Smart Sensor Placement for Thermal Monitoring of Concrete

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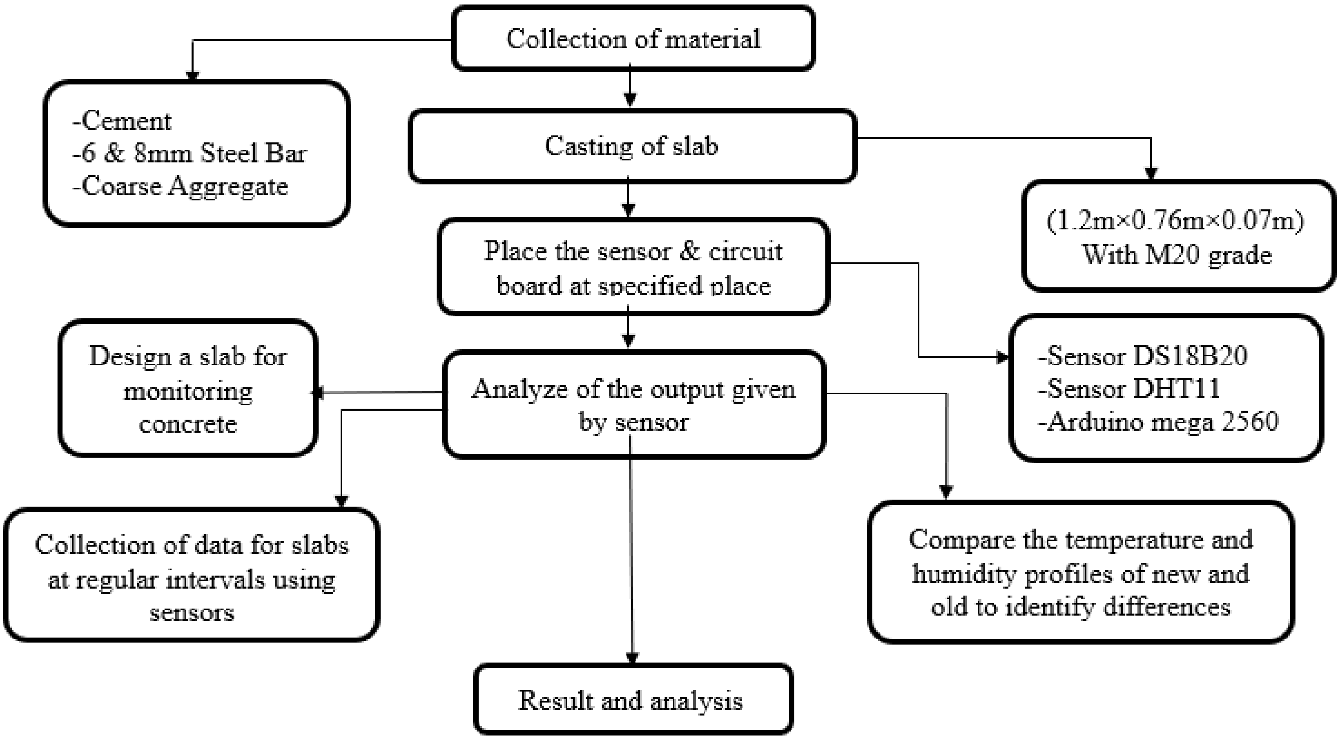
Abstract
Structural health monitoring (SHM) has become an inevitable part in a life span of a structure due to its potential to ensure the public safety and to increase the life span of the structure. Monitoring any kind of structures for various parameters, using wireless smart sensors has gained popularity in recent past. This paper discusses the development of low cost real time wireless smart sensor monitoring system to monitor early age concrete temperature in real time. Temperature of two early age concrete mixes (Mix1, Mix2) were measured in real time for 24 hours by using DS18B20 sensors connected with the Node Mcu, which is an open source IOT platform. Temperature measurements were saved and visualized in real time using Thing SpeakTM which is an open IoT online platform with MATLAB analytics. The temperature sensor DS18B20 was selected such that it is suitable to measure temperature readings of the concrete without any interference of the chemical reactions in concrete. Calibration methods and temperature variation with different concrete mixesare also discussed. It could be seen that the wireless temperature monitoring system performed adequately and it can be considered as a better low cost alternative for traditional wired temperature monitoring system.

