PACE-2021
International Congress on the Phenomenological Aspects of Civil Engineering
Research Article 20-23 June 2021

Application of Temperature Measurement in Concrete Structures with Remote Monitoring System

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Keywords

Internet Of Things,
Civil Engineering,
Concrete,
Sensor,
Temperature.

Abstract

With the development of sensors and Internet of Things (IoT) technology, intelligent systems are rapidly introduced into our daily lives. Today, Intelligent Systems find applications in very different areas with the advanced technology they use. In the field of civil engineering, the importance of IoT for the impression of buildings and building health is increasing day by day in order to achieve well-performing, long-lasting, sustainable buildings. In this study, remote monitoring of concrete internal temperature measurements of an automated wireless sensor monitoring system using IoT for Civil Engineering Structures was aimed. The LM35 sensor is embedded in the concrete. According to the experimental results in this case, the concrete temperature readings with wireless signal transmission measurement technique has been developed that allows simultaneous measurements in reinforced concrete structures. The development of new sensors, the parameters from an early age to the monitoring of environmental conditions have been shown to play an important and promising role.

1.Introduction

Ubiquitous detection systems provided by wireless sensor network technologies cover many areas of modern life. This system offers the ability to measure, subtract and understand environmental indicators. Thus, with the development of sensors and IoT technology, intelligent systems are rapidly increasing their popularity in our daily lives. With the development of IoT, more smart devices are entering people's lives and allowing them to develop applications aimed at making human life easier [1,2]. Transferring information to the internet and providing it to people real and simultaneously will make a serious contribution to making systems more efficient, reliable and comfortable. In the field of Civil Engineering, IoT is also widely used for different purposes, especially smart buildings, smart cities, smart homes, smart stops. In addition, integrated monitoring systems (sensors) and procedures are recognized to play a promising role in achieving long-lasting, sustainable buildings that perform well in terms of structural health of concrete structures, and their importance is growing day by day. Barroca et al. (2013) [3] these systems will enable monitoring of deformations occurring in concrete structures, planning maintenance programs and early warning of new problems, thus minimizing the costs involved. Fan et al. (2020) [4], realized the impression of corrosion of reinforced concrete structures with fiber optic sensors in its application. Liao et al. (2020) [5] has developed an intellectual system for monitoring concrete slab exposed to external temperature fluctuations. Shemin et al. (2019) [6] examined the early age compressive strength of concrete using the IoT method and they found that the early compressive strength matches well with the actual compressive strength using the maturity relationship. Ghoorun (2018) [7] conducted a lower-cost study that tracked environmental values by using the Internet of things instead of smart buildings that were high in cost, performing instant environment monitoring. Górriz et al. (2016) [8] used a new fiber optic sensor based on regenerated Fiber Bragg grids specifically designed to be embedded in concrete structures to monitor temperatures during fire events in their work. Romero et al. (2016) [9] has developed a Potentiometric sensor that uses thick film technology to monitor and control the carbonation process. The installation of small sensors inside or on the surface of concrete can be considered as one of the most promising developments for monitoring the long-term behavior of concrete structures. In this study, remote monitoring of internal temperature measurements of concrete together with wireless sensor monitoring system using IoT feature in concrete structures was examined. The use of LM35 (temperature) sensor with Arduino platform is discussed.

2. Experimental program

2.1. Materials used

The cement used in the experiment is standard CEM I 42,5 R Portland cement which is the production of the Afyonkarahisar Cement Industry factory (TS EN 197-1, 2012) [10]. The chemical and physical properties of CEM I 42,5 R cements used are shown in Table 1.

Table 1. Physical and chemical analysis of CEM I 42,5 R Portland cement

Chemical Analysis	Analysis Results
SiO_2	20,62
Al_2O_3	5,65
Fe_2O_3	4,05
CaO	62,08
MgO	2,55
SO_3	2,57
Other Features	
Ignition Loss	1,55
Intensity (gr/cm^3)	3,11
Blaine (cm^2/gr)	3054

In the production of concretes, two different aggregate sizes of thin and medium sizes were used: 0/6 mm and 6/12 mm. Physical properties of aggregates are given in Table 2. Afyonkarahisar province, which complies with TS EN 1008 [11], used city mains water.

