Field study to evaluate Built-in temperature

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Field study to evaluate Built-in temperature differential (BITD) at interior load position through concrete blocks

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ABSTRACT

Warping behavior of the rigid pavement is a well-known phenomenon and its root cause is daily variation in temperature at different regions of the concrete slab. Indian Road Congress (IRC) has recommended temperature differentials state wise, but due to variation in air temperature in different regions within the state the temperature differentials are likely to vary in different locations within the regions. This may have a major impact on the design thickness of pavements. In a bid to study Built-In Temperature Differential (BITD) a pavement quality concrete block of 20 cm, 25 cm and 30 cm thickness is constructed in the Udaipur region and compared with the IRC:58-2015 specifications. Block experienced a wide variation in the temperature distribution across the depth as rainfall water falling on the top surface is controlling the surface temperature. Temperature differential reported in the area under the study is substantially lesser than the value recommended in the IRC-58:2015 irrespective of block thickness hence, temperature differential needs to be given due consideration in the local region.

1. Introduction

The construction industry is a key sector employing a huge number of people and significantly contributes to the development of the nation [1,2]. Although, cement production releases an enormous amount of carbon dioxide in the atmosphere, yet it is dominantly utilized in concrete production for infrastructure development because of its reliability [3,4]. Fly ash and stone dust can partially replace cement and river sand respectively in conventional concrete production which helps in addressing the environmental concerns [5–9]. Cement concrete pavements perform better than flexible pavement over the life cycle because of their long life, durability and minimum maintenance requirements. Yet deterioration in cement concrete pavements is observed due to the combined effect of load and temperature stresses [3]. Temperature is a key factor that influences the concrete pavement performance and which if not addressed helps in developing warping. Warping and its impact on cement concrete pavement is a well-known phenomenon [10]. Warping takes place as a result of the temperature difference between the top and bottom fiber (also known as built-in temperature differential) of the concrete pavement which induces stresses. Top fiber or upper surface tends to expand, and bottom surface or fiber tends to contract if the temperature on top is higher than the bottom this results in compressive stress at the top and tensile stress at the bottom [11]. Temperature-induced stresses may result in untimely pavement cracking and loss of strength [13] Also, the positive and negative temperature differential increases with the thickness of the concrete pavement up to a certain extent [11–13]. Indian Road Congress (IRC) specifies various temperature differential for different states and regions which serves as a guideline for the design of pavement slab. Each state in India has its own unique topographical and climatic features which may impact the design thickness of the pavement slab [13]. This prompted authors of the present study to determine Built-In Temperature Differential (BITD) in the pavement quality concrete block of 20 cm, 25 cm and 30 cm thickness at the Udaipur region in the State of Rajasthan.

2. Material characterization

2.1. Aggregate

Aggregate utilized in this study in order to produce the concrete is procured from the local quarry. To assess the suitability of the

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material various properties are determined in the laboratory. Test results on the coarse aggregate are presented in Table 1.

2.2. Fine aggregates

In the present study, an attempt has been made to utilize the locally available crushed stone material and fly ash to develop a solution for stone waste management. Water absorption of crushed stone aggregate is found to be 0.6%. Test results of aggregates are presented in Table 2, Table 3 and Fig. 1.

2.3. Concrete mix

In the present study, fly ash and stone dust are partially replaced by fly ash and stone dust to produce the M–20, M–25 and M–30 grade concrete using the ordinary Portland Cement. In this regard, fly ash content is varied from 0% to 30%, whereas 30% of stone dust is added in each trial as various experimental studies concluded peak its strength [14,15]. Results of the test conducted on cement are presented in Tables 4 and 5, show the compressive strength of prepared concrete after 28 days of curing. Based on the compressive strength results, M–30 grade concrete prepared using 30% fly ash and 30% stone dust is adopted for further study.

3. Methodology

Three Concrete blocks namely Block-1, Block-2, and Block-3 are cast directly by fixing the wooden formwork on the prepared subgrade near the Civil Engineering Department of Sir Padampat Singhania University, Udaipur (Bhatewar), Rajasthan as shown in Fig. 2 (a). The thickness of Block-1, Block-2, and Block-3 are 20 cm, 25 cm and 30 cm respectively.

