

## RESEARCH ARTICLE



# 4-Channel Concrete Temperature Data Acquisition System Using GPRS data Network

## OPEN ACCESS

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## Abstract

**Objectives:** To design a non-destructive, low-effort, low-cost device that can estimate the early age and compressive strength of in-place concrete in real time. The maturity protocol eliminates the need for on-site concrete cylinder break checks or hammer tapping test saving time and resources. **Methods:** Four different temperature sensors were used to measure the temperature of concrete in order to improve the system's accuracy. As concrete structure monitoring with temperature sensors is a continuous process, the study includes automated data logging at regular intervals, storage of measured temperature data over time on an attached SD card, and transmission to a server through the SIM800L's GPRS capability. **Findings:** The current work presents a low-cost (31 USD), low-powered (3.7v/2.8A), and portable temperature sensor and logger that will track and record temperature values so that values can be monitored remotely from anywhere on the planet. Data can be managed and tracked from any location and on any computer that has internet access. Communication between presented units with MQTT platform has been studied. **Novelty/Applications:** This device is a simple battery-operated, small-size, compact, low-power data acquisition system with multiple sensors. With the support of GPRS, data can be sent to a server. Concrete testing delays are no longer a concern. It is possible to check the status of pour and receive updates anytime, wherever, on any computer with this method's real-time data and 24/7 remote monitoring capabilities. This simple, trouble-free module is completely integrated and needs no wires or testing laboratories, allowing for quick onsite decisions and preventing unnecessary setbacks.

**Keywords:** GPRS; DS18B20; ESP8266; MQTT (Message Queuing Telemetry Transport)

## 1 Introduction

Compressive strength plays a fundamental capacity in the solidness of designs. The compressive strength of standard examples is resolved in two unique manners is to be: Cubes and Cylinders. The curing of the concrete cube /standard cylinder ought to be accomplished for 7 days, 14 days, and 28 days as per the test results, and the concrete cube /standard cylinder should be cured appropriately<sup>(1)</sup>. This strategy is tedious while it is important to ensure the quality of the material. The current strategy is simply dependent on the time span to decide the concrete strength during the hydration process. Mainly, the concrete strength relies upon both time and temperature. Utilizing this TTF (Time Temperature Factor) the concrete strength will be predicted. Therefore, the assessment of concrete strength by checking the concrete temperature using a sensor is discovered to be applicable<sup>(2)</sup>. The temperature history would then be able to be utilized to figure out the time and temperature factor of concrete, empowering the client to predict its initial age compressive strength. Observing of the floor utilizing the implanted sensors is progressing with automatic data logging at successive time intervals<sup>(3)</sup>. Distantly observing the real-time strength of cement with wireless techniques is consequently appealing<sup>(4)</sup>.

Data acquisition is a significant segment of any automation system. Data acquisition is used to get data from sensors and different sources under PC control and bring the information from various channels together to store and control it<sup>(5)</sup>. Data logging can be characterized as collecting, analyzing, and storing data for future use. Where there is the need to gather data quicker than a human cerebrum, data loggers can gather the data and in situations where exactness is fundamental. One of the vital advantages of using data loggers is its capacity to naturally gather information on a 24-hour basis<sup>(6)</sup>. MQTT or the Message Queuing Telemetry Transport Protocol is a straightforward and lightweight messaging protocol. Its publish/subscribe mechanism is intended to be not difficult to execute. Utilizing the MQTT protocol, we see that it is without a doubt conceivable to communicate sensor information from one gadget to the next which can likewise be utilized to control electronic gadgets<sup>(7)</sup>.

In<sup>(8)</sup> focused on 20% to 90% various degrees and 50-degrees remote sensors organizations and area of Humidity temperature parameters through a framework that incorporates GTRs. Wired (Serial) and Wireless (Zigbee) and Ethernet communications are used to collect the data from multiple sensors in<sup>(9)</sup>. In paper<sup>(10)</sup> it explains for grid-connected photovoltaic system, checking is considered as a vital viewpoint for noticing the security and execution of the framework. A Zigbee-based wireless monitoring system is developing for online monitoring of a grid-connected photovoltaic system. In<sup>(11)</sup> describes that the data logger meets all the requirements of accuracy. The new Data logger is autonomous, open-source and flexible and this Data-logger is widely used for low-cost projects. In the field of wireless technologies and sensor networking, a lot of advancement is happening<sup>(12)</sup>. The concrete compressive strength is the most important to know in the construction process. The traditional and recommended process to make sure the concrete strength is to implement cylinder test. The early age test data is necessary to get reliable values of the two constants which are required for the prediction<sup>(13)</sup>.

