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WO 2009/144523 A2 **JP 2004098531 A**
US 20020169517 A1

(58) Field of Search:
INT CL **B28C, C04B, G05B, G06Q**
Other: **EPODOC, WPI**

(54) Title of the Invention: **System and process for mixing concrete having desired strength characteristics**
Abstract Title: **A system and method for mixing concrete having a desired strength**

(57) A system for mixing a concrete batch, the system having a processor 10 having a transceiver 16 to receive or transmit signals, the processor also having a database of lab and field information and an algorithm for calculating a water – cement ratio (WC ratio) and comparing this ratio against information in the database. The system also includes a concrete truck 50 with a water input system and a transceiver 56 to receive or transmit signals to the processor, and a concrete manufacturing plant 30 having a transceiver 36 to receive or transmit signals to the processor.
Also claimed is a process for mixing a concrete batch to meet or exceed a given compressive strength, including recording an amount of water added and an amount of cement added to the batch, transmitting the amounts of water and cement added to a processor, transferring the batch to a concrete truck, and prior to pouring, adding more water or cement, then calculating a water-to-cement ratio and comparing the ratio to that associated with a given compressive strength according to a database of concrete family characteristics.

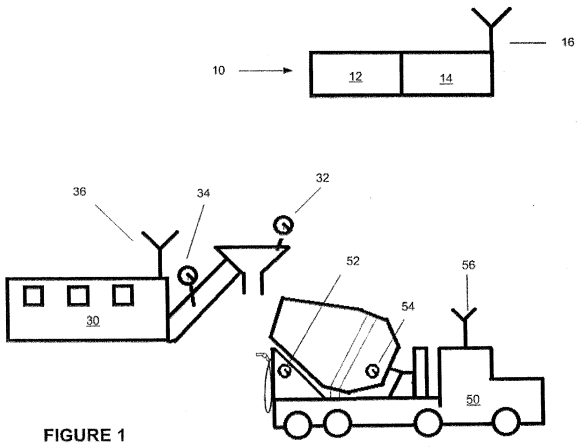

FIGURE 1

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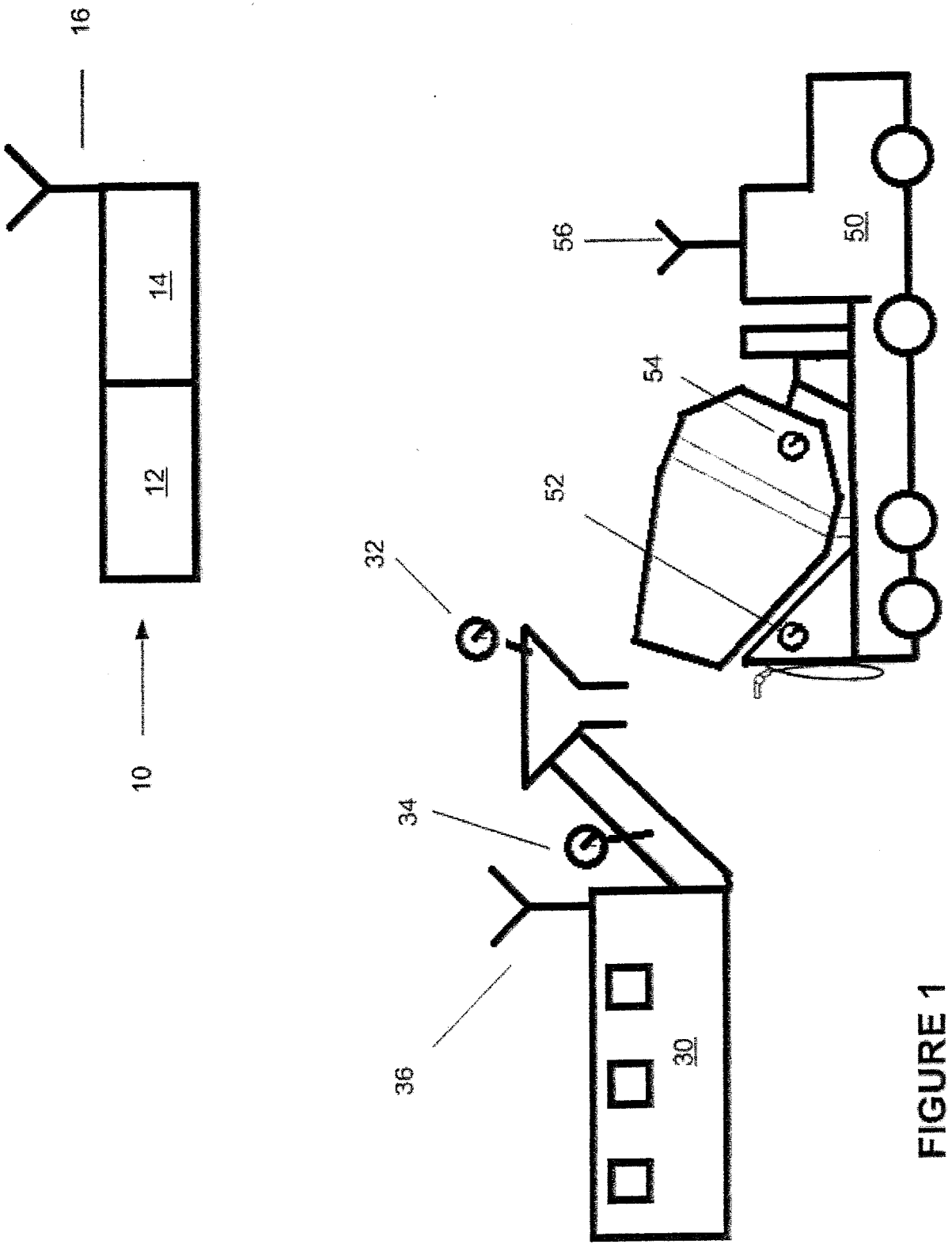

