containing information to control the real time moisture measurement module or sensor 20, the real time moisture measurement control module 30, or both.

The Continuous Real Time Moisture Measurements

By way of example, the continuous real time moisture measurements may be measured using a real time impedance measurement technique. Alternatively, the continuous real time moisture measurements may be measured using a real time nuclear high energy particle absorption measurement technique or a near infrared optical reflectance measurement technique. Techniques for implementing real time impedance measurements, real time nuclear high energy particle absorption measurements, or near infrared optical reflectance measurements are known in the art, and the scope of the invention is not intended to be limited to any particular type or kind thereof either now known or later developed in the future.

The Signal Processing of the Real Time Moisture Measurements

The signaling sensed containing information about the real time moisture measurements may be further processed, as follows:

By way of example, the signaling sensed may be processed to determine if and when water was added to the batch of wet cement in the rotating drum based upon the continuous real time moisture measurements received. For example, two continuous real time moisture measurements may be compared, and if a subsequent continuous real time moisture measurement is greater than a prior continuous real time moisture measurement, then the real time water content of the batch of cement increased, so water was added.

The signaling sensed may be processed to determine an amount of water added to the batch of wet cement in the rotating drum. For example, the real time moisture measurement control module 30 may be configured to receive associated signaling containing information about a known total weight of cementitious material of the batch of wet cement in the rotating drum; and determine a water/cement ratio using a real time moisture level measurement and the known total weight of cementitious material of the batch of wet cement in the rotating drum.

The signaling sensed may be processed to determine and monitor changes in the real time water content of the batch of wet cement using a temperature-based technique. For example, the real time moisture measurement control module 30 may be configured to receive associated signaling containing information about a known amount of cement added and a known temperature of the water added and determine a heat capacity and a thermal mass of the batch of wet cement using the temperature-based technique based upon the associated signaling received. The real time moisture measurement module or sensor 20 may include a temperature sensor 22 configured to determine the temperature of the batch of wet cement in the rotating drum.

By way of example, the continuous real time measurements may include an initial real time moisture measurement sensed after loading the batch of wet cement into the rotating drum of the ready-mix concrete truck; and the real time moisture measurement control module 30 may be configured to receive associated signaling containing information about an expected water content of after the batch of wet cement is loaded into the rotating drum of the ready-mix concrete truck, and validate the expected water content based upon a comparison of the expected water content received and the initial real time moisture measurement.

The real time moisture measurement control module 30 may be configured to receive associated signaling containing information about additional water added to the batch of cement loaded into the rotating drum and monitor a state of hydration of the batch of cement based upon the associated signaling received. By way of example, the associated signaling may contain information about no additional water being added to the batch of cement loaded into the rotating drum; and the real time moisture measurement control module 30 may be configured to receive the continuous real time moisture measurements and determine a downward trend of real moisture content of the batch of cement based upon the continuous real time moisture measurements received.

In contrast, the real time moisture measurement control module 30 may be configured to receive the continuous real time moisture measurements and determine an upward spike of real time moisture content of the batch of cement, which indicates that water has been added to the batch of cement, based upon the continuous real time moisture measurements received.

Multiple Real Time Moisture Measurement Modules Arranged at Multiple Points in the Rotating Drum

The real time moisture measurement module or sensor 20 may include, or take the form of, multiple real time moisture measurement modules 20 arranged at multiple points in the rotating drum; and each of the real time moisture measurement modules may be configured to

sensed corresponding continuous real time moisture measurements of the batch of wet cement at the multiple points of the ready-mix concrete truck; and

provide corresponding signaling containing information about the corresponding continuous real time moisture measurements sensed.

By way of example, the real time moisture measurement control module 30 may be configured to average the corresponding continuous real time moisture measurements determined of the batch of wet cement at the multiple points in the rotating drum, which provides a more consistent indication of the real time water content of the batch of cement. In particular, the real time moisture measurement control module 30 may be configured to average the corresponding continuous real time moisture measurements determined at the multiple points over multiple rotations of the rotating drum, and provide an averaged corresponding continuous real time moisture measurement for further processing. The real time moisture measurement control module 30 may also be configured to determine a homogeneity of the batch of wet cement based upon the averaged corresponding continuous real time moisture measurement.