INTRODUCTION

- Structural health monitoring (SHM) is one of the rapidly growing domains in civil engineering, which aims to assess the behavior of the structures and evaluate the performance of the materials during their life cycles.
- SHM involves the sensors, data transmission, computational power and processing inside the structure.
- Sensors play vital role in SHM and there are lot of studies going on sensors and its properties. Various sensors are used assess the environmental impact, temperature, humidity etc.
- SHM is mainly performed for critical structures like bridges, wind turbines, tunnels etc.
- SHM improves the understanding of field structural behavior and detect damages at early age on other hand it has high installation cost and are vulnerable to the earthquake conditions, as the size and complexity of the structure increases the difficult the SHM becomes.
- Nowadays use of temperature sensor is increasing to monitor the concrete structure, this helps in checking the maturity of concrete. If we get the maturity before the time period work will be done as early as possible.

- For big construction works they don't have more time to leave 28 days after one slab if they do like that their project gets delayed. To place the sensors in the concrete it costs more if they don't know the placement then they may run out of budget.
- In sensor optimization the usual objective is to minimize the sensor placements, is the sensor cost. There are several articles devoted to study of the design of sensor networks.
- Aside from the cost other objective function such as precision simply observability or reliability are important.

METHODOLOGY



OBJECTIVES

- Design a slab for monitoring concrete structure
- Collection of data for slabs at regular intervals using sensors
- Compare the temperature and humidity profiles of new and old to identify differences

WORKING ON MODEL

Used Material

1. 6mm & 8mm Steel Bar
2. Binding Wire
3. Cement
4. Coarse Aggregate
5. M Sand
6. DS18b20 Waterproof digital temperature sensor
7. DHT11 Humidity temperature sensor
8. Arduino Nano

Consumption of Material-

Sr.No	Material	Quantity
1)	Cement	25 Kg
2)	20mm Coarse Aggregate	50 Kg
3)	M Sand	70 Kg
4)	Water	30 lit
5)	6mm Steel bar	1 Nos.
6)	8mm Steel bar	1 Nos.