FIGURE 1

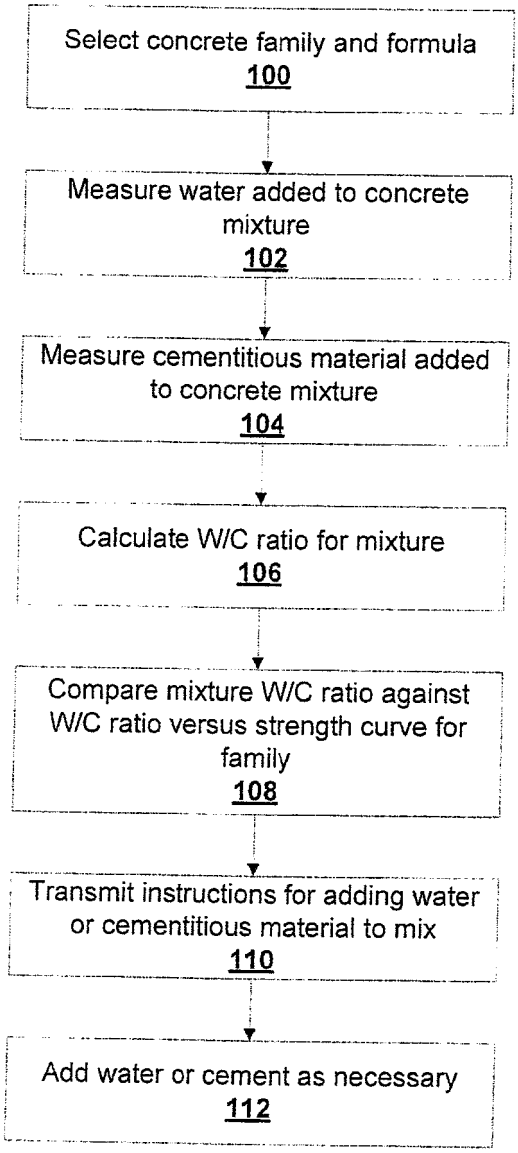
Select concrete family and formula
100
Measure water added to concrete mixture
102
Measure cementitious material added to concrete mixture
104
Calculate W/C ratio for mixture
106
Compare mixture W/C ratio against W/C ratio versus strength curve for family
108
Transmit instructions for adding water or cementitious material to mix
110
Add water or cement as necessary
112

FIGURE 2

SYSTEM AND PROCESS FOR MIXING CONCRETE HAVING DESIRED STRENGTH CHARACTERISTICS

FIELD OF THE INVENTION

[0001] The invention relates generally to concrete production.