The Signal Processor or Processing Modules 20a, 30a

The functionality of the signal processor or processor control modules 20a, 30a may be implemented using hardware, software, firmware, or a combination thereof. In a typical software implementation, the processor module may include one or more microprocessor-based architectures having a microprocessor, a random access memory (RAM), a read only memory (ROM), input/output devices and control, data and address buses connecting the same, e.g., consistent with that shown in Figure 1, as well as other signal processor circuits or components 20b, 30b.

A person skilled in the art would be able to program such a microprocessor-based architecture(s) to perform and implement such signal processing functionality described herein without undue experimentation. The scope of the invention is not intended to be limited to any particular implementation using any such microprocessor-based architecture or technology either now known or later developed in the future.

The Associated Signaling

Consistent with that disclosed herein, and by way of example, the associated signaling may be received, e.g., from the remote site and stored in a memory forming part of other signal processor circuits or components 20b. The scope of the invention is not intended to be limited to how the associated signaling is provided to, or received by, e.g., the real time moisture measurement control module 30.

The Rotating Container or Drum

By way of example, the present invention is disclosed based upon using a rotating drum forming part of a concrete mixing truck. However, the scope of the

invention is not intended to be limited to the same. For example, embodiments are envisioned, and the scope of the invention is intended to include, e.g., using other types or kinds of rotating containers or drums either now known or later developed in the future that may be configured to receive and contain concrete, as well as rotate and mix the concrete.

The Concrete

By way of example, the present invention is disclosed based upon mixing a slurry, e.g., such as concrete, using a rotating drum. However, the scope of the invention is not intended to be limited to the same. For example, embodiments are envisioned, and the scope of the invention is intended to include, e.g., processing other types or kinds of slurries either now known or later developed in the future, including other types or kinds of slurries that are sensitive to the amount of water contained therein, other types or kinds of or slurries that are mixed and poured from a rotating container or drum.

Means for Attaching

Means for attaching a sensor inside a rotating container or drum is known in the art, and the scope of the invention is not intended to be limited to any particular types or kinds thereof either now known or later developed in the future. By way of example, the sensor may include a sensor housing that may be fastened inside the rotating container or drum using fasteners like screws.

Signal Exchange between the Real Time Moisture Module 20 and the Real Time Moisture Control Module 30

The real time moisture measurement module 20 may be configured to provide the signaling to the real time moisture measurement control module 30 via a hardwire connection or via a wireless connection, which are both known in the art.

Techniques for connecting a component arranged on a rotating device are known in the art, and the scope of the invention is not intended to be limited to any type or kind of such a hardwire connection either now known or later developed in the future.

Moreover, techniques for connecting two components via a wireless connection are also known in the art, and the scope of the invention is not intended to be limited to any type or kind of such a hardwire connection either now known or later developed in the future.

The Scope of the Invention

While the invention has been described with reference to an exemplary embodiment, it will be understood by those skilled in the art that various changes may be made and equivalents may be substituted for elements thereof without departing from the scope of the invention. In addition, modifications may be made to adapt a particular situation or material to the teachings of the invention without departing from the essential scope thereof. Therefore, it is not intended that the invention be limited to the particular embodiment(s) disclosed herein as the best mode contemplated for carrying out this invention.

WHAT IS CLAIMED IS:

1. Apparatus for real time water content and water cement monitoring on a ready-mix concrete truck, comprising:

at least one real time moisture measurement module configured to

sense continuous real time moisture measurements of a batch of wet cement loaded into a rotating drum of a ready-mix concrete truck; and

provide signaling containing information about the continuous real time moisture measurements sensed.

2. The apparatus according to claim 1, wherein the continuous real time moisture measurements are measured using a real time impedance measurement technique.

3. The apparatus according to claim 1, wherein the continuous real time moisture measurements are measured using a real time nuclear high energy particle absorption measurement technique or a near infrared optical reflectance measurement technique.

4. The apparatus according to claim 1, wherein the at least one real time moisture measurement module or sensor forms part of the rotating drum of the ready-mix concrete truck that is loaded with the batch of wet cement having an amount of water and cementitious material.