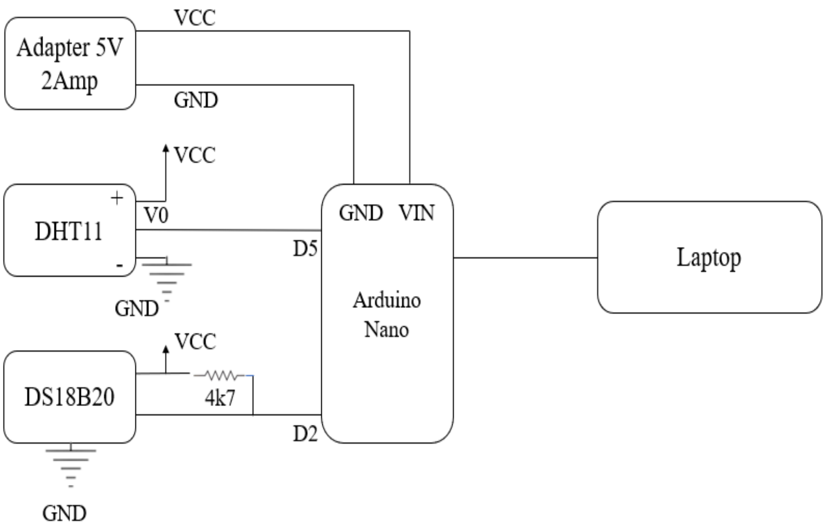
Slab Casting

Casting of slab – Use 8mm bar as main bar and 6mm bar as distribution bar

Concreting of slab- Use M20 grade of concrete

After 21 days curing slab-

Circuit diagram -



ircuit diagram assembly-

Used Software-

- Use language C++
- Software arduino IDE

Used Code-

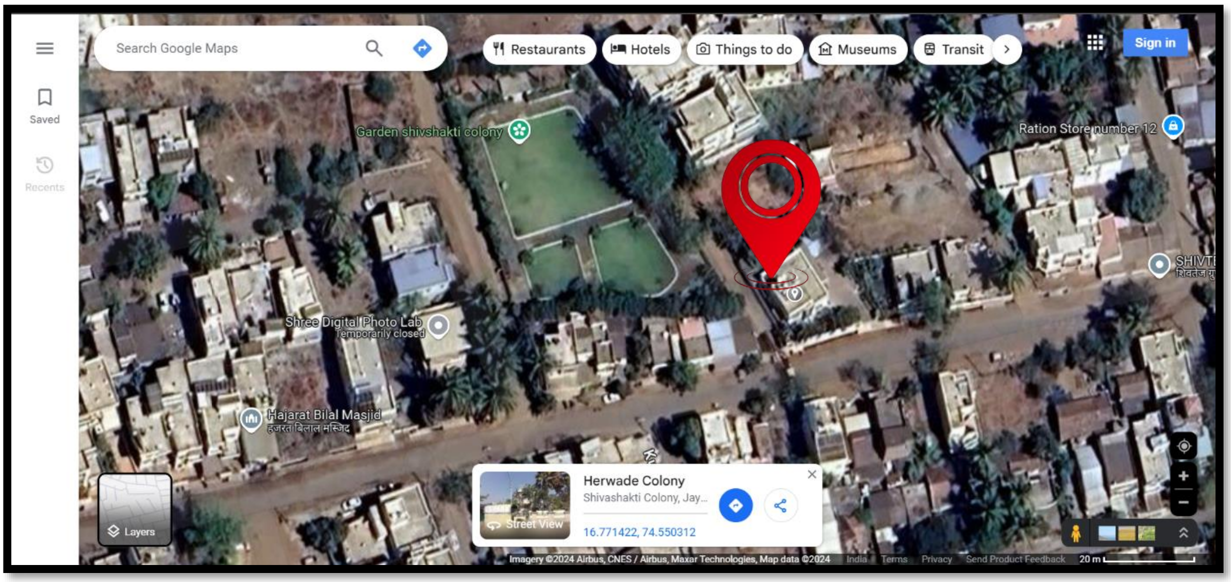
```
#include "DHT.h"
#define DHTPIN 5
#define DHTTYPE DHT11
DHT dht(DHTPIN, DHTTYPE);
#include <OneWire.h>
#include <DallasTemperature.h>
int x = 15;     // Change time as per requried in minutes
float t, h, tempC;
// Data wire is plugged into port 2 on the Arduino
#define ONE_WIRE_BUS 2
// Setup a oneWire instance to communicate
OneWire oneWire(ONE_WIRE_BUS);
// Pass our oneWire reference to Dallas Temperature.
DallasTemperature sensors(&oneWire);
//----------------------------------------------------
void setup(void)
{
  Serial.begin(9600);
  sensors.begin();
  dht.begin();
  Serial.print("Slab Temperature in *C: ");
  Serial.print(F("\tAir Humidity in %: "));
  Serial.print(F("\tAir Temperature in *C: "));
}
//---------------------------------------------
void loop(void)
{
  //Serial.print("Requesting temperatures...");
  sensors.requestTemperatures(); // Send the command to get temperatures
  //Serial.println("DONE");
  tempC = sensors.getTempCByIndex(0); // Check if reading was successful
  Serial.print("\n");
  Serial.print(tempC);
  h = dht.readHumidity();// Read temperature as Celsius (the default)
  t = dht.readTemperature();
  Serial.print("\t");
  Serial.print(h);
  Serial.print("\t");
```

```
  Serial.println(t);
  //delay(5000);
  delay(x*60*1000UL);
}
```

