IoT Sensors For Monitoring Curing Of Concrete And Monitoring Health Of Resulting Concrete Structure

Related Application

[001] The present invention claims priority to Singapore patent application no. 10202112510U filed on 10 November 2021, the disclosure of which is incorporated in its entirety.

Field of Invention

[002]The present invention relates to IoT sensors for monitoring the curing of concrete in the short-term. After a concrete structure is built, a selected embedded IoT sensor can be used to monitor the health or integrity of the resulting concrete structure in the long-term.

Background

[003] Conventionally, before building a concrete structure, concrete is moulded in cubes and allowed to cure; at specific days after curing, the cubes are crushed to determine the concrete strength according to a mixture of components and designed grade; determination of concrete strength is governed by ASTM C1074. Technology has since advanced and the strength of newly laid concrete can be estimated from the internal temperature history as concrete cures; consequently, the strength that has developed sufficiently in the concrete can affect the progress of constructing a concrete structure.

[004] From a survey of this modern technology, various types of sensors are used to estimate curing time of concrete and concrete strength attained after curing; these sensors are designed for short-term applications during curing of concrete.

[005] Despite the above developments, there is still a need for alternative IoT sensors and systems integration to enhance the above technology. Preferably, the systems are modular and the components can be configured to meet the requirements of users located in different climatic regions or environments.

Summary

[006] The following presents a simplified summary to provide a basic understanding of the present invention. This summary is not an extensive overview of the present invention, and is not intended to identify key features of the invention. Rather, it is to present some of the inventive concepts of this invention in a generalised form as a prelude to the detailed description that is to follow.

[007] The present invention seeks to provide IoT sensors, a system to monitor in-situ curing of concrete and continuous monitoring of health or integrity of the resulting concrete structure. The system is modular and can be configured to meet requirements of users and/or the environment. These IoT sensors are embedded in a curing concrete and real-time curing temperature and moisture data from the sensors are sent to a data centre. The curing parameters together with curing time are interpreted to determine the strength that has developed in the concrete. The results of computation are displayed on a user interface, preferably in a graphical form, together with information on the mix of the concrete. A mobile device is provided to facilitate registering and inputting locations of the IoT sensors. A gateway device is provided to aggregate data from a plurality of IoT sensors. Additional sensors may be embedded in the curing concrete, to monitor the health or integrity of the concrete structure obtained after erection or for maintenance.

[008] In one embodiment, the present invention provides a concrete curing system comprising: a sensor for embedding in a curing concrete, wherein curing parameters of temperature, moisture, time elapsed and concrete grade are captured and stored in a data centre; and a software application, operable at a control station, translates the curing parameters into a strength and curing time relationship.

[009] Preferably, a mobile device is provided as an input device for registering each sensor and recording a position of installation of the sensor. Preferably, the sensor is selected from the following types: electrode, MEMs, electrochemical, piezoelectric, optical fiber, or a hybrid thereof.

[0010] Preferably, a sensor controller is associated with a sensor, and the sensor controller is wired or wireless. The sensor may be passive or actively supplied with a power supply.

In one embodiment, the power supply is wirelessly chargeable, and comprises a capacitor and an associated charging pad.

[0011] Preferably, the concrete curing system comprises a circuit board, and the entire circuit board with associated electronic components and power supply are encapsulated in a resin for waterproof protection.

[0012] Preferably, the system further comprises a gateway device, wherein data from a plurality of sensors are operable to be aggregated into packages for transmission from the gateway device to the data centre. The gateway device may employ one or more of the following transmission protocols: LPWAN, Sigfox, Lora, NBIoT, wifi, Bluetooth and cellular.

[0013] Preferably, a moisture sensor is configured in a portable water-cement ratio probe, which is then operable to ascertain the water-cement ratio of wet cement that is being delivered to a construction site.

[0014] Preferably, the sensor is configured and calibrated to monitor strain-stress, corrosion, vibration, water seepage or relative humidity; these parameters are used to monitor integrity or health of the concrete structure thus erected. The sensor for monitoring relative humidity is embedded at a predetermined depth from a surface of the concrete to monitor the humidity level for tiling or plastering work.

[0015] In another embodiment, the present invention provides a method to implement the above system. The method comprises: embedding a sensor in a curing concrete; sending the sensor data to a data centre and a control station; and using a software application, operable at the control station, to translate the sensor data, together with curing time and grade of concrete, to determine a strength that the concrete has attained, so that follow on work can be performed promptly to completion.