In the interior region, the temperature variation within the concrete block at the bottom, middle and top fiber is recorded using the thermocouple. A thermocouple is attached to the wooden beads with the help of glue and sticky tape at three places bottom, middle and top according to the block thickness.

Table 1
Test results of coarse aggregates.

Sl. No.	Particulars	Test Results	Maximum Specification Limits IS 383:1970
1	Aggregate Crushing Value, %	22.47	30%
2	Aggregate Impact value, %	23.51	30%
3	Los Angeles Abrasion value, %	21.36	30%
4	Water Absorption	0.21	02%
5	Specific Gravity	2.72	–

Table 3
Test results of fine aggregate.

Particular	Stone Dust	Fly Ash
Specific Gravity	2.7	2.2
Fineness Modulus	2.96	–

While concreting, the thermocouple with the wooden beads is placed at the center of the block simulating the interior position with extreme care to avoid any kind of damage as shown in Fig. 2 (b). Embedded tip of the thermocouple remains in contact with the concrete, while another exposed end with two open lead is connected with the temperature measuring unit to record the temperature of the concrete block at the bottom, middle and top fiber as shown in Fig. 3 (a). Temperature is recorded every 2 h for a week. Fig. 3 (b) presents the finished concrete blocks left for curing.

4. Results and discussion

The study is carried out for two months during September and October in 2018 to cover the monsoon and early winter. Due to complexities involved in presenting the data of prolonged time, only 3 days of data that experienced the crucial temperature variation during the season is only presented graphically in Fig. 4 to Fig. 6. Temperature variation of the day noticing the maximum built-in temperature differential (BITD) is presented in Table 6.

Fig. 4, Fig. 5 and Fig. 6 shows the temperature variation of the 20 cm, 25 cm and 30 cm concrete block depth with respect to time. Roughly, the variation during the day and night seems more like a sine wave. However, it is very difficult to notice any particular temperature variation pattern during the monsoon (September) season in any concrete block. It may be due to a change in ambient temperature. Secondly, during rainfall water meeting the top surface is influencing the surface temperature.

The temperature at the bottom, mid and top fiber is recorded using a thermocouple. Based on the temperature recorded from the field, built-in temperature differential (BITD) is evaluated and the effect of temperature along the depth of concrete block is analyzed at the interior load position. BITD is defined as the difference in the temperature of the top and bottom fiber of the pavement. Fig. 7, shows the BITD distribution across the 20 cm, 25 cm and 30 cm thick concrete blocks. Positive built-in temperature differential indicates the upper face of the block is warm as compare to bottom while negative temperature differential means the upper face is cooler than the bottom portion.

The built-in temperature differential is higher during the daytime (positive BITD) than the night. This may be due to the high intensity of heat radiation during the daytime. Positive and negative temperature differential across the 20 cm, 25 cm and 30 cm thick concrete block is presented in Table 7. Most frequently, the maximum positive temperature differential during a day is about 12 PM –3 PM while somewhere about 2 AM-5 AM negative

Table 2
Sieve analysis of crushed stone aggregates.

Sieve Size (mm)	Percentage of Passing	Percentage of Retained	Percentage of Passing as per IS 383 – 1970 Reaffirmed on 2007			
			I	II	III	IV
10	100	0	100	100	100	100
4.75	91.8	8.2	90–100	90–100	90–100	95–100
2.36	77.37	22.63	60–95	75–100	85–100	95–100
1.18	56.9	43.1	30–70	55–90	75–100	90–100
0.6	42.59	57.41	15–34	35–59	60–79	80–100
0.3	29.85	70.15	5–20	8–30	12–49	15–50
0.15	5.46	94.54	0–10	0–10	0–10	0–10