In<sup>(14)</sup> investigated the mechanical properties, chloride ion permeability, relative dynamic elastic modulus, and mass loss ratio of concrete specimens cured in temperatures ranging from natural, 40, 60, 75, and 90 C, with humidity maintained at 90% continuously, to determine the durability of concrete in the actual temperature and humidity of the tunnel area. The high temperature curing environment can benefit early stage strength development but reduce long-term strength, according to experimental findings. It has been established that 60°C is a critical temperature. The strength of the concrete material and its resistance to chloride ion permeability decreased as the temperature rose above 60°C; however, in the acceptable temperature range, the strength and resistance to chloride ion permeability increased. The concrete's frost resistance properties increase as the temperature increases.

In<sup>(15)</sup>, the effect of temperature curing on HPC compression strength was investigated as part of our workplace's high-performance concrete (HPC) study. At 1, 3, 7, 14, and 28 days old, samples were checked.

- It has been shown that temperature treatment has a beneficial impact on the rate of increase in compressive strength in the early stages of concrete maturation. As a result, the hypothesis that temperature treatment could speed up the increase in compressive strength but not the final value of compressive strength was verified.
- 50°C is the optimum curing temperature for high short-term compressive strengths. The compressive strength of the samples treated in 50°C water and the reference samples increased by about 30% within the first 7 days at this temperature, then the variations in compressive strength between the samples treated in 50°C water and the reference samples decreased, and at the age of 28 days, the strengths were nearly equal.
- Temperature treatment in 10°C was only a complement of the research. A slower increase of the compressive strength compared to the reference samples was expected. Likewise, the reference samples reached higher values of compressive strength at the age 28 days.
- The belief that heat treatment causes a decrease in tensile strength was supported by tensile strength testing of the investigated type of high-performance concrete. Reference specimens had the maximum tensile strength. As compared to

specimens cured at 50°C and 80°C, it was 15% higher. It appears that a general conclusion about the impact of temperature treatment on tensile strength cannot be reached. This phenomenon is informal and varies depending on the type of cement composite and its composition.

- The tensile strength of specimens handled at 10°C was half that of reference specimens, which was an unexpected outcome.

Thermal shock can cause permanent deformation, and aggregate expansion can cause distress inside the concrete. Concrete's compressive strength is also impaired by high temperatures. As the temperature rises above 212°F, the cement paste dehydrates (loses chemically mixed water of hydration), weakening the paste and the paste-aggregate bond.

Infrastructure is a fundamental necessity for economic growth. It does not directly produce goods and services, but by developing positive external economies, it facilitates activity in primary, secondary, and tertiary economic activities. It is a well-known fact that a country's degree of economic growth is tightly connected to its infrastructure development. It has a major impact on the growth of not only the economy but also society. It is a public utility provider that provides products and services with location and time utility. They also connect manufacturing, fulfilment centres, and end users. As a result, infrastructures connect the various components of the economic system.

For such an important factor of any nation it is important to maintain good health of all these infrastructures so that they can function for long time duration. Early detection of any problem reduces the time and cost of repairing.

Concrete, steel, and fibre-optic cable are critical and fundamental components that contribute to the structural strength of any structure. By tracking and predicting the overall functional state of the systems, these essential factors can be tracked and maintained.

Concrete spalling and delamination, consistent cracking patterns, and the forming of concrete chunks are all clear warning signs before structural failure. Such warning signs of inevitable crisis, on the other hand, may be found in a structure's interior or top pieces. It is difficult to inspect the damage in such situations. It is difficult to inspect the damage in such situations. Sensors can help to alleviate such problems. Aside from reducing the risk of sudden structural failure, installing monitoring sensors will provide owners with actionable data that will help them prepare for the future [19]. In [19] reviewed the different types of sensing techniques and their functionality with advantages and disadvantages. Out of which present work is based on the "Wireless Sensors" method for structural health monitoring.