[0016] Preferably, the method further comprises calibrating the sensor to monitor strain-stress, corrosion, vibration, water seepage or relative humidity to monitor integrity or health of the concrete after curing.

[0017] In yet another embodiment, the present invention is directed to a software application for use with the above system to monitor concrete curing or integrity and health of a concrete structure after curing. Another software application is operable in a mobile device used with the above system.

Brief Description of the Drawings

[0018] This invention will be described by way of non-limiting embodiments of the present invention, with reference to the accompanying drawings, in which:

[0019] FIGs. 1-3 illustrate some advantages for motivating the present invention;

[0020] FIGs. 4-6 illustrate concrete curing and structural integrity and health monitoring systems according to embodiments of the present invention;

[0021] FIGs. 7-8 illustrate a wired concrete sensor controller according to an embodiment, whilst FIGs. 9-10 illustrate a wireless concrete sensor controller;

[0022] FIG. 11 illustrates concrete sensor controller according to another embodiment;

[0023] FIG. 12 illustrates a portable cement-moisture probe configured with a moisture sensor of the present invention;

[0024] FIG. 13 illustrates some concrete sensors for monitoring integrity and health of a concrete structure obtained after erection;

[0025] FIGs. 14-15 illustrate user interfaces of a software application for displaying the IoT sensor data recorded in the above system;

[0026] FIG. 16 illustrates casting of concrete cube samples and carrying out structural tests in a laboratory;

[0027] FIG. 17 illustrates simulating large volume in-place concrete curing and coring of samples for structural tests; and

[0028] FIGs. 18-22 illustrate structural test results obtained on the above concrete cube test samples, whilst FIG. 23 illustrates structural test results obtained on the above in-place concrete coring test samples.

Detailed Description

[0029] One or more specific and alternative embodiments of the present invention will now be described with reference to the attached drawings. It shall be apparent to one skilled in the art, however, that this invention may be practised without such specific details. Some of the details may not be described at length so as not to obscure the present invention.

[0030] The speed of concrete curing is observed to increase as the concrete volume increases. As mentioned in the background, this industry still uses 10cm concrete cubes samples to understand or interpret the strength of concrete for constructions or for building regulation requirements. However, the concrete strength of an actual structure is often higher than the concrete cube samples that are tested due to the large volume of concrete when building a structure. With a real-time sensor or sensors embedded within the curing concrete, users would know earlier the time when their structure has reached sufficient strength for the next stage of work; thus, this saves time on waiting. FIG. 1 shows that with use of these sensors of the present invention, the numbers of concrete cubes required at a construction site can be reduced from about 800 cubes/month to about 200 cubes/month. Reducing the numbers of cubes for testing also mean reducing CO_2 emissions. FIG. 1 shows that the waiting time for concrete to attain sufficient strength is shorter means that the cycle time for erecting a concrete structure becomes shorter by using this invention. Thus, there are economic savings to develop these sensors and accompanying systems. FIG. 3 shows that some sensors embedded during casting of concrete can be used for continuous monitoring of the integrity and/or health of the concrete structure that has been erected.

[0031] FIG. 4 shows an overview of the concrete curing system **100** and structural integrity and health monitoring system **400** according to embodiments of the present invention. As shown in FIG. 4, IoT concrete curing sensors **110** include a temperature sensor **110a** and a moisture sensor **110b**. These sensors may be wired or wireless; the sensors can also be

passive or active with regards to the power supply. It is possible to provide additional IoT sensors **410** to monitor a health status of the concrete, for eg. strain or stress sensor **410a**, corrosion sensor **410b** for monitoring condition of a reinforced bar, etc.; it is also possible to provide vibration sensor **410c**, water seepage sensor **410d**, relative humidity sensor **410e** to monitor conditions of use of the concrete structure after being erected; such additional sensors **410**,**410a**,**410b… 410e** are useful to monitor the health or integrity of the concrete structure during its designed life span. These curing sensors or additional sensors can operate using electrode, MEM (micro electromechanical), electrochemical, piezoelectric, optic fiber gratings or any sensor technology that is suitable to monitor the curing process and/or health status of concrete; it is also possible that the sensor is a hybrid type and provides multi-functional uses, for eg. the electromechanical sensor is coated or deposited with a chemical or another material. Preferably, data from these sensors are collected through a gateway **150** located near the building construction site, before the data are sent to a data centre **160** (such as, a cloud storage facility) and a control station **170**. At the user's control station **170**, the sensor data are retrieved and analysed with a software app **200** to determine the strength of the curing concrete. In another embodiment, structural integrity and health data transmitted from the structural integrity/health sensors **410**,**410a…410e** are also sent to the control station **170** to monitor condition of the concrete structure. Results of curing time and strength attained and concrete structural integrity/health conditions are displayed at a user dashboard **220**,**220a**, preferably, in a graphical form for quick cognition or visualisation.