5. The apparatus according to claim 1, wherein the at least one real time moisture measurement module or sensor is configured as, or forms part of, at least one hardened sensor element arranged in the rotating drum to determine the continuous real time moisture measurements.

6. The apparatus according to claim 1, wherein the real time moisture measurements include:

an initial real time moisture measurement of the batch of wet cement loaded into the rotating drum of the ready-mix concrete truck; and

subsequent real time moisture measurements after the initial real time moisture measurement of the batch of wet cement in the rotating drum, including as the ready-mix concrete truck travels from a patch plant to a pour site, or as the ready-mix concrete truck sits at the pour site.

7. The apparatus according to claim 1, wherein the apparatus comprises a real time moisture measurement control module configured to receive the signaling from the at least one real time moisture measurement module and further process the signaling received.

8. The apparatus according to claim 7, wherein the real time moisture measurement control module is arranged in a cab of the ready-mix truck, and includes a transceiver configured to provide the signaling from the cab to a remote site for still further processing.

9. The apparatus according to claim 7, wherein the real time moisture measurement control module is configured to determine if and when water was added to the batch of wet cement in the rotating drum based upon the continuous real time moisture measurements.

10. The apparatus according to claim 7, wherein the real time moisture measurement control module is configured to determine an amount of water added to the batch of wet cement in the rotating drum.

11. The apparatus according to claim 7, wherein the real time moisture measurement control module is configured to receive associated signaling containing information about a known total weight of cementitious material of the batch of wet cement in the rotating drum; and determine a water/cement ratio using a real time moisture level measurement and the known total weight of cementitious material of the batch of wet cement in the rotating drum.

12. The apparatus according to claim 7, wherein the real time moisture measurement control module is configured to determine and monitor changes in the real time water content of the batch of wet cement using a temperature-based technique.

13. The apparatus according to claim 12, wherein the real time moisture measurement control module is configured to receive associated signaling containing information about a known amount of cement added and a known temperature of the water added and determine a heat capacity and a thermal mass of the batch of wet cement using the temperature-based technique based upon the associated signaling received.

14. The apparatus according to claim 12, wherein the real time moisture measurement module includes a temperature sensor configured to determine the temperature of the batch of wet cement in the rotating drum.

15. The apparatus according to claim 7, wherein

the at least one real time moisture measurement module comprises real time moisture measurement modules arranged at multiple points in the rotating drum; and

each of the real time moisture measurement modules is configured to

sense corresponding continuous real time moisture measurements of the batch of wet cement at the multiple points of the ready-mix concrete truck; and

provide corresponding signaling containing information about the corresponding continuous real time moisture measurements sensed.

16. The apparatus according to claim 15, wherein the real time moisture measurement control module is configured to average the corresponding continuous real time moisture measurements determined of the batch of wet cement at the multiple points in the rotating drum.

17. The apparatus according to claim 16, wherein the real time moisture measurement control module is configured to average the corresponding continuous real time moisture measurements determined at the multiple points over multiple rotations of the rotating drum, and provide an averaged corresponding continuous real time moisture measurement for further processing.

18. The apparatus according to claim 17, wherein the real time moisture measurement control module is configured to determine a homogeneity of the batch of wet cement based upon the averaged corresponding continuous real time moisture measurement.

19. The apparatus according to claim 7, wherein

the continuous real time measurements includes an initial real time moisture measurement sensed after loading the batch of wet cement into the rotating drum of the ready-mix concrete truck; and

the real time moisture measurement control module is configured to receive associated signaling containing information about an expected water content of after the batch of wet cement is loaded into the rotating drum of the ready-mix concrete truck, and validate the expected water content based upon a comparison of the expected water content received and the initial real time moisture measurement.

20. The apparatus according to claim 7, wherein the real time moisture measurement control module is configured to receive associated signaling containing information about additional water added to the batch of cement loaded into the rotating drum and monitor a state of hydration of the batch of cement based upon the associated signaling received.