But as per the universal law "precaution is better than cure" it will be good to take care of the essential factors and follow precautions during its construction phase. One method out of such techniques is monitoring the temperature of concrete during the construction phase. Concrete temperature regulation is an essential tool for ensuring the long-term strength and stability of concrete structures. Sensors for structural health monitoring is non-destructive method and have many benefits over other methods for monitoring the health of concrete buildings, including the ability to track the danger from afar. Stiffness, moisture, density, dynamical properties, deformations, decay, and the cost, sustainability, and accuracy of the monitoring technique are all factors to consider when choosing suitable sensors for structural health monitoring. By considering all of these suitable sensors for present work is DS18B20.

The scope of this research is limited to the creation of a battery-powered multi sensory system that can communicate with a desired server or app via MQTT through GPRS and save data to an SD card at the same time.

## 2 Materials and Method

This study reports the design and development of an automated, IOT based low cost, multi-channel data acquisition and data logging system for civil construction application which is battery operated and reports the temperature at set intervals to MQTTLens. ESP8266 micro controller with DS18B20 temperature sensor is used to measure concrete temperature. Continuous temperature data is stored in the attached SD card. Measured temperature data with time is sent to server through GPRS facility of SIM800L. Message Queuing Telemetry (MQTT) is used for the data transfer.

### 2.1 System Design

The block diagram of the proposed system is shown in Figure 1. This system consist of five working blocks which includes Temperature sensor, RTC module, SD card module, and GSM/GPRS module are all attached with the ESP8266 microcontroller. The code is written in the Arduino IDE and then uploaded to the ESP8266. The ESP8266 (Wi-Fi enabled chip) chip is combined with the NodeMCU Development board, making it a self-contained device for IoT applications.