BACKGROUND ART

[0002] Concrete is produced by mixing cementitious material, water, aggregates (such as gravel, crushed limestone, or sand) into a plastic mixture, which undergoes a chemical process (known as hydraulic curing) to harden and strengthen. Other materials, such as admixtures, pozzolans, plasticizers, reinforcers or other compounds, may be added to the mix, depending on the concrete formula selected. Concrete formulas are grouped into concrete families, which are characterized by similarities in composition and function, and for which a reliable relationship between relevant properties can be determined. For example, a concrete family may be defined by concrete formulas sharing type or source characteristics (e.g., Portland pozzolan cement, masonry cement, blends, etc.); demonstrably similar aggregates or admixtures; the use and type of plasticizers or other water-reducing compounds; consistence (or slump) classes; entrained air content; mixing and curing methods; or combinations of these various qualities or categories. Particular concrete families are desired for various applications, based upon the performance and cost constraints of the end use.

[0003] Each concrete family is characterized by a relationship between various relevant material design properties. For concrete, such properties include among others the water-cement ratio (W/C ratio), which is the ratio of water mass to cement mass (including pozzolanic materials, if used) in the mixture, the compressive strength, the tensile strength, elasticity, and thermal expansion coefficient. For example, in a particular concrete family, the W/C ratio is inversely related to the compressive strength. However,

the particular nature of that inverse relationship is influenced by other characteristics inherent to the concrete family.

[0004] Although the general relationship between W/C ratio and compressive strength in concrete is known, builders and concrete producers have been unable to quickly and accurately determine the water and concrete amounts for a particular delivery of concrete. In current practice, the concrete production process consists of a series of automated and manual steps that may result in an inaccurate record of exactly how much water and cement actually went into the delivery. Also, trucks delivering concrete to a construction site may add varying amounts of water to the mixture it is transporting. Because this will alter the W/C ratio of each individual mixture transported to the site, the resulting concrete pour may exhibit inadequate strength properties unless corrected. Current practice is to use more cementitious material in the concrete formula mixed at the plant to compensate for water that may be added during transport. However, because cementitious material is generally the most expensive component of concrete, this has the effect of increasing cost. Furthermore, if substantial quantities of water must be added to the delivered concrete during transport or pouring, the resulting concrete may still exhibit inadequate strength. Concrete exhibiting inadequate compressive strength must be removed and reworked, resulting in substantial time delays and cost overruns. Because concrete is not considered fully cured and of maximum strength until twenty-eight days after pouring, the resulting delay may be very substantial, and replacement of the defective concrete can be very expensive and require reworking of other parts of the construction.

[0005] What is needed, then, is a concrete production method and system for quickly and accurately determining water and concrete inputs in order to determine an expected compressive strength for the cured concrete.

SUMMARY OF THE INVENTION

[0006] In some respects, the disclosure relates to a process for mixing a concrete batch to meet or exceed a predetermined compressive strength, having steps of recording an amount of water added to the batch; recording an amount of cement added to the batch;

transmitting the amount of water added and amount of cement added to a processor; prior to pouring the concrete, calculating from the added water weight and added cement weight a batch water-to-cement ratio with the aid of the processor; prior to pouring the concrete, comparing the batch water-to-cement ratio to a desired water-to-cement ratio associated with concrete exhibiting the predetermined compressive strength according to a database of concrete family characteristics maintained on a computer; and prior to pouring the concrete, providing a notification of the predicted concrete strength.

[0007] In other aspects, the disclosure relates to a method for preparing a batch of concrete to meet or exceed a predetermined compressive strength and made of water, cement, and aggregate mixed according to a predefined concrete family, having the steps of mixing a batch of concrete characterized by an initial water-to-cement ratio; periodically measuring an amount of water added to the batch; transmitting the measurement of the amount of water added to a processor; prior to pouring the concrete, calculating a revised water-to-cement ratio for the batch with the aid of the processor; prior to pouring the concrete and for each calculation of the revised water-to-cement ratio, comparing the revised water-to-cement ratio to a desired water-to-cement ratio associated with the predetermined compressive strength for the concrete family according to a database of concrete family characteristics maintained on a computer; prior to pouring the concrete, correlating the revised water-to-cement ratio to a predicted concrete strength of the batch; and prior to pouring the concrete, providing a notification of the predicted concrete strength.