21. The apparatus according to claim 20, wherein

the associated signaling contains information about no additional water being added to the batch of cement loaded into the rotating drum; and

the real time moisture measurement control module is configured to receive the continuous real time moisture measurements and determine a downward trend of real moisture content of the batch of cement based upon the continuous real time moisture measurements received.

22. The apparatus according to claim 20, wherein the real time moisture measurement control module is configured to receive the continuous real time moisture measurements and determine an upward spike of real moisture content of the batch of cement, which indicates that water has been added to the batch of cement, based upon the continuous real time moisture measurements received.

Method Claims

23. A method for real time water content and water cement monitoring on a ready-mix concrete truck, comprising:

sensing with at least one real time moisture measurement module continuous real time moisture measurements of a batch of wet cement loaded into a rotating drum of a ready-mix concrete truck; and

providing with the at least one real time moisture measurement module signaling containing information about the continuous real time moisture measurements sensed.

24. The method according to claim 23, wherein the method comprises measuring the continuous real time moisture measurements using a real time impedance measurement technique.

25. The method according to claim 23, wherein the method comprises measuring the continuous real time moisture measurements using a real time nuclear high energy particle absorption measurement technique or a near infrared optical reflectance measurement technique.

26. The method according to claim 23, wherein the method comprises forming the at least one real time moisture measurement module as part of the rotating drum of the ready-mix concrete truck that is loaded with the batch of wet cement having an amount of water and cementitious material.

27. The method according to claim 23, wherein the method comprises configuring the at least one real time moisture measurement module as part of at least one hardened sensor element arranged in the rotating drum to determine the continuous real time moisture measurements.

28. The method according to claim 23, wherein the continuous real time moisture measurements include:

an initial real time moisture measurement of the batch of wet cement loaded into the rotating drum of the ready-mix concrete truck; and

subsequent real time moisture measurements sensed after the initial real time moisture measurement of the batch of wet cement in the rotating drum, including as the ready-mix concrete truck travels from a patch plant to a pour site, or as the ready-mix concrete truck sits at the pour site.

29. The method according to claim 23, wherein the method comprises receiving with a real time moisture measurement control module the signaling from the at least one real time moisture measurement module and further processing the signaling received.

30. The method according to claim 29, wherein the method comprises arranging the real time moisture measurement control module in the ready-mix truck and providing the real time moisture measurement control module with a transceiver to send the signaling from the ready-mix truck to a remote site for still further processing.

31. The method according to claim 29, wherein the method comprises determining with the real time moisture measurement control module if and when water was added to the batch of wet cement in the rotating drum based upon the continuous real time moisture measurements.

32. The method according to claim 29, wherein the method comprises determining with the real time moisture measurement control module an amount of water added to the batch of wet cement in the rotating drum.

33. The method according to claim 29, wherein the method comprises receiving with the real time moisture measurement control module associated signaling containing information about a known total weight of cementitious material of the batch of wet cement in the rotating drum; and determining a water/cement ratio using a real time moisture level measurement and the known total weight of cementitious material of the batch of wet cement in the rotating drum.

34. The method according to claim 29, wherein the method comprises determining and monitoring with the real time moisture measurement control module changes in the real time water content of the batch of wet cement using a temperature-based technique.

35. The method according to claim 34, wherein the method comprises receiving with the real time moisture measurement control module associated signaling containing information about a known amount of cement added and a known temperature of the water added and determining with the real time moisture measurement control module a heat capacity and a thermal mass of the batch of wet cement using the temperature-based technique based upon the associated signaling received.

36. The method according to claim 34, wherein the method comprises configuring the real time moisture measurement module with a temperature sensor to determine the temperature of the batch of wet cement in the rotating drum.

37. The method according to claim 29, wherein the method comprises

configuring the at least one real time moisture measurement module with real time moisture measurement modules arranged at multiple points in the rotating drum; and

configuring each of the real time moisture measurement modules to

sense corresponding continuous real time moisture measurements of the batch of wet cement at the multiple points of the ready-mix concrete truck; and

provide corresponding signaling containing information about the corresponding continuous real time moisture measurements sensed.

