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METHODS FOR REMOTE QUALITY CONTROL OF COMPOSITES WITH ORGANIC AGGREGATES

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The Chinese construction industry has been using the Internet of Things (IoT) to monitor building materials and structures for many years. The achievements of the Chinese construction industry in IoT applications can be used to study and monitor the performance of building materials, including green buildings (energy-efficient building materials).

The aim of research: study and optimization methods for remote quality control of composites with organic aggregates.

With the help of the developed methods, the following dependencies were obtained: dependences of stresses inside composites with organic aggregates on external influences obtained using a sensor Keyes brick thin film pressure sensor, dependences of deformations inside composites with organic aggregates on external influences obtained using a sensor ultrasonic ranging sensor, dependences of humidity inside composites with organic aggregates on external influences obtained using a sensor Soil moisture sensor, dependences of rheology (cement paste setting time) obtained using a sensor Ph-sensor module.

Keywords: *internet of things, methods for remote quality control, composites with organic aggregates*.

Introduction. In order to ensure the safety of the building, it is necessary to monitor the health of the key parts of the building in real time and forecast the safety situation, so as to find the location of the problems inside the building structure and the severity of the related problems as soon as possible, and then accurately predict the performance of the building structure and predict the situation [1]. Estimate the remaining life of the building and make corresponding maintenance decisions according to the specific situation of building safety, so as to effectively solve the problem of building safety prevention and health monitoring, prevent the occurrence of building-related accidents and disasters, and ensure the safety of users' lives and property [2]. In normal production and life, building safety monitoring has received more and more attention from people.

The Chinese construction industry has been using the Internet of Things (IoT) to monitor building materials and structures for many years [3–8]. The achievements of the Chinese construction industry in IoT applications can be used to study and monitor the performance of building materials, including green buildings (energy-efficient building materials [9–26]).

The aim of research: Study and optimization methods for remote quality control of composites with organic aggregates. To achieve the aim, the following objectives were solved: make an overview of the experience of the Chinese construction industry in implementing methods internet of things for remote quality control of building materials and structures; compare the quality characteristics of composites with organic aggregates tested in the laboratory and using special sensors: compressive strength, deformation, humidity, cement paste setting time; give recommendations on optimizing the accuracy of the sensors for remote quality control of composites with organic aggregates.

Main part. Methods for monitoring various indicators in building materials and structures will be presented below.

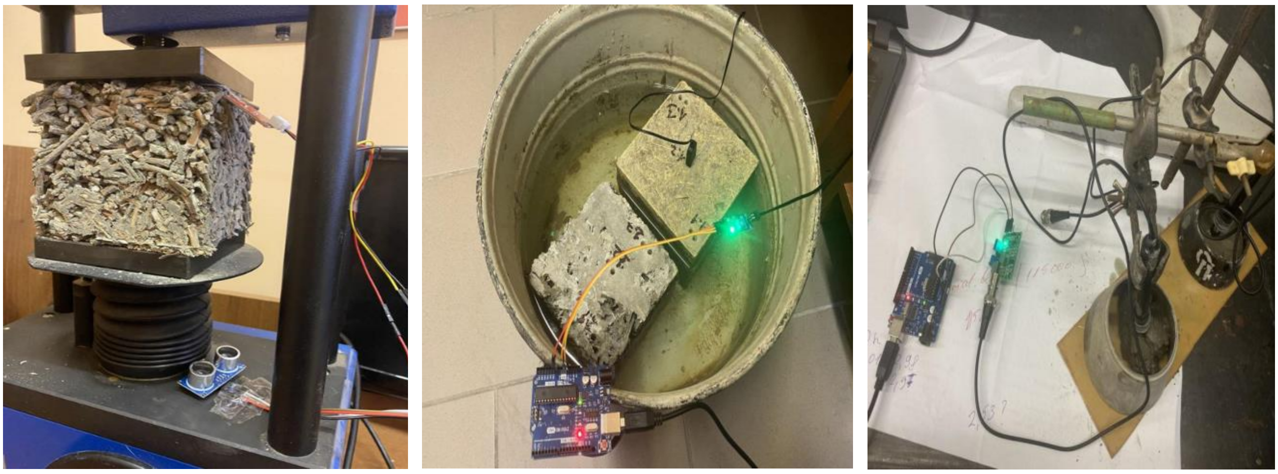
Method for remote quality control of the stress-strain state of composites with organic aggregates using ultrasonic ranging sensor and Keyes brick thin film pressure sensor: Ultrasonic ranging sensor and Keyes brick thin film pressure sensor are placed on the outer surfaces and inside the material (figure 1, *a*). Sensors collect information about the material. The example is placed in the PM-2MG4 press and the test begins. The press shows the load and strain values. Sensors show similar values. As can be seen from table 1, these values correlate well with each other.