[0008] In other aspects, the disclosure relates to a system for mixing a concrete batch to have a predetermined compressive strength, the system having a processor comprising a transceiver to receive or transmit signals, a database comprising laboratory information and field information, and an algorithm for calculating a W/C ratio and comparing the calculated ratio against information in the database; a concrete truck comprising a truck water input system, and a transceiver to receive or transmit signals to the processor; and a concrete manufacturing plant comprising a plant water input system, a plant cement input system, and a transceiver to receive or transmit signals to the processor.

DESCRIPTION OF THE DRAWINGS

[0009] FIG. 1 depicts an embodiment of a system according to the disclosure.

[0010] FIG. 2 depicts an embodiment a process according to the disclosure.

DETAILED DESCRIPTION

[0011] FIG. 1 depicts an embodiment of a system according to the disclosure. A server **10** (or a group of servers) maintains a database **14** of characteristics and properties for various families of concrete. The term "database" as used herein refers to an organized data structure comprising a plurality of records stored in machine-readable format. These properties may be tabulated from laboratory experiments, field testing of known concrete mixtures, and construction and engineering theory. The database **14** may include some combination of information concerning the batch materials, amounts, and ratios for a particular family; properties for particular formulas, such as slump, strength, elasticity, and thermal expansion coefficients; and graphs, curves, mathematical models, or other information or mathematical relations relating the properties of particular formulas in the family to other properties, material amounts, or material ratios.

[0012] In some embodiments and as depicted in FIG. 1, the server **10** also includes a specific processor **12** programmed to calculate the W/C ratio for a particular concrete mixture and comparing the W/C ratio to characteristics set forth in the database **14**. The term "processor" or "central processing unit" (CPU) as used herein refers to a software execution device capable of executing a sequence of instructions ("program"). The CPU comprises an arithmetic logic unit, and may further comprise one or both of a register and cache memory. In other embodiments the processor **12** may be located on a different server **10**, or may be located at a plant **30** or on a truck **50**. The particular location of the processor **12** is not critical so long as it can receive or transmit information from or to the database **14** and other components providing information regarding the water or cementitious material content of a concrete mixture. To receive and transmit information, the server **10** of FIG. 1 has a modem, transceiver, wireless router, or other

communications device **16** commonly used for communication between various locations to maintain electronic communication with the other components of the system.

[0013] For many concrete delivery methods, the constituent materials for the concrete are pre-mixed at a concrete plant **30** and then carried by truck **50** to a pouring location at a construction site. The plant **30** mixes concrete according to the formula determined to be most suitable for the construction site and to achieve the predetermined compressive strength. The particular formula will belong to a concrete family and have a particular combination of the various constituent materials, including water, cementitious material, aggregates, and (depending on the concrete family or formula selected) other admixtures, pozzolans, plasticizers, reinforcers or other compounds. In order to control production of the mixture, the plant **30** measures the mass or weight of both water and cementitious material mixed into the concrete mixture. The water-measuring device **32** and cement-measuring device **34** may be any device useful for measuring an amount (such as the mass, weight, or volume) of water or cement, respectively, such as a scale, load cell, pressure or mass sensor, or mass flow meter. The water measuring device **32** and cement-measuring device **34** are connected to a communications device **36** which transmits the mass of water and cementitious material added to the concrete mixture to the processor **12**. Other measuring devices may measure the temperature, content, and amount of other constituent materials added to the mixture, and these measurements may be transmitted via the communications device **36** to the processor **12** as well.

[0014] Once the concrete is mixed at the plant **30**, a concrete truck **50** receives the concrete mixture. More cement or water may be added while at the plant **30**, during the post-production period. After post-production, the truck **50** transports the concrete to the construction site for pouring. During transportation and pouring, water may be added for various reasons. For example, water may be added to improve the consistence or slump of the concrete, or may simply be present in the delivery truck **50** mixing barrel after being washed out from the previous delivery. However, adding water also increases the W/C ratio and decreases the compressive strength of the concrete.