38. The method according to claim 37, wherein the method comprises averaging with the real time moisture measurement control module the corresponding continuous real time moisture measurements determined of the batch of wet cement at the multiple points in the rotating drum.

39. The method according to claim 38, wherein the method comprises averaging with the real time moisture measurement control module the corresponding continuous real time moisture measurements determined at the multiple points over multiple rotations of the rotating drum, and providing an averaged corresponding continuous real time moisture measurement for further processing.

40. The method according to claim 39, wherein the method comprises determining with the real time moisture measurement control module a homogeneity of the batch of wet cement based upon based upon the averaged corresponding continuous real time moisture measurement.

41. The method according to claim 29, wherein the method comprises

including in the continuous real time measurements an initial real time moisture measurement sensed after loading the batch of wet cement into the rotating drum of the ready-mix concrete truck; and

receiving with the real time moisture measurement control module associated signaling containing information about an expected water content after the batch of wet cement is loaded into the rotating drum of the ready-mix concrete truck, and validating the expected water content based upon a comparison of the expected water content received and the initial real time moisture measurement.

42. The method according to claim 29, wherein the method comprises receiving with the real time moisture measurement control module associated signaling containing information about additional water added to the batch of cement loaded into the rotating drum and monitoring with the real time moisture measurement control module a state of hydration of the batch of cement based upon the associated signaling received.

43. The method according to claim 42, wherein

the associated signaling contains information about no additional water being added to the batch of cement loaded into the rotating drum; and

the method comprises receiving with the real time moisture measurement control module the continuous real time moisture measurements and determining a downward trend of real moisture content of the batch of cement based upon the continuous real time moisture measurements received.

44. The method according to claim 42, wherein the method comprises receiving with the real time moisture measurement control module the continuous real time moisture measurements and determining an upward spike of real moisture content of the batch of cement, which indicates that water has been added to the batch of cement, based upon the continuous real time moisture measurements received.

45. The apparatus according to claim 1, wherein the apparatus comprises a hatch door of the rotating drum of the ready-mix concrete truck.

46. The apparatus according to claim 1, wherein the apparatus comprises the rotating drum of the ready-mix concrete truck.