Monitoring of Slab-

a) New Slab- **b) Old Slab-**

Location of old slab building-



RESULTS-

Day 1

New Slab-

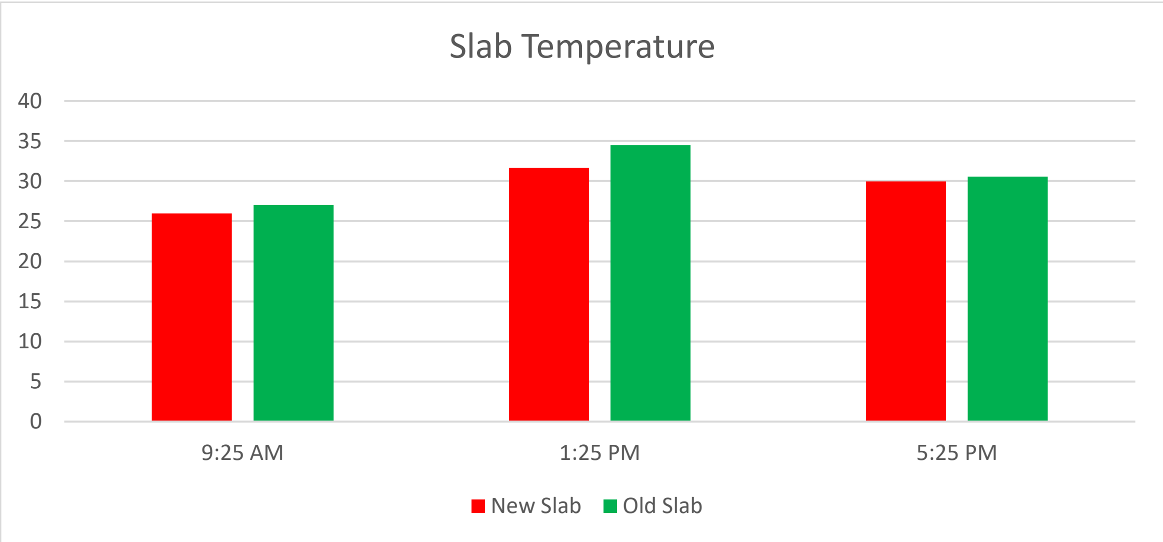
Date	Time	Slab Temperature	Air Humidity in %:	Air Temperature in *C:
25-09-2024	9:25	25.98	95	27.48

25-09-2024	1:25	31.67	83.8	33.44
25-09-2024	5:25	29.97	95	28.16

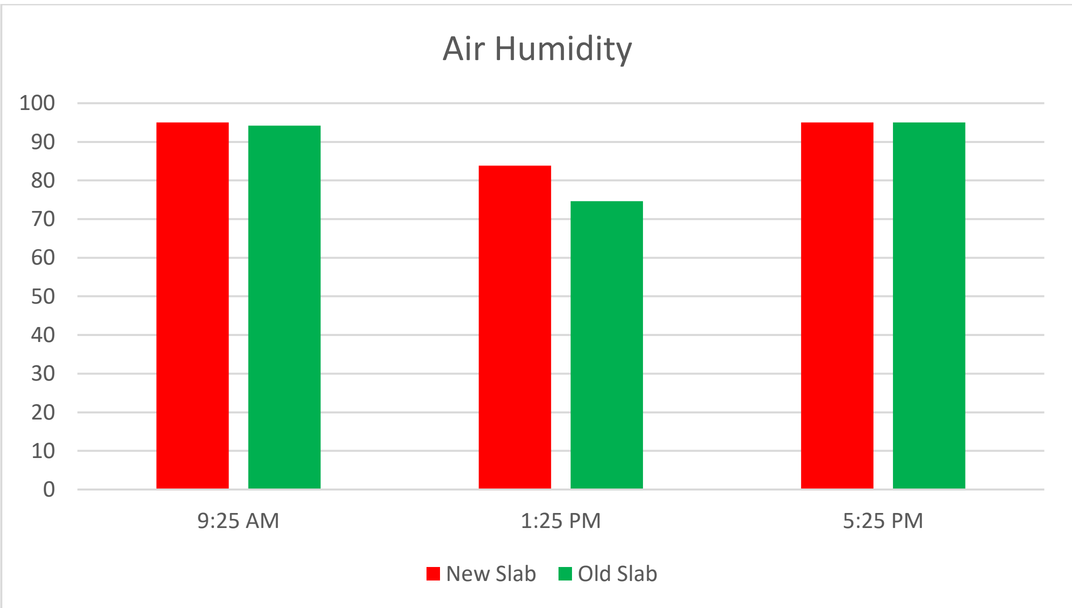
Old Slab-

Date	Time	Slab Temperature	Air Humidity in %:	Air Temperature in *C:
25-09-2024	9:45	27	94.2	28.54
25-09-2024	1:40	34.5	74.6	36.62
25-09-2024	5:45	30.56	95	27.64