[0015] Because adding water or cementitious material to the concrete mixture during production, transport, or pouring alters the W/C ratio of the concrete, these changes will affect the compressive strength of the concrete poured by the delivery truck **50.** In the system disclosed herein, the truck **50** has a water-measuring device **52** such as a sensor, load cell, scale, or meter, to measure the amount of water (such as the mass, weight or volume) added to the concrete mixture.

[0016] Current concrete delivery protocol generally does not provide for the addition of cementitious material to the mix after the truck **50** leaves the plant **30**, due to the potential for concrete to harden too quickly and the typical driver's lack of expertise in concrete formula design. However, it is possible for the truck **50** to be further equipped with a cement-measuring device **54** to measure the amount of cement added to the mixture, in the event that cement is added. This could provide further flexibility in responding to changes in the concrete during transportation and pouring in connection with the disclosure herein.

[0017] The water measuring device **52** (and cement-measuring device **54**, if equipped on the truck **50**) connects to a communication device **56**, such as a transceiver, wireless router, modem, or other device, to communicate the added water and cement amounts to the processor **12.** Alternatively, the truck driver may manually input into the communications device **56** known amounts of water that were added but not measured by the truck's **50** onboard water-measuring device **52.**

[0018] The system provided above allows the concrete engineer or designer to rapidly and accurately determine the W/C ratio and predicted strength for a batch of concrete prior to or during pouring and therefore allows the concrete engineer to determine the suitability of the batch of concrete in real time. Previously, concrete engineers have been unable to make this determination accurately and quickly and have generally relied on guesswork and over-strengthening the concrete by adding additional cementitious material during the initial mix and batching process. This results in substantially higher costs, because cementitious material is the most expensive component of concrete. However, applicant's system and the following process provide concrete engineers the

ability to accurately determine strength prior to pouring the concrete at the construction site.

[0019] An example process depicted in FIG. 2 for utilizing the system and depicted allows for mixing the concrete to pour at the delivery site and cure with the desired compressive strength while minimizing or eliminating the concern of inadequate concrete strength.

[0020] In step **100**, a preliminary determination is made as to the concrete family and formula and the quantity of concrete to be used in conjunction with a particular construction site. This is done in accordance with standard principles of concrete design and construction. After the family and formula are selected, the components and mix instructions for the concrete are sent to the plant **30** for the production phase. Cement, aggregate, and water are added to the mix during the production and post-production phases, along with any other admixtures, pozzolan, plasticizers, or other materials used in formulating the batch. As noted above, the truck **50** or driver may add more water to the concrete mix during the transportation and pouring phases.

[0021] In step **102**, the water-measuring devices **32** and **52** measure the amount of water added to the concrete during the production, post-production, transport, and pouring stages. The water-measuring devices **32** and **52** may record the amount added and transmit the measurements through the communication devices **36** and **56** to the processor **12**. The water measuring devices **32** and **52** may transmit the quantity of water added continuously, at periodic intervals (e.g., every ten minutes), or upon prompting or request by the user. Transmission upon user request or prompt may be useful, for example, when a user desires to know the current W/C ratio and whether further water or cement needs to be added.

[0022] In step **104**, the cement-measuring devices **34** and **54** measure the amount of cementitious material added during the production and post-production processes (and, if permitted, during transport and pouring). The cement-measuring devices **34** and **54** may record the amount added and transmit the measures through the communication devices **36** and **56** to the processor **12**. Similar to transmission of the water measurements, such

transmissions may be made continuously, at periodic intervals, or upon user request or prompt.

[0023] Measurements of additional constituent materials or properties, such as mass of the aggregates, temperature of the concrete, and slump, may also be made by sensors (not shown) at the plant **30** or truck **50** and transmitted via communication devices **36** and **56** to the processor **12**. These properties determine the formula and composition of the concrete that is actually mixed at a particular plant **30** and delivered by the truck **50** and may be correlated with a particular concrete family or formula to further determine characteristics of the concrete. While taking such measurements is not necessary to perform the process described herein, such measurements can result in a more accurate determination of the quality of the concrete delivered.