47. The apparatus according to claim 1, wherein the apparatus comprises the ready-mix concrete truck.

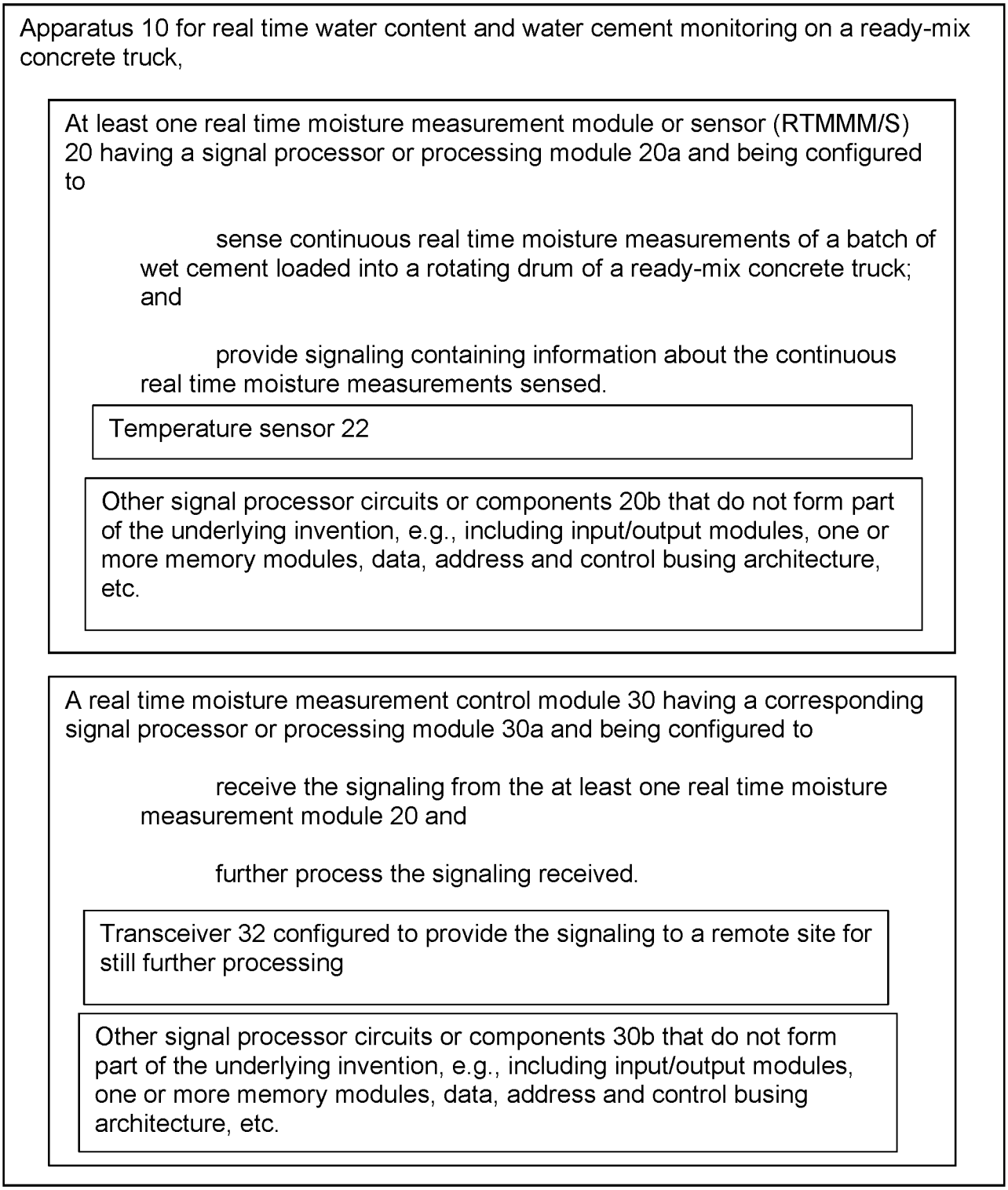

Figure 1: The Apparatus 10

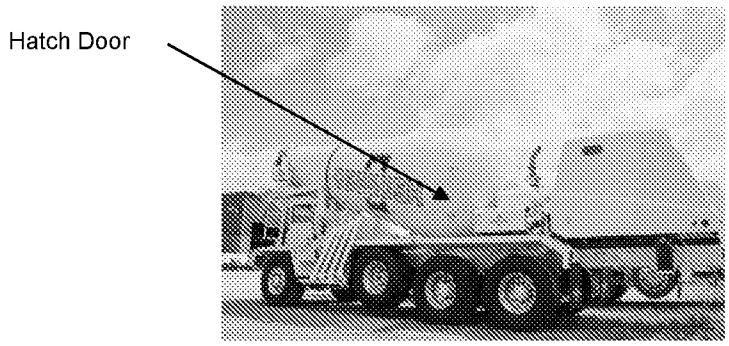

Figure 2: Ready mix truck with an arrow pointing to a hatch door indicating a potential location of a real time moisture measurement module or sensor (RTMMM/S) installation.

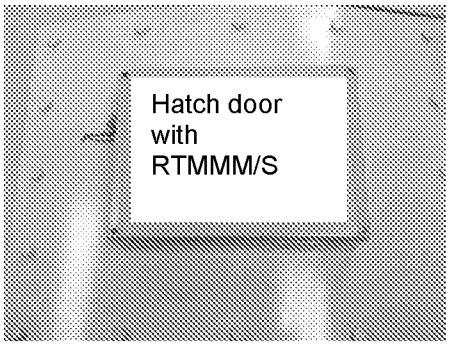

Figure 3: Hatch door with a real time moisture measurement module or sensor (RTMMM/S) installed therein.