[0032] FIG. 5 shows a way of using the above concrete curing system **100**. As shown in FIG. 5, a curing sensor **110a**,**110b** is selected, a position for installing the sensor is identified and registered or paired with a mobile device **210** operating as an input device for the software app **200**. The curing sensors include at least a pair of the temperature sensor **110a** and the moisture sensor **110b**, and leads from the curing sensors are pulled to a location where the leads are terminated in a controller box **112** during the period of concrete curing; in one embodiment, the controller box **112** is secured to a nearby rebar **20** by cable ties **117** connected to lugs **116** extending from the controller box **112**; as laying of concrete progresses, the controller boxes **112** are removed and are re-used with newly embedded curing sensors **110a**,**110b**. The mobile device **210** can be any electronic device, a smart phone, tablet or a portable computer, with each input device preferably equipped

with a scanner or a camera for capturing a unique bar code or a QR code affixed onto the curing sensor 110a,110b; alternatively, identity numbers on the curing sensors **110a**,**110b** can be entered manually through the mobile device **210**. The pair of temperature and moisture sensors **110a**,**110b** are then attached to a rebar **20** at the registered position (for eg. with an identity name and/or coordinate grid x,y and z). After concrete is poured in to embed the sensors, data from the sensors are sent to the user's control station **170** via the associated gateway **150** and the data centre **160**. The sensor data can then be analysed at the control station **170** to determine the time for the concrete to attain a predetermined strength before the formwork at the current position can be moved to another position. In one embodiment, after erecting the concrete structure or part of the structure complete with the utility riser, the sensor controller box **112** is relocated to the utility riser, and the leads from the curing sensors **110a**,**110b** are terminated inside the sensor controller box **112**. In another embodiment, the controller box **112** is connected to more than one pair of temperature and moisture sensors **110a**,**110b**. The curing sensor controller box **112** may include a battery, an antenna for sending curing data to the gateway **150** and other supporting electrical and electronic components and wirings. In another embodiment, the controller box is miniaturized **312** or a controller **312a** configured by an encapsulated circuit board **315** (as will be described) can be embedded in the curing concrete together with the curing sensors **110a**,**110b**.

[0033] FIG. 6 shows further details of the way the above concrete curing system **100** works in FIG. 5. In FIG. 6, curing data from a plurality of sensors **110a**,**110b** (connected to a sensor controller box **112**) are sent wirelessly to the base station or the gateway device **150**. The sensor data (such as, temperature, moisture level, sensor name and location, concrete grade, and so on) are, preferably, aggregated in the base station/gateway device **150** and are then sent periodically to the data centre **160** (preferably, in cloud storage). For example, the sensor data are transmitted to the gateway **150** via short-range SR and long-range LR communications; these communications may adopt protocols like Sigfox, Lora, Bluetooth long-range low-power wide area network (LPWAN), wifi or cellular (3G/4G/5G,NBIoT). Preferably, the sensor data are aggregated into packages in the gateway **150** and this will reduce the bandwidth and cost for data transmission. In another embodiment, sensor data are transmitted directly from the sensor controller box **112** to the data centre **160**, for example, using wifi or cellular (3G/4G/5G,NBIoT) without need for

the gateway. At the control station **170**, the sensor data are analysed, so that continual construction steps are followed up promptly to realise the advantages of knowing early of the concrete reaching sufficient strength.

[0034] FIGs. 7 and 8 show the sensor controller box **112** with a plurality of ports **114** for connecting to a plurality of curing sensors **110a**,**110b** with their leads 118. Preferably, the sensor controller box **112** is provided with a size that can accommodate termination of the sensors **410**,**410a-410e** for monitoring the structural integrity and health of the concrete structure. In addition, the controller box **112** is made up of a base box and a cover, with the cover being removeably mounted onto the base box by using some screws. The base box can be mounted to a rebar **20** with cable ties or wires connected to lugs **116** extending from the base box, or with screws to the lugs after the controller box is relocated to the utility riser.

