International Journal of Innovative Technology and Exploring Engineering (IJITEE)
ISSN: 2278-3075 (Online), Volume-9 Issue-3, January 2020

Measurement of Temperature of the Core of Concrete during Progressive Compressive Loading using Temperature Sensors

T. Sai Bindhusha, S.M.V. Narayana, T. Naresh Kumar

Abstract: ***Structural health monitoring and health diagnosis have become the integral parts of 21st century structural engineering practice. Many non-destructive tests are being used to assess the condition of the concrete in existing RCC structures. In addition to these Non-destructive tests sensing systems are also used to monitor the structural health of RCC structures. If a structure fails pre maturely; the consequences are not only the in effective usage of materials and reduction in life span of structures but also loss of money and sometimes loss of lives. When the load is applied on a structural element, it undergoes some deformation or volume change. Deterioration of concrete may be due to many reasons. But the serviceability is very important for the structures. During the application of external loading, concrete structures, and offer resistance and during this process, energy is utilized by the structure to resist the external load. The concrete is solid like a stone and some heat is developed in concrete during the process of loading. By embedding the temperature sensors in the concrete, it is possible to read the temperature developed inside the concrete. In the present investigation an attempt is made to find the change in temperature of concrete at different ages at regular intervals of progressive compressive loading starting from no load to failure of concrete. This will be useful for estimating the health of concrete structures as it is possible to find the temperature changes and the condition of concrete at different percentages of ultimate load.***

Keywords: core of concrete, progressive compressive loading, temperature sensors.

I. INTRODUCTION

Upon loading matured concrete resists the external force and during this process heat is generated. Internal energy of material changes with the creation of internal defects such as vacancies, interstitials and dislocations. The stored internal energy depends on the amount of defects and also their arrangement within the material [1]. Structural health monitoring is the process of identifying or detecting the damages. The damage refers to impairing the use or function of concrete or concrete structures. In case of structural health monitoring of concrete, the sensors can be used to measure and predict the damage.

Revised Manuscript Received on January 30, 2020.
* Correspondence Author

T. Sai Bindhusha*, PG Student**,** Dept. of Civil Engineering, AITS Rajampet, Kadapa, AP, India. Email: saibindhushat@gmail.com

S.M.V. Narayana, Principal, AITS Rajampet, Kadapa, AP, India.

T. Naresh Kumar, Assistant Professor, Dept. of Civil Engineering, AITS Rajampet, Kadapa, AP, India.

Digital thermometer sensors are used to measure the temperature of the concrete when load is applied on the concrete. Structural health monitoring is a system that includes the integration of sensing, intelligence and activation devices to record the loading and damage causing conditions of a concrete structure. Based on the knowledge of the condition of the structure, preventive measure can be taken to increase the service life of the structure. The maximum concrete temperature, maximum concrete temperature differences affect the performance of a bridge member [2]. In concrete, heat is generated due to hydration process, weather conditions, pressure conditions etc. The heat generated in the material is either dissipated to the surrounding or is used to increase the temperature of material. For all concrete structures, the thermal effects inside the concrete are strictly related to their structural health [3]. Thermal load is very important in bulk concrete structures. Cement hydration, the sun radiation, the temperature change of water and air may produce tensile stress which can cause cracking of structure [4]. Concrete strength and durability depend mainly on the temperature and the dynamics of moisture transport. Concrete material properties change with time and these properties are significantly influenced by heat of hydration and moisture content in concrete at early ages [5]. Temperature field in concrete has a significant effect on the durability of concrete structures. Carbonation, corrosion of steel bars in concrete, chloride ingress in concrete are closely related to the temperature field in concrete [6]. There are many non-destructive tests available to monitor the health of the concrete structures. When mechanical vibrations are introduced into a friction and consequent deformation are induced and heat will be released which can be read by using infrared camera to detect the defects [7]. Extensive studies have been conducted related to long term temperature monitoring of concrete structures. Most of those studies focused on the surrounding environmental conditions that contributed to the temperature effects in concrete structures, especially the highest and lowest temperatures that could be expected to occur throughout the year [8]. In the present investigation the study was focused on finding out the temperature change in the core of concrete during the loading till the failure of the concrete specimen. The temperature sensors were embedded in concrete during the casting of concrete cubes and the concrete cubes were water cured for 14, 28 and 60 days. The cubes were subjected to compressive force and at every 50KN increment of load; the temperature of the core of concrete was noted.

The load was applied up to failure. At failure the load and the corresponding temperature were taken. At every change in temperature of the core, the corresponding load was calculated as percentage of ultimate load with this data, the structural health of concrete can be studied.