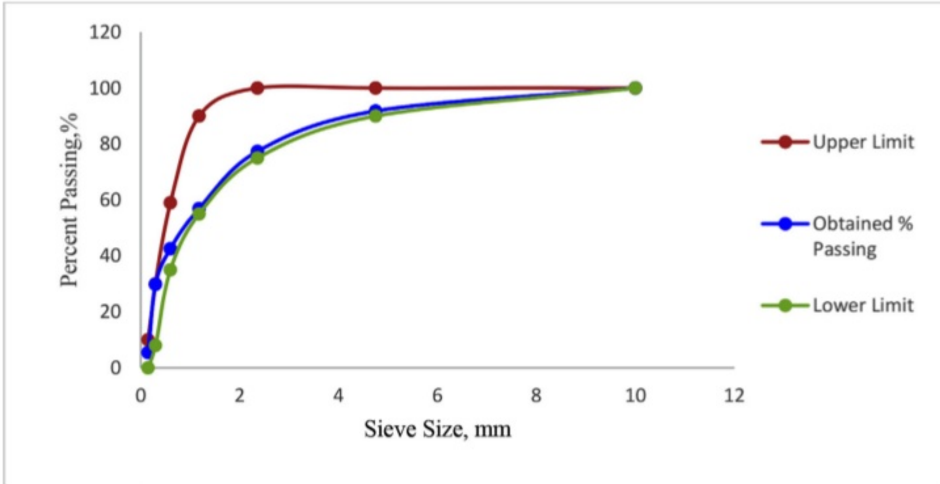

Fig. 1. Fine Aggregate gradation confirming Zone-II.

Table 4
Cement test results.

Sl. No.	Test	Test Results	Specification Limits as per IS 12269:1987
1	Initial Setting Time, Minute	53	Min 30
2	Final Setting Time, Minute	354	Max 600
3	Normal Consistency limit	35%	–
4	Fineness	3%	Max 10%
5	Specific Gravity	3.01	2.99–3.15

temperature differential is noticed. There is marginal variation in temperature variation in the 20 cm and 25 cm thick concrete block. However, the 30 cm thick concrete block revels the maximum temperature differential. The reason may be attributed to block thickness because of which temperature requires more time to vary from top to bottom and vice versa.

Table 7, also represents the maximum temperature differential value suggested by IRC-58:2015 in the Rajasthan, India excluding the hilly region. Codal provisions are silent about the hilly regions however in the absence of specified values it has been advised to utilize realistic values estimated for the given site considering

Table 5
Compressive strength of prepared concrete.

Sl. No.	Description	Average Compressive Strength (28 days)		Average Compressive Strength (28 days)		Average Compressive Strength (28 days)	
		M 20	w/c = 0.5	M 25	w/c = 0.45	M 30	w/c = 0.43
1	0% Fly ash + 30%Stone dust	27.35		37.76		38.89	
2	15% Fly ash + 30%Stone dust	29.12		38.41		40.45	
3	30% Fly ash + 30%Stone dust	25.26		34.29		37.21	

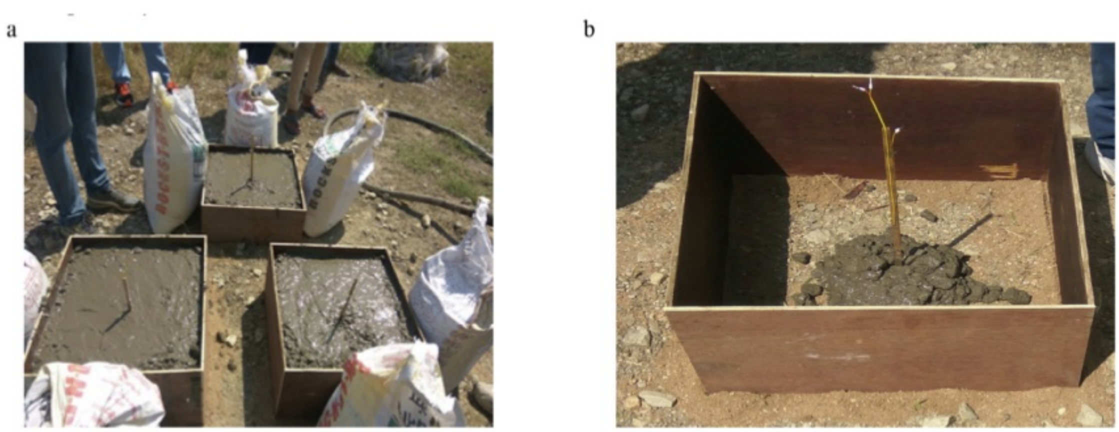

Fig. 2. (a) Concrete blocks with thermocouple; (b) Fixing the thermocouple.