[0024] As the processor **12** receives the measurements, the processor **12** is programmed to calculate the W/C ratio in step **106** by dividing the total amount of water added to the concrete mix by the total amount of cementitious material added to the mix.

[0025] In step **108**, the processor **12** is programmed to compare the W/C ratio calculated in step **106** against the concrete family (or against the formula) preselected in step **100**. The qualities of the concrete family and formula are maintained in the database **14**. As noted above, the database **14** may include entries for concrete formulas and corresponding qualities based on lab tests, field testing, or onstruction engineering theory. If measurements of slump, temperature or other qualities are made, these may also be compared against information contained in the database **14** to further refine the nature of the concrete and provide for more accurate comparisons.

[0026] By comparing the W/C ratio of the concrete mix to the established relationship between W/C ratio and compressive strength tabulated for the concrete family or formula in the database **14**, the processor **12** predicts whether the concrete mix will cure with sufficient compressive strength to meet or exceed the compressive strength that is predetermined or supplied by the construction design requirements.

[0027] In step **110** the processor **12** transmits the result of the comparison to the truck **50**. The result may also be transmitted to appropriate quality control and management

personnel via electronic mail or other form of electronic communication. In some embodiments, this result may indicate whether the predicted strength for the concrete mix in the truck **50** is higher or lower than the required strength determined in step **100**. Also in some embodiments, the result mayu indicate whether the W/C ratio for the concrete mix in the truck **50** is higher or lower than the desired W/C ratio preselected in step **100**.

[0028] It is critical to this invention that the determination of the W/C ratio and the predicted compressive strength of the concrete and its transmission to the driver, concrete engineer, construction foreman, or other person responsible for pouring the concrete be done prior to pouring the concrete. Because concrete will continue to harden during transport, preparation for pouring, and pouring, the steps above are time-sensitive. If the predicted concrete strength cannot be determined in a timely manner, either the concrete will harden and become unusable or pouring must proceed without the benefits and advantages obtained by practicing the procedures disclosed herein.

[0029] In step **112**, if the W/C ratio is lower than the necessary W/C ratio according to the database **14**, then the driver may either leave the mix as it is or, if necessary, add water to correct other properties of the concrete mix, such as slump. If the predicted strength is less than the required strength, the load may be returned to the plant **30** for recycling, or the delivery may be diverted to a different project with less demanding strength requirements. (If the driver is permitted to added cement to the mix, the driver may perform that task as well.) The process may be repeated as often as necessary during mixing, transport, and pouring to maintain the appropriate W/C ratio and compressive strength.

[0030] After delivery, the total amounts of water and cement added to the concrete mix are provided to the database **14**. After twenty-eight days, the strength of the concrete is determined through standard concrete strength tests. The actual strength for the concrete delivered to the construction site is entered into the database **14**. In this way, the data relating to various concrete families may be updated to provide for more accurate comparisons during future concrete deliveries.

[0031] While the invention has been described with respect to a limited number of embodiments, those skilled in the art, having benefit of this disclosure, will appreciate that other embodiments can be devised which do not depart from the scope of the invention as disclosed here. Accordingly, the scope of the invention should be limited only by the attached claims.

CLAIMS

1. A system for mixing a concrete batch to have a predetermined compressive strength, the system comprising:

a processor comprising a transceiver to receive or transmit signals, a database comprising laboratory information and field information, and an algorithm for calculating a W/C ratio and comparing the calculated ratio against information in the database;

a concrete truck comprising a truck water input system, and a transceiver to receive or transmit signals to the processor; and

a concrete manufacturing plant comprising a plant water input system,
a plant cement input system, and a transceiver to receive or transmit signals to the processor.

2. A process for mixing a concrete batch to meet or exceed a predetermined compressive strength, the process comprising:

(a) recording an amount of water and an amount of cement added to the batch during mixing at a concrete plant;

(b) transmitting the amount of water added and amount of cement added to a processor;

(c) transferring the concrete batch to a concrete truck;

(d) adding an amount of water or an amount of cement to the concrete batch while the concrete batch is in the truck;

(e) transmitting to the processor the amount of water and amount of cement added while the concrete batch is in the truck;

(f) prior to pouring the concrete, calculating from the added water weight and added cement weight a batch water-to-cement ratio with the aid of the processor;

(g) prior to pouring the concrete, comparing the batch water-to-cement ratio to a desired water-to-cement ratio associated with concrete exhibiting the predetermined compressive strength according to a database of concrete family characteristics maintained in a database; and

(h) prior to pouring the concrete, providing a notification of the predicted concrete strength.