[0035] FIGs. 9 and 10 show the sensor controller **312** according to another embodiment. The sensor controller **312** is miniaturized and can be fixedly mounted to a rebar **20** by a cable tie or wire **117** threaded through a lug **316** extending from the sensor controller **312**. As shown in FIG. 10, the sensor controller **312** includes an integrated chip **310** mounted on a circuit board **315**. Some electronic signal processors are also provided on the circuit board **315** to convert, condition or calibrate signals from the curing sensors **110a**,**110b**. A capacitor **331** on the circuit board is provided as a power source; to charge the capacitor **331**, a portable charging pad **332** is brought into proximity to the sensor controller **312** and the capacitor **331** can be charged in a wireless manner through inductive charging, where an alternating current is passed through an induction coil in the portable charging pad **332**. The charging pad **332** is placed near a surface of the concrete where the embedded curing sensors **110a**,**110b** and the sensor controllers **312** are located. The magnetic field penetrates the concrete and generates an electric current in the sensor controller **312**, to charge up the capacitor **331**, which will then power up the curing sensors **110a**,**110b** and the sensor controllers **312**, and to transmit the sensor data to the gateway **150**. It is also possible that a wireless communication chip **333** is also provided on the circuit board **315** to support wireless sensor data transfer to the gateway **150**.

[0036] FIG. 11 shows the sensor controller **312a** according to yet another embodiment. As in the above embodiment, the sensor controller **312a** includes at least a circuit board **315**

and equipped with some electronic signal processors, a capacitor **331** and a wireless communication chip **333**. The sensor controller **312a** differs from the above embodiment in that the sensor controller **312a** is encapsulated in a resin, which gives the sensor controller water-proof protection. This embodiment may be useful in a use application where a concrete structure is erected in a marine environment; this embodiment is also useful where the concrete structure may experience underground water seepage.

[0037] Water-Cement Ratio: Water-to-cement ratio is a factor in determining the quality and durability of concrete. It is desirable to determine precisely the water-to-cement ratio of curing or freshly mixed concrete during construction. The electrical resistivity of concrete is a material property independent of sample geometry. FIG. 12 shows a portable water-cement probe **110c** is configured by adapting the moisture sensor **110b** of the present invention. For example, a voltage-drop across the moisture sensor **110b** using an electrical resistivity method is measured and calibrated to provide an accurate measure of the water-cement ratio of the curing or freshly mixed concrete. The water-cement probe **110c** includes a casing **113c** housing at least the moisture sensor **110b**, a circuit board **315** and a battery **330**. The casing **113c** has apertures **111** for water in the wet concrete to enter the water-cement probe **110c** and wet the moisture sensor **110b**. As described above, the circuit board **315** may be further supported by some electronic signal processors and a wireless communication chip **333**, to enable the water-cement probe **110c** to be used as a portable hand tool. For example, with the wireless communication chip **333**, the water-cement ratio data to be captured and sent wirelessly to the mobile device **210** or the gateway **150**. In addition, the water-cement probe **110c** can be provided with a read-out screen to display a reading of the moisture sensor **110b**.

[0038] FIG. 13 show the sensor elements **410**,**410a …410e**, which are also shown in FIG. 4; these sensor elements **410**,**410a…410e** are embeddable in curing concrete and the leads are extended to some junction boxes, which may be the same as the controller boxes **112**. These sensor elements **410**,**410a…410e** may be embedded alongside the above curing sensors **110a**,**110b** or being embedded separately away from the curing sensors. In one embodiment, after the building is erected, the junction boxes are furnished with associated circuit boards, electrical and electronic components, and power supplies. It is possible that the sensor elements may require calibrations with the electronic chips and signal processors located on the circuit boards. It is also possible that the power supply is

supplied externally, for eg., during periodic inspection and monitoring. This embodiment is useful in that some of the sensors are selectively used to monitor the health or integrity of the relevant parts of the concrete structure during its designed life; as shown in FIG. 3; such health or integrity monitoring may be for strength (strain or stress), corrosion, water seepage (such as, in a marine or underground structure), vibration, relative humidity; for eg.:

[0039] Corrosion monitoring: Corrosion is often caused by the imperfection during concreting and curing. Corrosion is mostly due to the incorporation of Cl^- and the reaction of atmospheric CO_2 with the constituents of concrete. Control measures are desirable because the corrosion evolution in the reinforced concrete structure produces expansion forces that lead to cracking, spalling or detachment of the concrete. In an embodiment, a corrosion sensor electrode or wire is tied to a rebar **20**, embedded in the curing concrete and the corrosion sensor electrode or wire is extended out with an electric conductor to a surface. After the concrete is hardened, the corrosion sensor wire is then terminated at a junction box or controller box **112** located at the utility riser. For structural health monitoring, the corrosion sensor electrode or wire is connected to a voltmeter, which will also be connected to a reference electrode where the potential is known (such as, copper or copper sulfate); this creates two half-cells; by examining the difference in the electrical potential between the two half-cells, the user can deduce the rate of corrosion. This application can be useful in an environment with high humidity, such as, a marine or underground environment.

[0040] Moisture monitoring: Moisture is important in curing of concrete. Moisture can exist as either water, especially at the start when the concrete is wet and curing, or as water vapour which provides a level of relative humidity in the concrete after the drying process. During curing, chemical reaction between cement and water (known as hydration) allows concrete to harden. Hence, it is common practice to take measures, such as wetting the surface of bare concrete and covering the concrete in plastic to control drying, especially in the early age process. Poor control of moisture can cause cracks, shrinkages and curling. However, past an elapsed of time after hardening, moisture level of the concrete needs to be lower through drying. For eg. according to ASTM F2170, the relative humidity of a concrete slab should generally be at or below 75% to be acceptable for tile application.

With this invention, users are able to monitor work quality or compliance to the relevant codes of practices by using the relative humidity sensor or element **410e**.

[0041] Although moisture control of concrete is desirable, many existing or conventional tests are more representative of the moisture level at the concrete surface than in-situ. As described above, the present invention provides a moisture sensor **110b** to monitor concrete curing. Users get a more accurate and in-situ measurement of the moisture level directly. In addition, moisture relative humidity sensor **410e** can be used for later stage monitoring of concrete integrity and health. The measurement of moisture relative humidity sensor is done by measuring the amount of water vapour in the air or environment. Capacitive or resistive humidity sensors can be used. For eg. a capacitive sensor may use a thin metal strip, which capacitance changes directly proportionally to changes in humidity. Resistive humidity sensor utilises ions in a salt medium and the amount of water vapour in the air is measured by the change in resistance of the salt medium between two electrodes. According to ASTM F2710, in-situ relative humidity test should be measured at a specific depth, which is at substantially 40% of the slab's thickness for slab drying from one side, or substantially 20% for a slab drying at two sides. In use, the moisture relative humidity sensor or element **410e** can be strategically embedded at these positions.

[0042] In the above description, some of the curing sensors **110a**,**110b** and their specific technologies have been described. Some of the structural integrity/health sensors **410**,**410a-410e** may be fabricated using other technologies. For eg., MEM sensors, such as, strain gauges, may be used as the structural integrity sensor element **410a** in which changes in strain, stress or vibration can be monitor at the associated controller box **112** or junction box. Similarly, piezoelectric or optic grating sensor elements may be used, in which changes in electric or optical properties can be used to monitor strain, stress or vibration on the concrete structure.

[0043] FIGs. 14-15 describe features of the software application **200** operable in the control station **170**. For eg., the software application **200** displays the temperature **226** of curing of the concrete, the corresponding strength **222**,**224** that the concrete has attained and provides some milestones **228** regarding the progress of construction work. Also displayed

are information relating to supplier of the concrete, batch identification, concrete specification and grade, and so on, that had been inputted through the mobile device **210**, transmitted to the associated gateway devices **150**, aggregated therein and sent to the data centre **160**. An associated software application **205** resides in each of the mobile device **210**.

[0044] To meet building regulations, the above curing sensors **110a**,**110b** are also used inside concrete sampling cubes, as shown in FIG. 16. This augment data recording and data aggregation from the test laboratories **250** into the data centre **160**.

[0045] The above concrete curing system **100** has been extensively tested at the structural laboratory. For eg. the temperature and humidity sensors **110a**,**110b** were selected, calibrated and tested **250** with sampling cubes and simulated large volume curing **260**. In the latter large volume curing tests **260**, shown in FIG. 17, concrete blocks were cored out and tested, and the sensors data were correlated to the test results. FIGs. 18-23 show some of the results of structural tests compared to the results obtained from the present invention using the above curing sensors **110a**,**110b**.