Table 2. Physical properties of aggregates

Grain Size (mm)	Rate of Humudity (%)	Water Absorption (%)	Specific Gravity (kg/m3)
0/6	1.72	1.564	2.630
6/12	0.56	0.563	2.694

9.3 Testing system and manufactured specimen

As a result of sieve analysis conducted in accordance with TS 3539 EN 933-1 standard [12], the amounts of 0/6 mm and 6/12 mm were proportioned and blended to determine the amount of aggregate before the concrete was prepared. In all mixtures, the amount of cement as a binder and the ratio of water to cement were kept constant. The materials and quantities used in the production of concrete samples are given in Table 3. Mixtures are mixed in batches in concrete for 5 min to be produced homogenously. Aggregates and cement were put in the mixer and dry mixture was made for 1 minute. Then, the mixture water was added to the mixer and the mixture continued for another 4 minutes. Concrete is manufactured to be a cube sample with a size of 150x150x150 mm. Sensors measuring LM35 temperature are embedded in the fresh concrete produced. In the vibration machine, concrete was placed in molds and kept in a laboratory environment for 24 hours. At the end of 24 hours, samples that complete the socket in the mold are removed from their molds and left in water at a temperature of 20±2 °C for 1 day until they become saturated. IoT application was applied to concrete samples produced in laboratory environment. In conjunction with the Arduino platform shown in Figure 1, the use of the LM35 sensor was carried out. The samples produced were placed in the study oven with the experimental assembly and heated to 110 °C and data flow readings were made. Finally, the heated samples were put back into water and subjected to cooling process, and data reading through the samples was monitored remotely along with the wireless sensor monitoring system.

Table 3. Components and quantities of materials used in the experiment

Components	**Quantities (kg/m³)**
Cement	300
Water	180
Thin Aggregates	896
Medium Aggregates	908
Total	2284
W/C	0.6

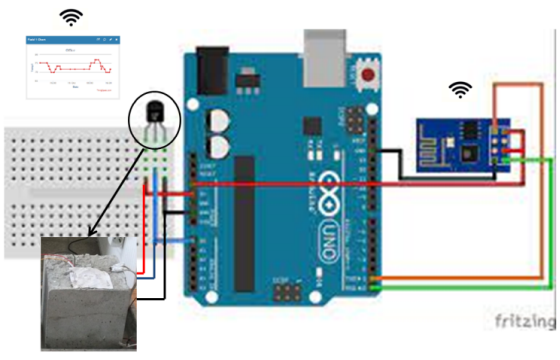


Figure 1. Together with the Arduino platform, LM35 (temperature) sensors and IoT test assembly

3. RESULTS AND DISCUSSIONS

3.1. Receiving Data from Heated Sample

Data flows from heated samples can be seen in Figure 2. As the temperature of the furnace increases depending on time, the graph shows that the internal temperature of the measured samples usually increases in a regular manner. The measured temperature is similar to the ambient temperature, where small changes are also caused by the drying process. The maximum internal temperature read in heated samples is 93.84 °C.

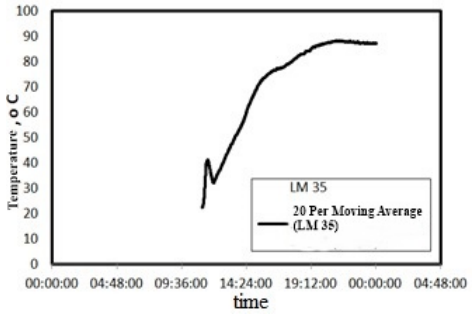


Figure 2. Values taken from the heated sample

a. Obtaining Data from The Cooled Sample

Data flows obtained from cooled samples can be seen in Figure 3. In this process, it is possible to read from the graph that the internal temperature of the concrete decreases regularly over time, as concrete samples are subjected to cooling. The minimum value read during the experiment is 34.19 °C.

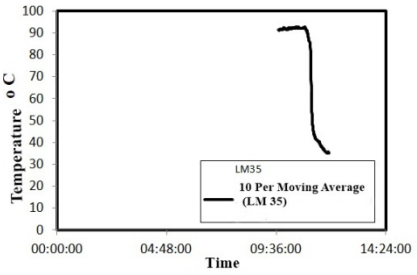


Figure 3. Values taken from the cooled sample

4. CONCLUSIONS

In this study, applications were made for remote monitoring of concrete internal temperature measurements together with wireless sensor monitoring system using IoT feature in concrete structures and the following results were reached.

- The internal temperature of heated samples increases over time,
- In cooled samples, the internal temperature decreases over time,
- A new measurement technique has been developed that provides real and simultaneous measurements with wireless signal transmission.
- Instantaneous data was obtained successfully over the internet from any place desired.
- In the field of Civil Engineering, IoT technologies, especially in the field of building health, have been seen to be used in durability and building material applications.
- The rapid development and implementation of intelligent and IoT-based technologies allows for a variety of possibilities in technological advances for different aspects of life.

It will offer practical solutions that perform well with IoT, long life, monitor the deterioration process of structures, and minimize associated maintenance costs. As a result of these studies, it is seen that intelligent systems can be used effectively in different applications in the field of civil engineering.

Declaration of Conflict of Interests

The authors declare that there is no conflict of interest. They have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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