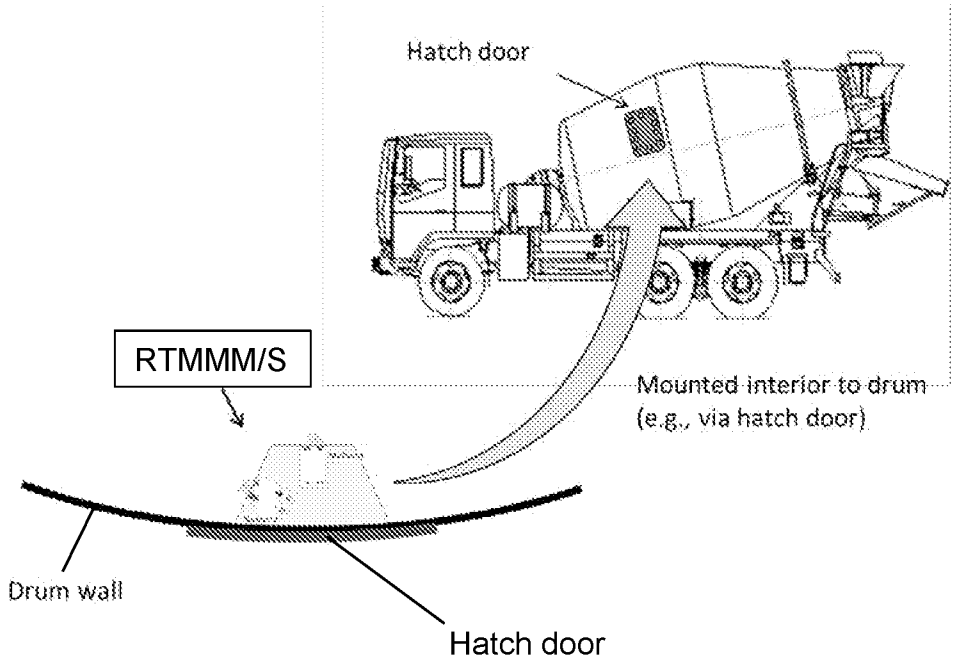

Figure 4: The mounting of the real time moisture measurement module or sensor (RTMMM/S) on an interior surface of a mixing drum wall.

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US 21/46211

A. CLASSIFICATION OF SUBJECT MATTER

IPC - G01N 29/024; G01N 29/24; G01N 29/44 (2021.01)

CPC - G01F 1/74; G01F 17/00; G01N 29/024

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)
See Search History document

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
See Search History document

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
See Search History document

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X ----- Y	US 2018/238820 A1 (Giatec Scientific, Inc.) 23 August 2018 (23.08.2018) para [0004], para [0023]-[0029], para [0035]-[0039], para [0047]-[0052], para [0203]-[0204], para [0212], para [0214], para [0216], para [0235]-[0236], para [0252], para [0268], para [0311], para [0321], para [0342], para [0348], para [0392], para [0402],	1-2, 4, 6-12, 14-24, 26, 28-34, 36-44, 46-47 ----- 3, 5, 13, 25, 27, 35, 45
Y	US 2018/372624 A1 (Panasonic Intellectual Property Management Co., Ltd) 27 December 2018 (27.12.2018) para [0011], para [0151],	3, 25
Y	WO 1993/004485 A1 (American Technology, Inc.) 4 March 1993 (04.03.1993) pg 14, ln 18-23,	5, 27
Y	US 2015/376489 A1 (The Regents of The University of Michigan) 31 December 2015 (31.12.2015) para [0004], para [0028], para [0054],	13, 35
Y	US 2020/173899 A1 (Cidra Corporate Services, LLC.) 4 June 2020 (04.06.2020) para [0004], para [0017],	45
A	US 2006/191631 A1 (Kojima) 31 August 2006 (31.08.06) para [0095],	13, 35
A	US 2019/217044 A1 (Fisher & Paykel Healthcare Limited) 18 July 2019 (18.07.2019) para [0091],	13, 35
A	US 2,533,362 A (Devine et al.) 12 December 1950 (12.12.1950) col 1, ln 1-4, col 3, ln 25-32,	45

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:
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"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
28 October 2021	DEC 09 2021
Name and mailing address of the ISA/US Mail Stop PCT, Attn: ISA/US, Commissioner for Patents P.O. Box 1450, Alexandria, Virginia 22313-1450 Facsimile No. 571-273-8300	Authorized officer Kari Rodriquez Telephone No. PCT Helpdesk: 571-272-4300