[0046] From the above description, one can appreciate that the sensor data, information on the concrete used in the construction of a structure and, possibly, structural tests data are stored in the data centre **160**; these data are accessible when needed, by the user, for regulatory or maintenance purposes. This invention implements all the advantages mentioned above, at least, reducing the numbers of test cubes required at a construction site, faster progression of work, and ability to monitor work quality and codes compliance.

[0047] While specific embodiments have been described and illustrated, it is understood that many changes, modifications, variations and combinations of variations disclosed in the text description and drawings thereof could be made to the present invention without departing from the scope of the present invention. For example, learning from data collected from the above system, it is possible to predict temperature, strength and other measurements pertaining to concrete curing (at a given concrete flow rate or volume) and health status ahead to allow users to take pro-active measure to maintain the concrete structure without causing further damage and harms.

CLAIMS:

1. A concrete curing and concrete health monitoring system comprising:

a portable water-cement probe to ascertain a water-cement ratio of wet cement that is delivered to a construction site, wherein the water-cement probe comprises a casing that houses a moisture sensor, a circuit board and a battery, with the casing having apertures for the wet concrete to enter the water-cement probe, and the circuit board is supported by some electronic signal processors and a wireless communication chip to send an output signal from the portable water-cement probe to a display screen located on the casing and/or to a mobile device that is connectable to a data centre and a control station;

wherein the mobile device is operable to register location and grade of the wet concrete to the data centre and the control station, so that after the water-cement ratio of the wet cement and the use location are ascertained, the wet concrete is allowed to be delivered.

2. The system according to claim 1, further comprising:

a temperature sensor and a moisture sensor for embedding in the wet concrete to monitor curing of the wet concrete;

the mobile device is operable to register identities and locations of the temperature sensor and the moisture sensor to the data centre and the control station; and

a software application, operable at the control station, translates curing parameters of temperature, moisture, time elapsed and concrete grade into a strength and curing time relationship.

3. The system according to claim 2 comprising a plurality of pairs of temperature and moisture sensors, further comprises a gateway device to aggregate outputs of the sensors into packages for transmission from the gateway device to the data centre and the control station to monitor curing of concrete at each location.

4. The system according to claim 3, further comprising:

a strain or stress sensor;

a corrosion sensor;

a vibration sensor;

a water seepage sensor; or

a relative humidity sensor, or a combination thereof to monitor integrity or health of the concrete after curing.

5. The system according to claim 3 or 4, wherein the sensor is selected from the following types: electrode, MEMs, electrochemical, piezoelectric, optical fiber, or a hybrid thereof.

6. The system according to any one of claims 1-3, further comprising a sensor controller associated with each of the sensor, wherein the sensor controller is wired or wireless.

7. The system according to claim 6, wherein the sensor controller is passively or actively supplied with a power supply.

8. The system according to claim 6, wherein the power supply is wirelessly chargeable, and comprises a capacitor and an associated charging pad.

9. The system according to claim 8, wherein the sensor controller further comprises an electric chip and a circuit board, with the circuit board being equipped with associated electronic components, so that the electronic components and the capacitor are encapsulated in a resin for waterproof protection.

10. The system according to claim 4, wherein the sensor for monitoring relative humidity is embedded at a predetermined depth from a surface of the concrete to monitor the humidity level to facilitate tiling or plastering work.

11. A method to monitor curing of concrete when building a concrete structure and to monitor integrity and health of the concrete structure after being built, the method comprises:

ascertaining a water-cement ratio of wet cement with a portable water-cement probe when the wet concrete is delivered to a construction site;

identifying a grade of the wet concrete;

pouring the wet concrete over a sensor to monitor curing of the wet concrete and providing sensor data output;

sending the sensor data to a data centre and a control station; and

using a software application, operable at the control station, to translate the sensor data, together with curing time and the grade of concrete, to determine a strength that the concrete has attained, so that follow on work can be performed promptly to completion.

12. The method according to claim 11, further comprises presenting results of concrete curing strength and curing time relationship at a user dashboard in a graphical format.

13. The method according to claim 11 or 12, further comprises aggregating data from a plurality of sensors into packages in a gateway device for periodic transmission to the data centre.

14. The method according to any one of claims 11-13, further calibrating the sensor to monitor strain-stress, corrosion, vibration, water seepage or relative humidity in order to monitor integrity and health of the concrete after curing.

15. The method according to any one of claims 11-14, further augmenting data recording and data aggregation from test laboratories to the data centre.

16. A software application for use in a mobile device for registering and recording sensor identity and position as recited in any one of claims 1-10.