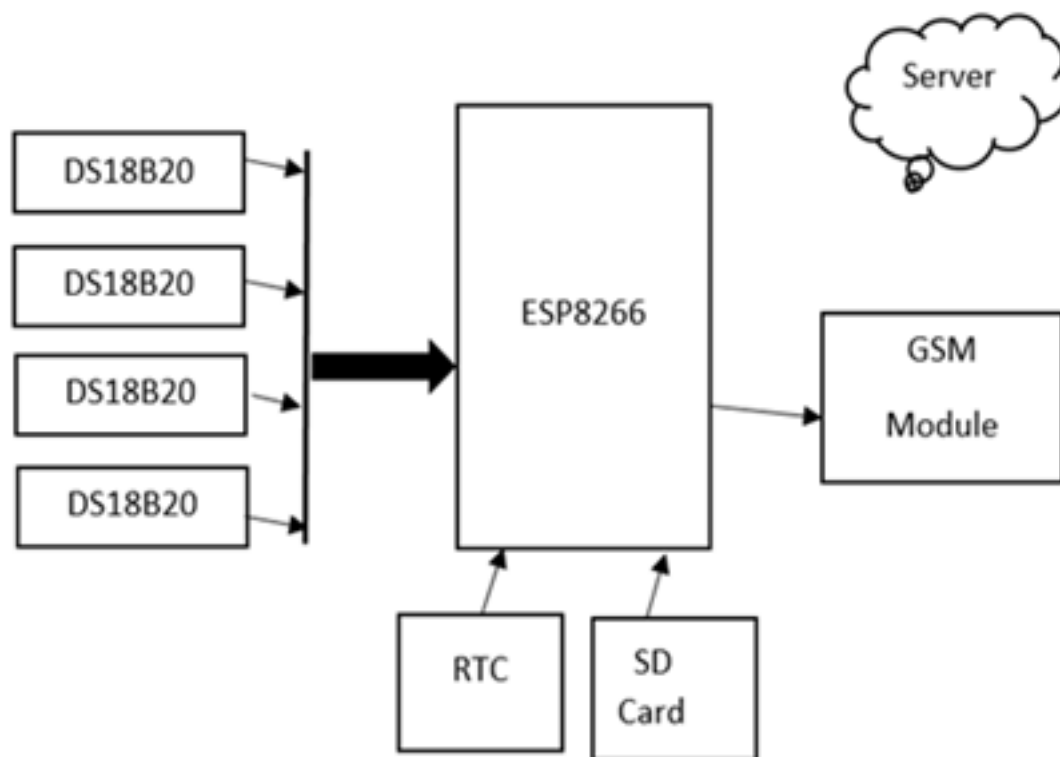


Fig 1. Block Diagram of Proposed System

### 2.1.1 Why DS18B20

Each DS18B20 temperature sensor has a 64-bit serial code that is special. This enables multiple sensors to be connected to the same data cable. As a consequence, a single GPIO can be used to obtain temperature from multiple sensors. Additionally, the temperature sensor's resolution can be set to 9, 10, 11, or 12 bits, which correspond to  $0.5^{\circ}\text{C}$ ,  $0.25^{\circ}\text{C}$ ,  $0.125^{\circ}\text{C}$ , and  $0.0625^{\circ}\text{C}$  increments, respectively. The default resolution at power-up is 12-bit. The waterproof version of the DS18B20 temperature sensor is suitable for outdoor projects or measuring liquid temperature.

It is simple to link the hardware with the data logger shield DS1307. It has an SD card slot, a Real Time Clock, and a level shifter for Arduino. It's a plug-and-play data logging shield, and we can start saving data to the SD card with the Arduino library. The DS1307 RTC (Real Time Clock) IC included in the kit can be used to timestamp all of the data with the current time. SIM800L is a full Quad-band GSM/GPRS arrangement in an LGA type that can be mounted in client applications and can communicate Voice, SMS, and information data while consuming very little power.

The data is transferred using MQTT. MQTT Lens is a chrome browser add-on that allows us to send messages to a MQTT broker by subscribing to MQTT topics and receiving messages via the chrome web browser. There are two TCP and Network sockets on it. Connection name, Protocol: tcp/ (default), Hostname: are all required credentials to build an account to receive or submit data. 1883 as a port (default). User Name and Password can also be specified for security purposes. User names and passwords are not included in this project. Simply subscribed using the topic name as the ESP8266 chip-id. Once subscription done, MQTTlence receives data and displays on its dashboard as shown in Figure 5.

## 2.2 PCB Design

The PCB design is shown in Figure 2. The PCB design is done with Eagle PCB design software. This software is easy to use and has a lot of features for designing circuit PCBs, whether they are basic or complex. We can also render new libraries.

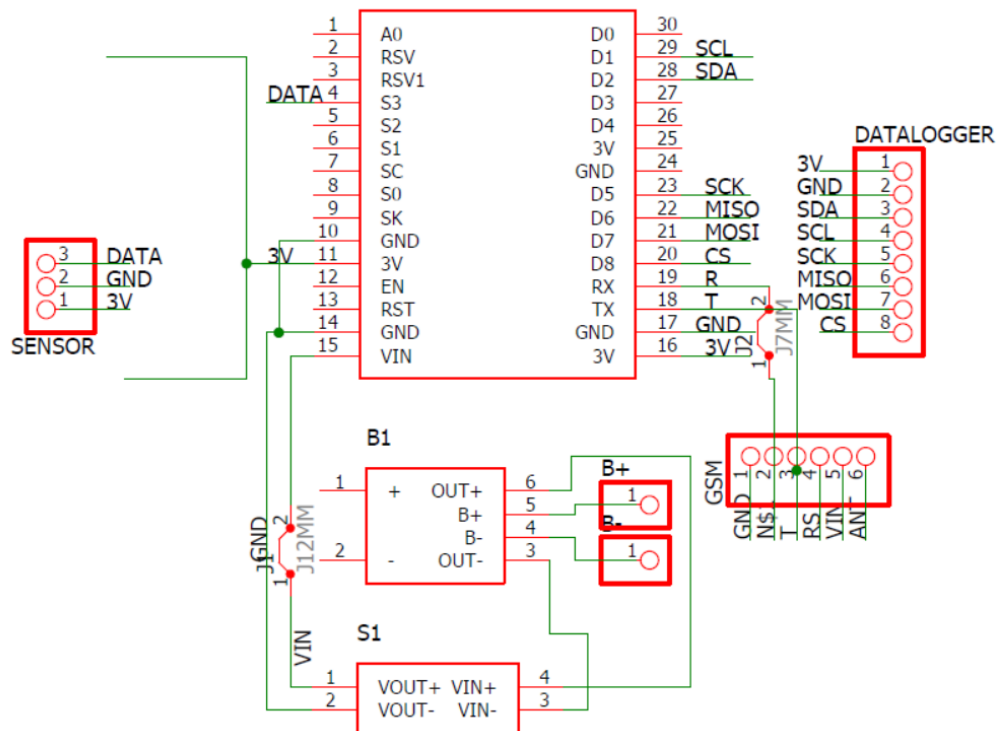


Fig 2. PCB Design of Proposed System

### 2.3 Concrete Temperature Monitoring System

The IOT based, low cost, multi-channel data acquisition and data logging system for civil construction application is designed and implemented. Figure 3, shows the Physical view of the proposed system.