Day 1



Graph- 1.1



Graph- 1.2

Day 2

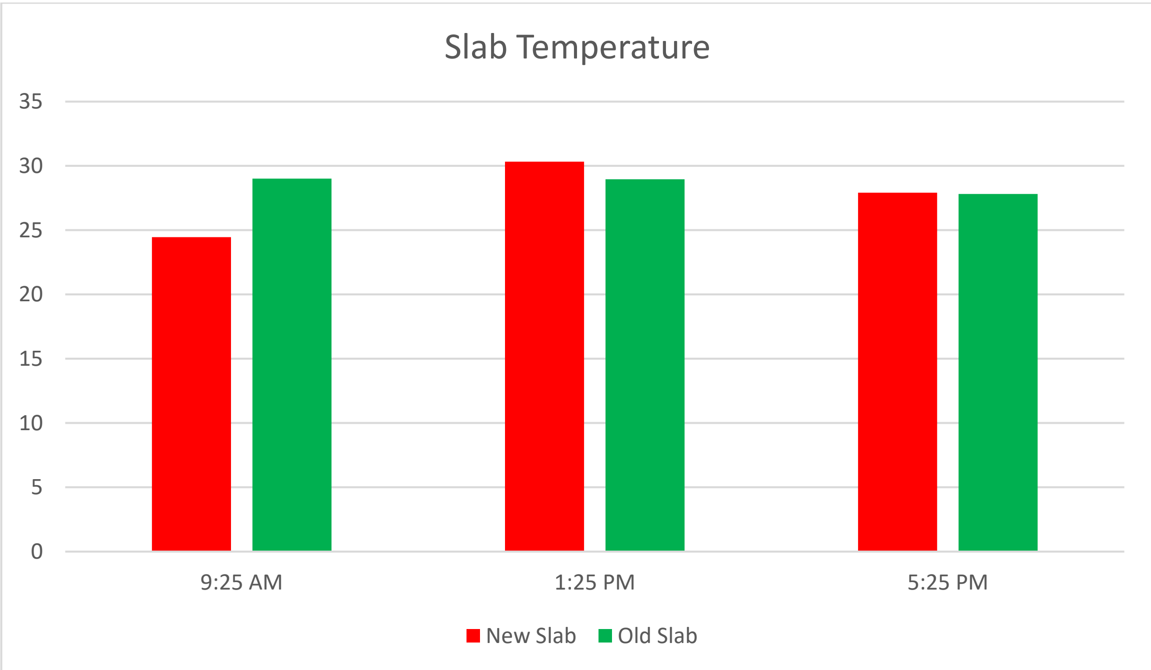
New Slab-

Date	Time	Slab Temperature	Air Humidity in %:	Air Temperature in *C:
26-09-2024	9:25	24.45	95	28.62
26-09-2024	1:25	30.32	81.2	33.78
26-09-2024	5:25	27.91	95	27.02