The following samples were used: straw-cement sand block with a density of 1350 kg/m^3 (example 1) and wood concrete with a density of 550 kg/m^3 (example 2).

Method for remote quality control of the humidity state of composites with organic aggregates using humidity sensor: Humidity sensor are placed on the inside the material (figure 1, *b*). Sensor collect information about the material. For moisture monitoring, samples are first dried to constant weight and then placed in a container of water. At certain intervals, they are removed from the water and weighed (their moisture content is determined). Humidity sensors show their values in parallel. The results of moisture determination at different points of the material, as well as their correlation, are shown in table 2. The results showed a high correlation with the standard method.

The following samples were used: straw-cement sand block with a density of 1350 kg/m^3 (example 1) and wood concrete with a density of 550 kg/m^3 (example 2).

Method for remote quality control of the rheology (cement paste setting time) using Ph-sensor module: Ph-sensor are placed on the inside the control liquid for calibration. After Ph-sensor are placed on the inside the cement paste (figure 1, *c*). For tests, a cement paste of normal density (example 1) and a cement paste of normal density with the addition of a giperplasticizer (example 2) were selected with a reduction in water consumption by 30%. In parallel with the work of the sensors, the setting time was determined on the Vicat device. Sensors collect information about the material. The results obtained by the sensors generally coincide with the tests on the Vicat device (figure 2).



a **b** ***c***

a **– of the stress and strain;** ***b*** **– of the humidity;** ***c*** **– of the setting time of the cement paste**

Figure 1. − Location of sensors in the material to obtain the values

Table 1. – Changes in pressure and deformation of composite materials tested by sensors and press

Example 1					
Data obtained from the press PM-2MG4:		Data received from sensors:		Statistical indicators	
Compressive strength, kN	Deformations, mm	Pressure sensor	Distance sensor	Correlation compressive strength	Correlation deformations
0,003	0,2	430	6,90	0,93	0,99
0,005	0,3	626	6,92		
0,019	1,5	847	7,50		
0,032	1,7	946	7,60		
Example 2					
Data obtained from the press PM-2MG4:		Data received from sensors:		Statistical indicators	
Compressive strength, kN	Deformations, mm	Pressure sensor	Distance sensor	Correlation compressive strength	Correlation deformations
0,189	0,6	563	7,50	0,83	0,95
0,233	0,8	747	7,60		
0,363	1,0	859	7,60		
0,774	2,1	911	7,69		
0,961	3,8	953	7,79		

Table 2. – Changes in pressure and deformation of composite materials tested by sensors and press

Example 1 (Dry mass = 4,714 kg)								
Time (min)	Humidity Sensor Value in point №:			Mass of moistened per time,kg	Humidity per time, %	Correlation between sensor value and humidity		
	1,1	1,2	1,3			1,1	1,2	1,3
0	1	0	0	4,714	0,00	0,997	0,999	0,993
10	366	426	345	5,374	14,00			
15	391	429	352	5,380	14,13			
20	397	429	381	5,380	14,13			
25	402	429	397	5,380	14,13			
Example 2 (Dry mass = 2,180 kg)								
Time (min)	Humidity Sensor Value in point №:			Mass of moistened per time,kg	Humidity per time, %	Correlation between sensor value and humidity		
	1,1	1,2	1,3			2,1	2,2	2,3
0	0	0	0	2,180	0,00	0,997	0,999	0,994
10	382	395	459	2,772	27,16			
15	449	421	461	2,834	30,00			
20	472	430	461	2,850	30,73			
25	476	430	461	2,850	30,73			