II. EXPERIMENTAL PROGRAM

To find out the condition of concrete during the loading, in the present investigation, different concrete cubes were subjected to compressive loading up to the failure of the specimen. The concrete cubes embedded with temperature sensors in the core during the fabrication of cubes and cured in water are taken out from the curing tanks and after wiping out the water on the cubes, the cubes were placed on the bottom plate of CTM. The top plate is adjusted in such a way that just touches the top surface of the cube (without exerting any pressure). The room temperature and the core temperature of the cube at no load condition were noted from the display monitor connected to the temperature sensor. Then compressive load is applied gradually on the cube as per the guide lines given in IS 516-1959. At every 50KN of increment of load the temperature of the core of the concrete was noted and the same was continued till the failure of the specimen.

III. DISCUSSION AND RESULTS

Sample Cube: 1

Grade of concrete: M_{35}
Age of concrete: 14 days
Room temperature: $34^{o}c$
Concrete core temperature:$33.3^{o}c$

Table-I: Showing the change/increase of temperature with load

S.NO.	LOAD KN	CORE TEMPERATURE DURING LOADING (o_c)	TEMPERATURE DIFFERENCE (o_c)
1	0	33.3	0
2	50	33.3	0
3	100	33.3	0
4	150	33.3	0
5	200	33.3	0
6	250	33.3	0
7	300	33.3	0
8	350	33.3	0
9	400	33.3	0
10	450	33.3	0
11	500	33.3	0
12	550	33.3	0
13	600	33.4	0.1
14	650	33.4	0.1
15	700	33.4	0.1
16	720	33.5	0.2

From table 1 it can be observed that the M_{35} concrete tested at the age of 14 days at $34^{o}c$ room temperature shows an increase in core temperature of $0.1^{o}c$ at 600 KN load and remains the same upto 700 KN of load and at failure load i.e; at 720KN the temperature is increased by $0.2^{o}c$.

Upon loading, M_{35} concrete at 14days, tested at $34^{o}c$ room temperature, generates heat that increased the core temperature by $0.1^{o}c$ at 83.3%of ultimate load. At ultimate load, the core temperature is increased by $0.2^{o}c$.

Sample Cube: 2

Grade of concrete: M_{35}
Age of concrete: 14 days
Room temperature: $34^{o}c$
Concrete core temperature: $33^{o}c$

Table-II: Showing the change/increase of temperature with load

S.NO	LOAD KN	CORE TEMPERATURE DURING LOADING (o_c)	TEMPERATURE DIFFERENCE (o_c)
1	0	33.0	0
2	50	33.0	0
3	100	33.0	0
4	150	33.0	0
5	200	33.0	0
6	250	33.0	0
7	300	33.0	0
8	350	33.0	0
9	400	33.0	0
10	450	33.0	0
11	500	33.0	0
12	550	33.0	0
13	600	33.1	0.1
14	650	33.1	0.1
15	700	33.2	0.2
16	770	33.2	0.2

From table 2 it can be seen that the M_{35} concrete shows an increase in temperature by $0.1^{o}c$ at 78% of ultimate load, $0.2^{o}c$ rise in temperature at 91% of ultimate load and at ultimate load the increase in core temperature is $0.2^{o}c$.

Sample Cube: 3

Grade of concrete: M_{35}
Age of concrete: 14 days
Room temperature: $34^{o}c$
Concrete core temperature: $33.1^{o}c$

Table-III: Showing the change/increase of temperature with load

S.NO	LOAD KN	CORE TEMPERATURE DURING LOADING (o_c)	TEMPERATURE DIFFERENCE (o_c)
1	0	33.1	0
2	50	33.1	0
3	100	33.1	0
4	150	33.1	0
5	200	33.1	0
6	250	33.1	0
7	300	33.1	0
8	350	33.1	0
9	400	33.1	0
10	450	33.1	0
11	500	33.1	0
12	550	33.2	0.1
13	600	33.2	0.1
14	650	33.2	0.1
15	700	33.3	0.2
16	730	33.3	0.2

From table 3 it can be observed that the M_{35} concrete at 14 days shows an increase in temperature of $0.1^{o}c$ at 82% of ultimate load, $0.2^{o}c$ at 96% of ultimate load.