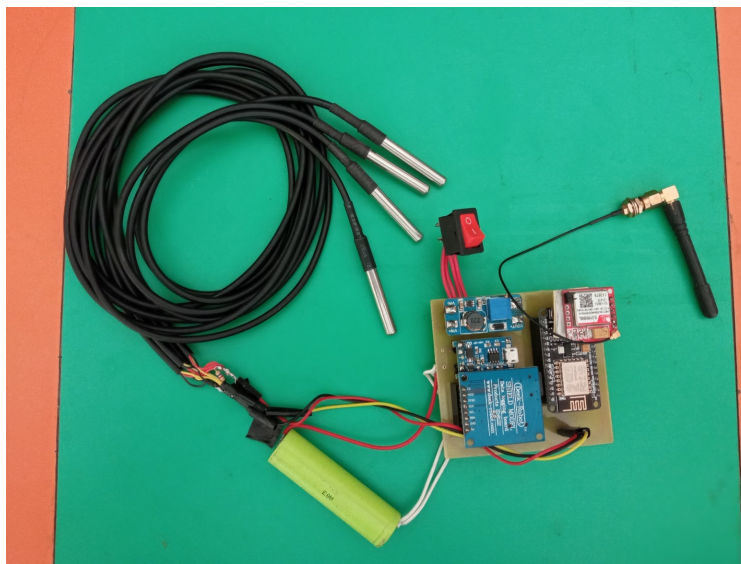


Fig 3. Concrete Temperature Monitoring System

## 2.4 Flow Chart

In Figure 4, the flow chart shows the working, or we can say the flow of information from the beginning of the project to the end. The first step is to connect the board to the computer and start the battery to begin the operation. The second step is to initialize RTC, SD card module, and four DS18B20 temperature sensors. The third step is to initialize the GPRS with the correct APN. When the GPRS got connected then the next step will be connecting to MQTT. Check the MQTT is connected or not. To connect the MQTT we need an active internet connection. After all the connection is done temperature data will be taken from all 4 sensors. The next step is to store the data into the SD card with the date and time. The final step is to send the data to MQTTLens with the correct date and time.