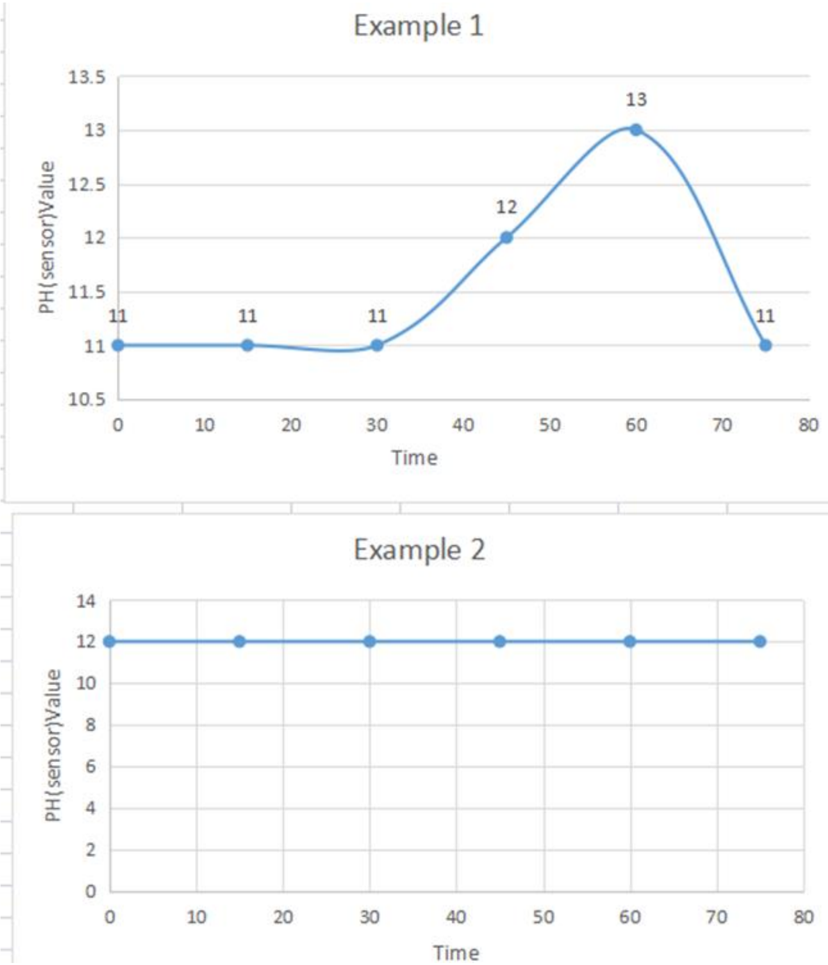


Figure 2. − Rheology (set time of cement paste) linear diagram

Conclusions and recommendations for the further use of sensors for remote monitoring of properties. Method for remote quality control of the stress-strain state of composites with organic aggregates using ultrasonic ranging sensor and Keyes brick thin film pressure sensor, method for remote quality control of the humidity state of composites with organic aggregates using temperature and humidity sensor, method for remote quality control of the rheology (cement paste setting time) using Ph-Sensor Module – work and show good results. With the help of the developed methods, the following dependencies were obtained: dependences of stresses inside composites with organic aggregates on external influences obtained using a sensor Keyes brick thin film pressure sensor, dependences of deformations inside composites with organic aggregates on external influences obtained using a sensor ultrasonic ranging sensor, dependences of humidity inside composites with organic aggregates on external influences obtained using a sensor Soil moisture sensor, dependences of rheology (cement paste setting time) obtained using a sensor Ph-sensor module. The results obtained using the developed methods showed a high degree of correlation with standard tests and can be recommended for determining the properties during the operation of buildings and structures. For a more reliable determination of the strength and deformation characteristics, it is recommended to isolate the sensors from interference. For a more accurate determination of the characteristics of materials and structures, it is recommended to use ADCs of higher accuracy classes. Method for remote quality control of the rheology (cement paste setting time) using Ph-Sensor Module can also be used to control concrete carbonation and durability, but this needs more research.

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МЕТОДЫ ДИСТАНЦИОННОГО КОНТРОЛЯ КАЧЕСТВА КОМПОЗИТОВ С ОРГАНИЧЕСКИМИ ЗАПОЛНИТЕЛЯМИ

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Китайская строительная отрасль уже много лет использует Интернет вещей (IoT) для мониторинга строительных материалов и конструкций. Достижения китайской строительной отрасли в приложениях IoT могут быть использованы для изучения и мониторинга характеристик строительных материалов, в том числе зеленых зданий (энергоэффективных строительных материалов).

Цель исследования: изучение и оптимизация методов дистанционного контроля качества композитов с органическими заполнителями.

С помощью разработанной методики были получены следующие зависимости: зависимости напряжений внутри композитов с органическими заполнителями от внешних воздействий, полученные с помощью тонкопленочного датчика давления Keyes, зависимости деформаций внутри композитов с органическими заполнителями от внешних воздействий, полученные с помощью ультразвукового датчика перемещений, зависимости влажности внутри композитов с органическими заполнителями от внешних воздействий, полученные с помощью датчика влажности, зависимости реологии (время схватывания цементного теста), полученные с помощью датчика Ph-sensor.

Ключевые слова: *интернет вещей, методы дистанционного контроля качества, композиты с органическими запонителями.*