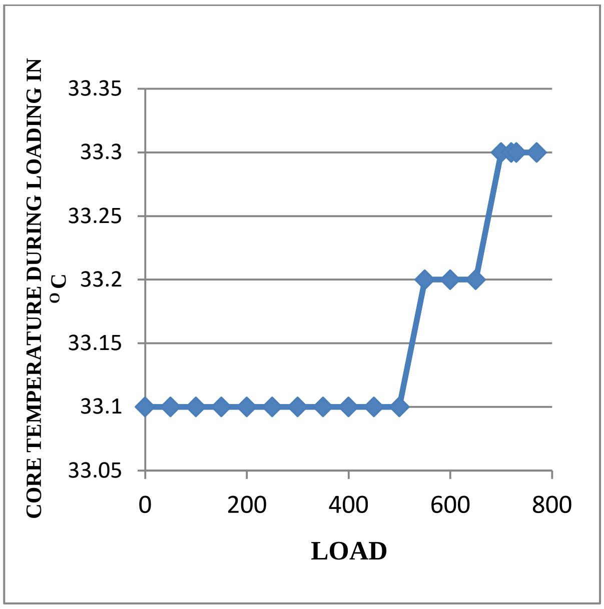

Fig. 1. Shows the change of temperature with the change of load.

Sample Cube: 1

Grade of concrete: M_{35}
Age of concrete: 28 days
Room temperature: $32^o c$
Concrete core temperature$29.8^o c$

Table-IV: Showing the change/increase of temperature with load

S.NO	LOAD (KN)	CORE TEMPERATURE DURING LOADING (o_c)	TEMPERATURE DIFFERENCE (o_c)
1	0	29.8	0
2	50	29.8	0
3	100	29.8	0
4	150	29.8	0
5	200	29.8	0
6	250	29.8	0
7	300	29.8	0
8	350	29.8	0
9	400	29.8	0
10	450	29.8	0
11	500	29.8	0
12	550	29.8	0
13	600	29.8	0
14	650	29.9	0.1
15	700	29.9	0.1
16	750	29.9	0.1
17	800	30.0	0.2
18	830	30.0	0.2
19	880	30.1	0.3

From table 4 shows that core temperature of M_{35} concrete at 28 days increases by $0.1^o c$ at 74% of ultimate load, by $0.2^o c$ at 92% of ultimate load and by$0.3^o c$ at ultimate load

Sample Cube: 2

Grade of concrete: M_{35}
Age of concrete: 28 days
Room temperature: $32^o c$
Concrete core temperature: $29.7^o c$

Table-V: Showing the change/increase of temperature with load

S.NO	LOAD (KN)	CORE TEMPERATURE DURING LOADING (o_c)	TEMPERATURE DIFFERENCE (o_c)
1	0	29.7	0
2	50	29.7	0
3	100	29.7	0
4	150	29.7	0
5	200	29.7	0
6	250	29.7	0
7	300	29.7	0
8	350	29.7	0
9	400	29.7	0
10	450	29.7	0
11	500	29.7	0
12	550	29.7	0
13	600	29.7	0
14	650	29.8	0.1
15	700	29.8	0.1
16	750	29.9	0.2
17	800	29.9	0.2
18	850	29.9	0.2
19	900	30.0	0.3

From table 5 it can be observed that the temperature of the core of concrete remained unchanged up to 550KN of load. At 550Kn the temperature of the core increased by $0.1^o c$ and remained the same upto 700kn. At 750kn load, the temperature increased $0.2^o c$ and at ultimate load of 900kn, the temperature rise was $0.3^o c$ M_{35} concrete shows an increase in temperature by $0.1 o_c$at 72% of ultimate load, $0.2^o c$ at 83% of ultimate load and $0.3 o_c$at ultimate load.

Sample Cube: 3

Grade of concrete: M_{35}
Age of concrete: 28 days
Room temperature: $32^o c$
Concrete core temperature: $29.8c$

Table-VI: Showing the change/increase of temperature with load

S.NO	LOAD KN	CORE TEMPERATURE DURING LOADING (o_c)	TEMPERATURE DIFFERENCE (o_c)
1	0	29.8	0
2	50	29.8	0
3	100	29.8	0
4	150	29.8	0
5	200	29.8	0
6	250	29.8	0
7	300	29.8	0
8	350	29.8	0
9	400	29.8	0
10	450	29.8	0
11	500	29.8	0
12	550	29.0	0
13	600	29.9	0.1
14	650	29.9	0.1
15	700	30.0	0.2
16	750	30.0	0.2
17	800	30.0	0.2
18	860	30.0	0.2

From table 6 shows that core temperature of M_{35} concrete at 28 days increases by $0.1^{o}c$ at 70% of ultimate load, by $0.2^{o}c$ at 81% of ultimate load and remains the same at failure.