3. The process of claim 2, further comprising after providing a notification and prior to pouring the concrete, the step of adding a quantity of water to the concrete batch to result in a revised water-to-cement ratio, where the revised water-to-cement ratio does not exceed the desired water-to-cement ratio.

4. The process of claim 2 or 3, further comprising after the step of providing a notification and prior to pouring the concrete, the step of adding cement to the concrete batch to result in a revised water-to-cement ratio, where the revised water-to-cement ratio does not exceed the desired water-to-cement ratio.

5. The process of claim 2, 3 or 4, where the recording of either the amount of water added or the amount of cement added is performed constantly.

6. The process of claim 2, 3 or 4, where the recording of either the amount of water added or the amount of cement added is performed periodically.

7. The process of any of claims 2-6, where the recording of either the amount of water added or amount of cement added is entered by a user.

8. The process of any of claims 2-7, further comprising pouring the concrete batch, recording the batch water-to-cement ratio in the database, measuring the actual strength of the cured concrete; and identifying within the database the actual concrete strength with the batch water-to-cement ratio.

9 A method for preparing a batch of concrete to meet or exceed a predetermined compressive strength and comprising water, cement, and aggregate mixed according to a predefined concrete family, the method comprising mixing a batch of concrete characterized by an initial water-to-cement ratio, transferring the concrete batch to a concrete truck, periodically measuring an amount of water added to the batch,

transmitting the measurement of the amount of water added to a processor, prior to pouring the concrete, calculating a revised water-to-cement ratio for the batch with the aid of the processor, prior to pouring the concrete and for each calculation of the revised water-to-cement ratio comparing the revised water-to-cement ratio to a desired water-to-cement ratio associated with the predetermined compressive strength for the concrete family according to a database of concrete family characteristics maintained on a computer, prior to pouring the concrete, correlating the revised water-to-cement ratio to a predicted concrete strength of the batch, and prior to pouring the concrete, providing a notification of the predicted concrete strength.

10. The process of claim 9, further comprising after receiving a notification of predicted strength and prior to pouring the concrete, adding water to the concrete to result in a second revised water-to-cement ratio, where the second revised water-to-cement ratio does not exceed the desired water-to-cement ratio.

11. The process of claim 9 or 10, further comprising the step of adding cement to the concrete prior to pouring the concrete.

12. The process of claim 11, further comprising, after mixing a batch of concrete, the steps of periodically measuring a weight of cement added to the batch and transmitting the weight of cement added to the processor.

13. The process of any of claims 9-12, further comprising pouring the concrete batch, recording the second revised water-to-cement ratio in the database, measuring the actual strength of the cured concrete, and identifying within the database the actual strength with the second revised water-to-cement ratio.

Intellectual Property Office

Application No:	GB1602550.4	**Examiner:**	Mr Kevin Gartland
Claims searched:	1-13	**Date of search:**	29 February 2016

Patents Act 1977: Search Report under Section 17

Documents considered to be relevant:

Category	Relevant to claims	Identity of document and passage or figure of particular relevance
X	1	US2002/169517 A1 (HUDELMAIER), see figure 1, transceivers 8 and 9.
X	1	JP2004098531 A (AIZAWA), see figure 1
X	1	WO2009/144523 A2 (BERMAN), see figures and pg 7-8 of description

Categories:

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
&	Member of the same patent family	E	Patent document published on or after, but with priority date earlier than, the filing date of this application.

Field of Search:

Search of GB, EP, WO & US patent documents classified in the following areas of the UKC^{X} :

Worldwide search of patent documents classified in the following areas of the IPC

B28C; C04B; G05B; G06Q

The following online and other databases have been used in the preparation of this search report

EPODOC, WPI

International Classification:

Subclass	Subgroup	Valid From
B28C	0007/04	01/01/2006
B28C	0005/42	01/01/2006
B28C	0007/02	01/01/2006