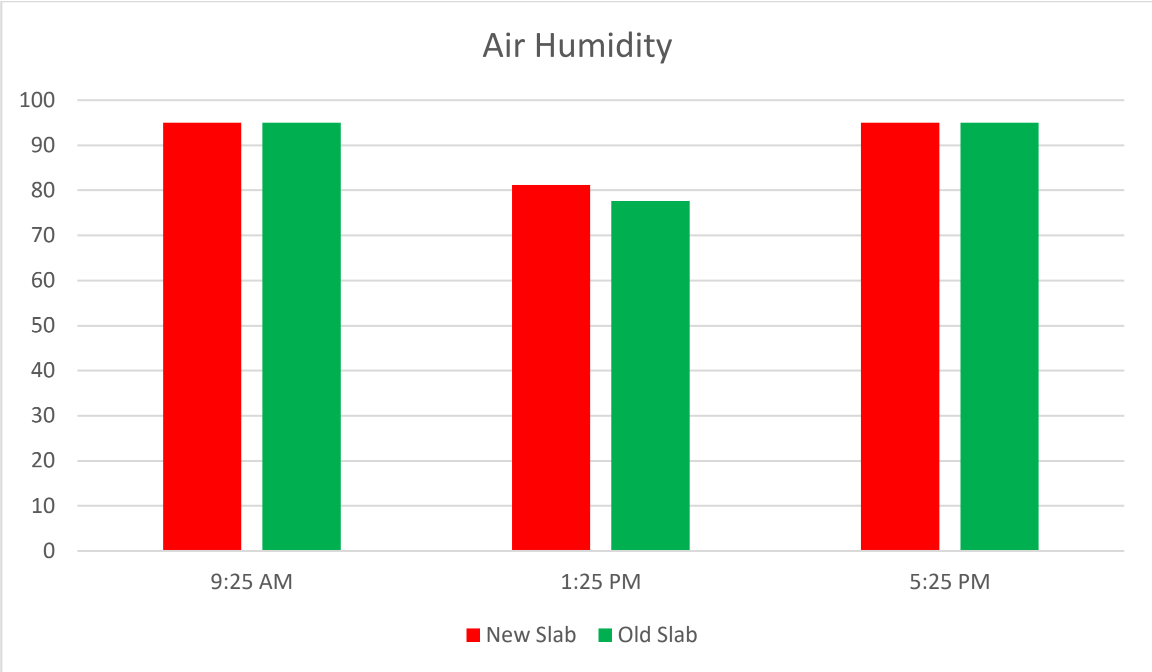
Old Slab-

Date	Time	Slab Temperature	Air Humidity in %:	Air Temperature in *C:
26-09-2024	9:50	29	95	28.54
26-09-2024	1:40	28.97	77.6	34.36
26-09-2024	5:35	27.81	95	26.32