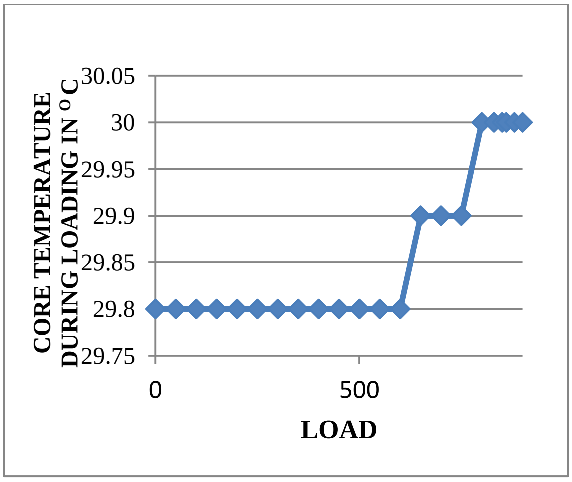

Fig. 2. Shows the increase in temperature with increase in load

Sample Cube: 1

Grade of concrete: M_{35}
Age of concrete: 60 days
Room temperature: $30^{o}c$
Concrete core temperature: $29.1^{o}c$

Table-VII: Showing the change/increase of temperature with load

S.NO	LOAD KN	CORE TEMPERATURE DURING LOADING(o_C)	TEMPERATURE DIFFERENCE (o_C)
1	0	29.1	0
2	50	29.1	0
3	100	29.1	0
4	150	29.1	0
5	200	29.1	0
6	250	29.1	0
7	300	29.1	0
8	350	29.1	0
9	400	29.1	0
10	450	29.1	0
11	500	29.1	0
12	550	29.1	0
13	600	29.1	0
14	650	29.1	0
15	700	29.2	0.1
16	750	29.2	0.1
17	800	29.3	0.2
18	850	29.3	0.2
19	900	29.3	0.2
20	950	29.4	0.3
21	1040	29.4	0.3

From table 7 the temperature of the core of 60 days age of M_{35} concrete increases by $0.1^{o}c$ at 67% of ultimate load. It increases by $0.2^{o}c$ at 77% of ultimate load. Before failure the temperature increases by $0.3^{o}c$ at 91% of ultimate load.

Sample Cube: 2

Grade of concrete: M_{35}
Age of concrete: 60 days
Room temperature: $30^{o}c$
Concrete core temperature: $28.9^{o}c$

Table-VIII: Showing the change/increase of temperature with load

S.NO	LOAD KN	CORE TEMPERATURE DURING LOADING (o_C)	TEMPERATURE DIFFERENCE (o_C)
1	0	28.9	0
2	50	28.9	0
3	100	28.9	0
4	150	28.9	0
5	200	28.9	0
6	250	28.9	0
7	300	28.9	0
8	350	28.9	0
9	400	28.9	0
10	450	28.9	0
11	500	28.9	0
12	550	28.9	0
13	600	28.9	0
14	650	28.9	0
15	700	29.0	0.1
16	750	29.0	0.1
17	800	29.0	0.1
18	850	29.1	0.2
19	900	29.1	0.2
20	950	29.1	0.2
21	1000	29.2	0.3
22	1050	29.2	0.3
23	1070	29.2	0.3

From table 8 the temperature of the core of 60 days age of M_{35} concrete increases by $0.1^{o}c$ at 65% of ultimate load. It increases by $0.2^{o}c$ at 81% of ultimate load. Before failure the temperature increases by $0.3^{o}c$ at 93% of ultimate load.

Sample Cube: 3

Grade of concrete: M_{35}
Age of concrete: 60 days
Room temperature: $30^{o}c$
Concrete core temperature at no loading: $28.9^{o}c$

Table-IX: Showing the change/increase of temperature with load

S.NO	LOAD KN	CORE TEMPERATURE DURING LOADING (o_C)	TEMPERATURE DIFFERENCE (o_C)
1	0	28.9	0
2	50	28.9	0
3	100	28.9	0
4	150	28.9	0
5	200	28.9	0
6	250	28.9	0
7	300	28.9	0
8	350	28.9	0
9	400	28.9	0
10	450	28.9	0
11	500	28.9	0
12	550	28.9	0
13	600	28.9	0
14	650	28.9	0
15	700	28.9	0
16	750	29.0	0.1
17	800	29.0	0.1
18	850	29.0	0.1
19	900	29.1	0.2
20	950	29.1	0.2
21	1000	29.1	0.2
22	1050	29.2	0.3
23	1080	29.2	0.3

From table 9 the temperature of the core of 60 days age of M_{35} concrete increases by $0.1^o c$ at 70% of ultimate load. It increases by $0.2^o c$ at 83% of ultimate load, by $0.3^o c$ at 97% of ultimate load and remains the same at failure.