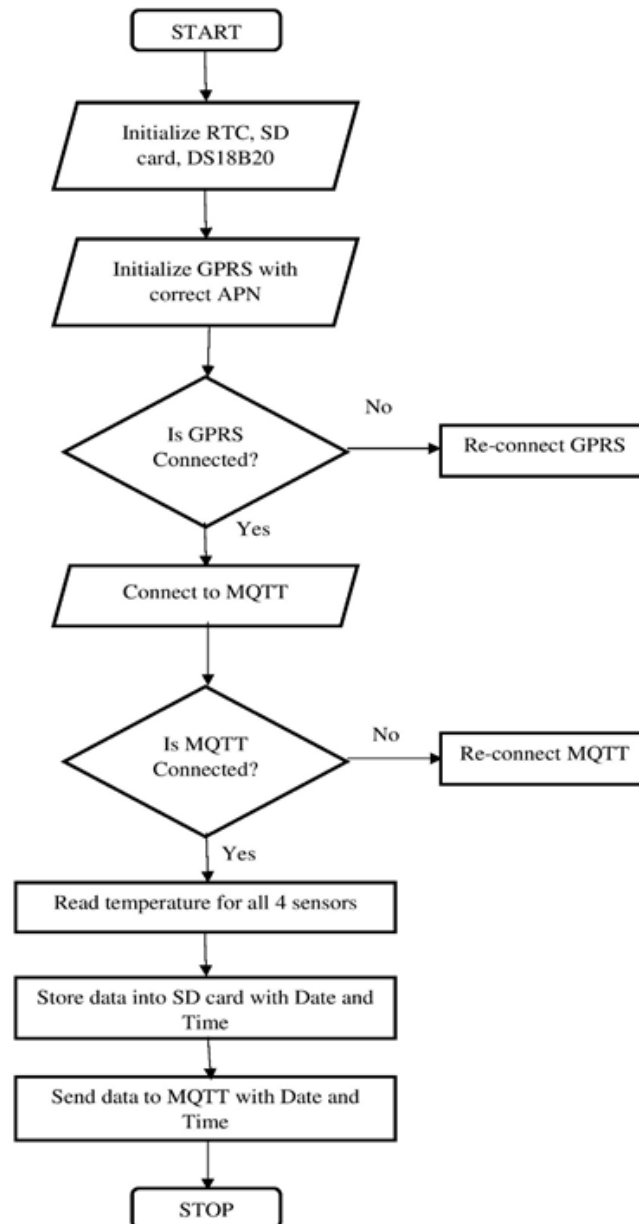


Fig 4. Flow Chart of the Proposed System



### 3 Results and Discussion

Use of ESP8266 facilitates the low power consumption and small size

#### 3.1 Data stored in SD card

The data stored in the SD card is shown in Figure 5. We can communicate with memory cards and write or read information on them using SD and micro SD card modules. In the memory card, a text file is created with the number of columns for each unit number and temperature. Device numbers are mentioned in columns, along with their associated temperatures. The following two columns correspond to the corresponding date and time. The generated text file is suitable to use as an excel file in the future.

Device No.	Temp.°C	Device No.	Temp.°C	Device No.	Temp.°C	Device No.	Temp.°C	Date	Time
1	25.5	2	25	3	26.06	4	27.19	1/15/2021	23:39:34
1	26	2	25	3	26.19	4	27.06	1/15/2021	23:39:40
1	25.5	2	25	3	26.19	4	27.19	1/15/2021	23:39:46
1	25.5	2	25	3	26.13	4	27.13	1/15/2021	23:39:52
1	25.5	2	25	3	26.19	4	27.13	1/15/2021	23:39:58
1	25.5	2	25	3	26.19	4	27.13	1/15/2021	23:40:04
1	25.5	2	25	3	26	4	27.13	1/15/2021	23:40:10
1	25.5	2	25	3	26.13	4	27.19	1/15/2021	23:40:16
1	25.5	2	25	3	26.13	4	27.19	1/15/2021	23:40:22
1	25.5	2	25	3	26.19	4	27.13	1/15/2021	23:40:27
1	25.5	2	25	3	26.06	4	27.13	1/15/2021	23:40:33
1	25.5	2	25	3	26.19	4	27.25	1/15/2021	23:40:39
1	25.5	2	25	3	26.13	4	27.25	1/15/2021	23:40:45
1	25.5	2	25	3	26.13	4	27.19	1/15/2021	23:40:51
1	25.5	2	25	3	26.13	4	27.13	1/15/2021	23:40:57
1	25.5	2	25	3	26.19	4	27.13	1/15/2021	23:41:03
1	25.5	2	25	3	26.19	4	27.19	1/15/2021	23:41:09
1	25.5	2	25	3	26.19	4	27.19	1/15/2021	23:41:15
1	25.5	2	25	3	26.19	4	27.19	1/15/2021	23:41:21
1	26	2	25	3	26.25	4	27.25	1/15/2021	23:41:26
1	25.5	2	25	3	26.13	4	27.19	1/15/2021	23:41:32

Fig 5. Data stored in SD card in C with Time and Date

#### 3.2 Temperature displayed on the MQTTLence

Figure 6, shows the temperature displayed on the MQTTLence via mqtttdashboard broker. MQTT Lens is an add-on for the chrome browser that publish messages to an MQTT broker, we have to subscribe to MQTT topics, and receive messages using the chrome web browser. The topic name we are using is "00a59160" which is ESP8266 chip-id.