Day 2-



Graph- 2.1



Graph- 2.2

Day 3

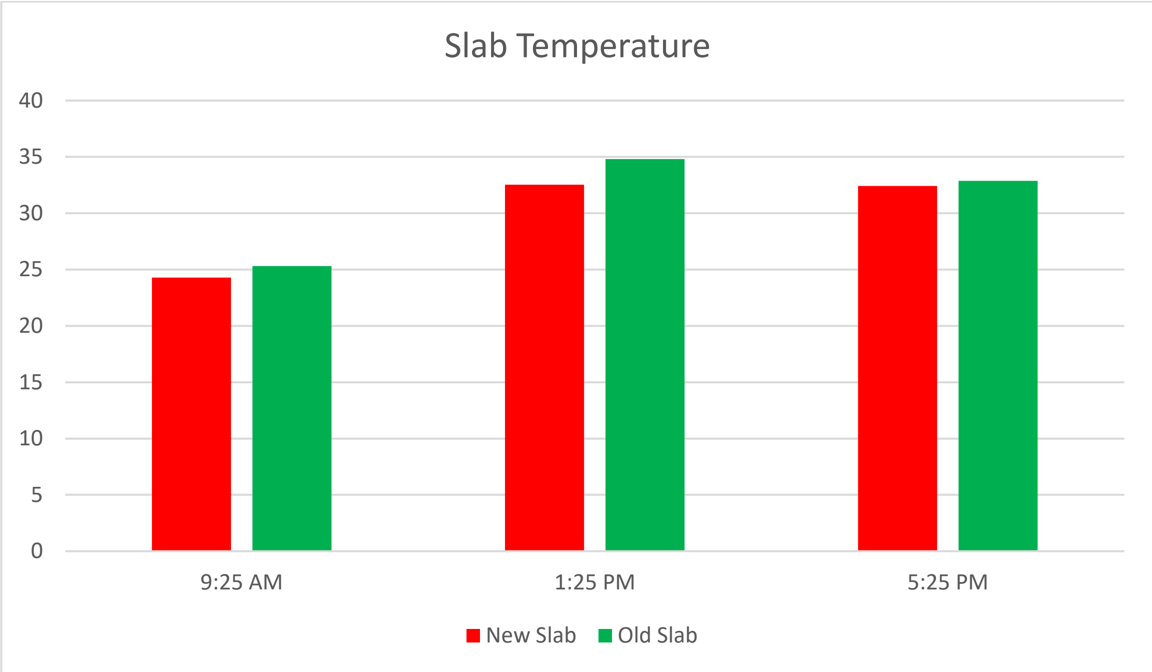
New Slab-

Date	Time	Slab Temperature	Air Humidity in %:	Air Temperature in *C:
27-09-2024	9:25	24.28	90	28.8
27-09-2024	1:25	32.52	85	31.2
27-09-2024	5:25	32.42	85.8	29.5

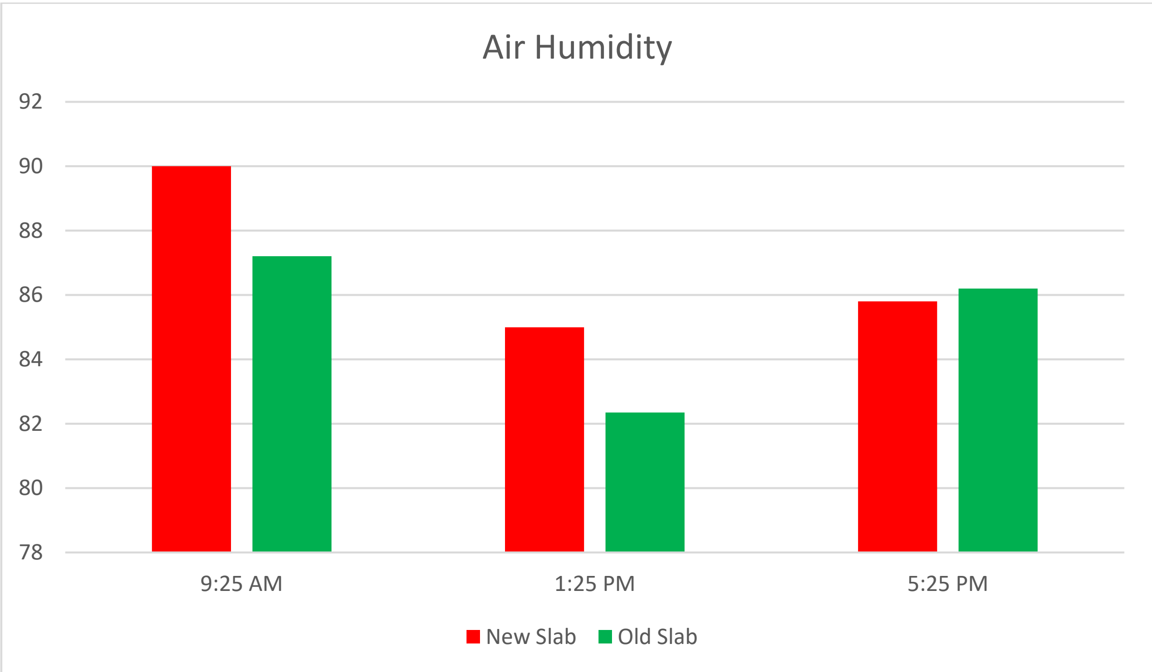
Old Slab-

Date	Time	Slab Temperature	Air Humidity in %:	Air Temperature in *C:
27-09-2024	9:40	25.32	87.2	30.04
27-09-2024	1:45	34.82	82.35	32.6
27-09-2024	5:50	32.38	86.2	29.38

Day 3-



Graph- 3.1



Graph 3.2

CONCLUSIONS

- As compared to morning slot and evening slot, temperature (inside) is more in slab having
- life more than 20 years. (Ref. Graph No. 1.1, 2.1, 3.1).
- Due to temperature and weather changes Air humidity is also slightly more in afternoon slot than morning and evening slot. (Ref. Graph No. 1.2, 2.2, 3.2).

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