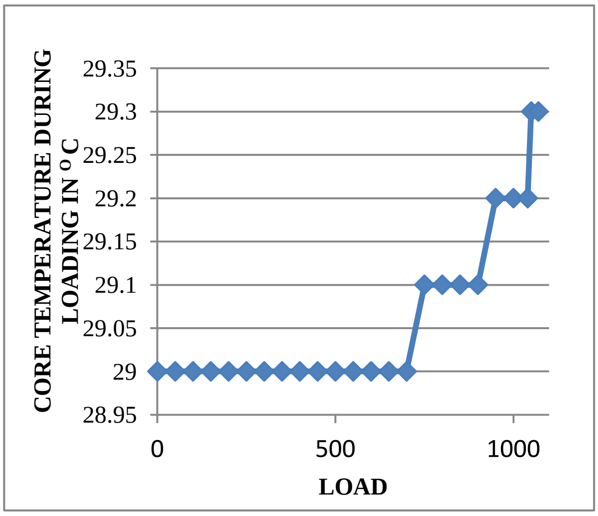

Fig. 3. Shows the change of temperature with change of load

IV. CONCLUSIONS

Hardened concrete resists loads and during this process the concrete releases heat. The internal energy of the materials change with creation of internal defects. The bridge decks and roads etc, receive the loads continuously and during the loading the heat generated or the temperature rise can be measured by embedding temperature sensors in concrete. The results of the present investigation show that the M_{35} concrete of 14 days age when loaded developed heat which raises the core temperature by $0.1^o c$ at about 80% of ultimate load. The temperature rises by $0.2^o c$ at about 90% of ultimate load. The increase in temperature of the core give the idea about the load and the load interms of the ultimate load that the concrete received which gives the idea about the health of the structure.

The M_{35} concrete of 28 days age when loaded developed heat which raises the core temperature by $0.1^o c$ at about 70% of ultimate load. The temperature rises by $0.2^o c$ at about 80% of ultimate load. The increase in core temperature at nearly ultimate load is $0.3^o c$

The M_{35} concrete of 60 days age when loaded developed heat which increases the core temperature by $0.1^o c$ at about 70% of ultimate load. The temperature rises by $0.2^o c$ at about 77% of ultimate load. Before the failure of the specimen the core temperature was $0.3^o c$ at 95% of ultimate load.

REFERENCES

1. Rajeev kapoor, Sia Nemat - Nasser(1998)- Determination of temperature rise during high strain rate deformation- Mechanics of materials 27(1998) pp1-12
2. Shindler AK Junenger MCG et al (2006) - Evaluation of temperature prediction methods for mass concrete members – ACI materials Journal 103(5), pp 357-365.
3. J.Ou.H.Li et al (2000) - Structural health monitoring in mainland china: Review and future trends- Structural health monitoring 9(2010) pp: 219-231.
4. Sun Mingqing et al (2000) - A study on thermal self-diagnostic and self-adaptive smart structures – cement and concrete research 30(2000) pp 1251- 1253
5. Ashley Norris et al (2008) – Temperature and moisture monitoring in concrete structures using embedded nanotechnology/microelectro mechanical systems (MEMS) sensors – construction and building materials 22(2008) pp 111-120.
6. Weiping Zhang et al (2016) – Temperature response and moisture transport in damaged concrete under an atmospheric environment – construction and building materials 123(2016) pp 290-299.
7. Changhang Xu et al (2017) – Experimental investigation on detection of multiple surface cracks using vibro thermography with a low power piezoceramic actuator – Sensors 2017, 1, 2705.
8. Xiaotian Zou et al (2012) – An experimental study on the concrete hydration process using fabry- perot fiber optic temperature sensors - Measurement 45(2012), 1017-1082.
9. IS 516-1959 – Indian standard – Methods of tests for strength of concrete.

AUTHORS PROFILE

T. Sai Bindhusha, PG student, Structural Engineering in Department of Civil Engineering, AITS Rajampet, Andhra Pradesh, India-516126

S.M.V. Narayana, is presently working as Principal, AITS Rajampet, Kadapa, AP, India. He has 21 years of field experiences. He has published articles in various National and International journals. he have professional memberships from FIE, MISTE, IEEE.

T Naresh Kumar, holds PhD and published various research publications and have professional memberships from MIE, MISTE, MISET, MICE(I), C.Eng(I), MIAEng.

.