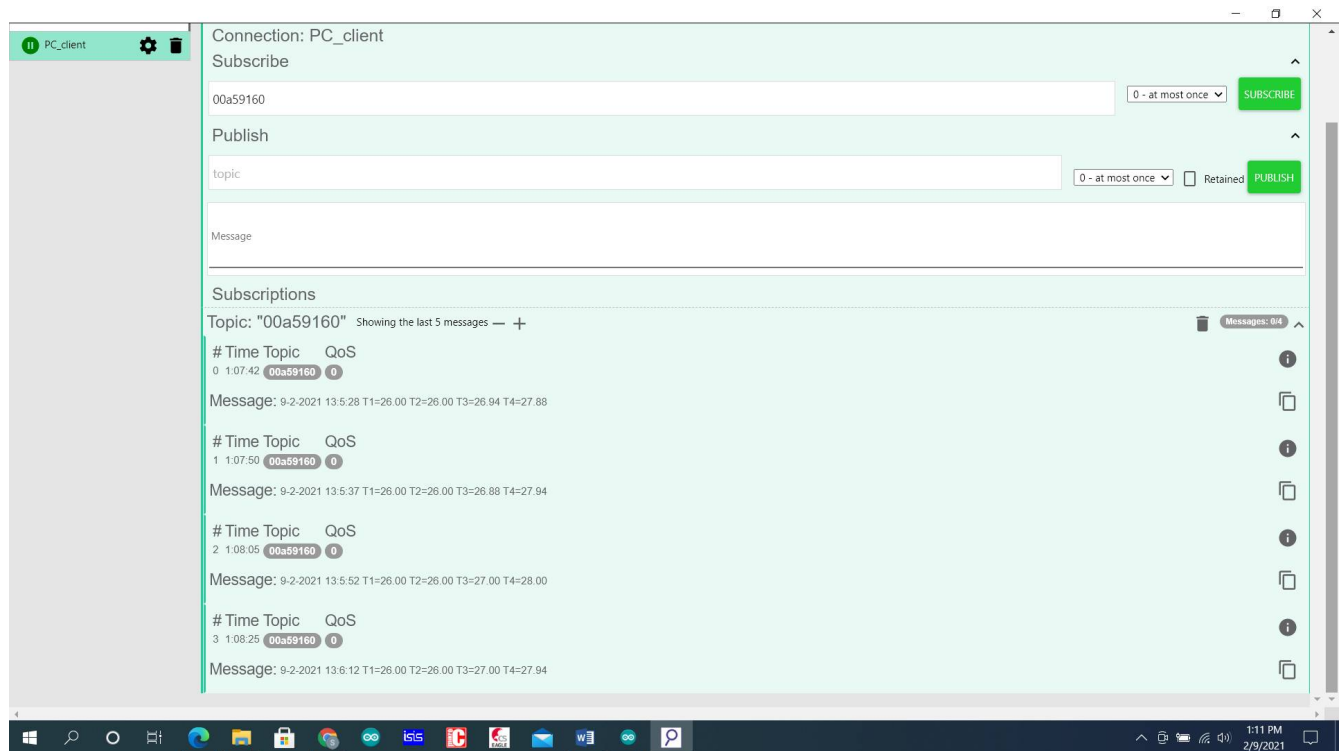


Fig 6. Output on the MQTTLence via mqtt dashboard broker

## 4 Conclusion

This work presented straightforward and trouble-free module is fully integrated and requires no wires or testing labs, allowing for fast onsite decisions and avoiding unnecessary delays. It accurately reflects in-situ strength gain as compared to laboratory or field-cured specimens. Untethered Quad temperature monitoring for easy differential analysis, fast, simple, and safe installation. Existing devices has maximum 2 sensors for the sensing part but here 4 sensors are used to increase the accuracy and increase the size of the area we can sense at a time. SIM800L module allows use of GPRS communication with its small size and low voltage (3.7v) requirement. GPRS is used to transmit data to MQTT as shown in Figure 6. User can access this information from the MQTT to its desired web or app easily by knowing respected MQTT credentials. Same information is stored in memory card with corresponding date and time (Figure 5). Memory card gives the facility to collect the information regardless of wireless communication. Easy onboard battery charger gives advantage to use device efficiently.

Although Wireless sensors have a number of advantages, including the ability to track for long periods of time at a low cost, sensitivity, functionality, low maintenance, and operating costs. However, they also have a number of drawbacks, including the probability of a communication failure between the central system and the peripheral sensors, as well as power outages.

Addition of the solar panel to the present work will remove the charging time of the device. The accuracy of results would improve by combining this sensor performance with emerging technologies such as deep learning, artificial neural Networks (ANNs), and convolutional neural network (CNN) methods. With these new methods, not only will it be possible to detect sensor faults, damage recognition, and the actual area of damage, but it will also be possible to detect sensor faults, damage identification, and detection of the actual area of damage.

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