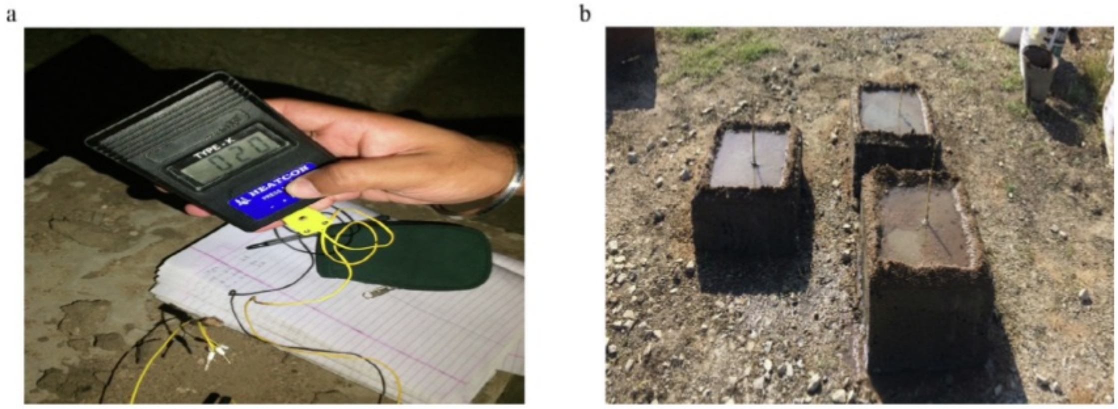

Fig. 3. (a) Temperature measuring unit; (b) Finished concrete blocks left for curing.

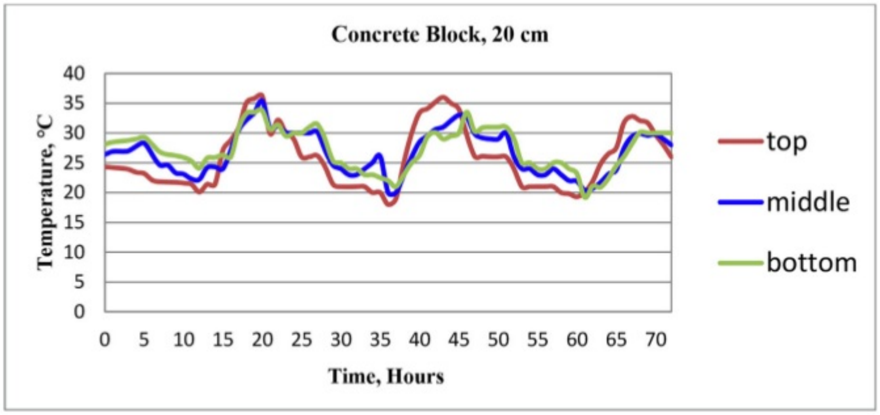

Fig. 4. Temperature distribution in 20 cm thick concrete block.

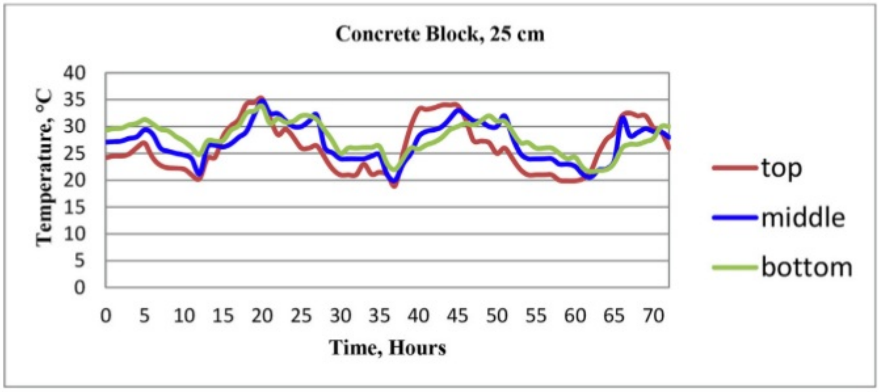

Fig. 5. Temperature distribution in 25 cm thick concrete block.

the geographical parameters. As the area under study does not belong to the absolute plain area nor the hilly region hence the temperature differential study may be given due consideration in the local region.

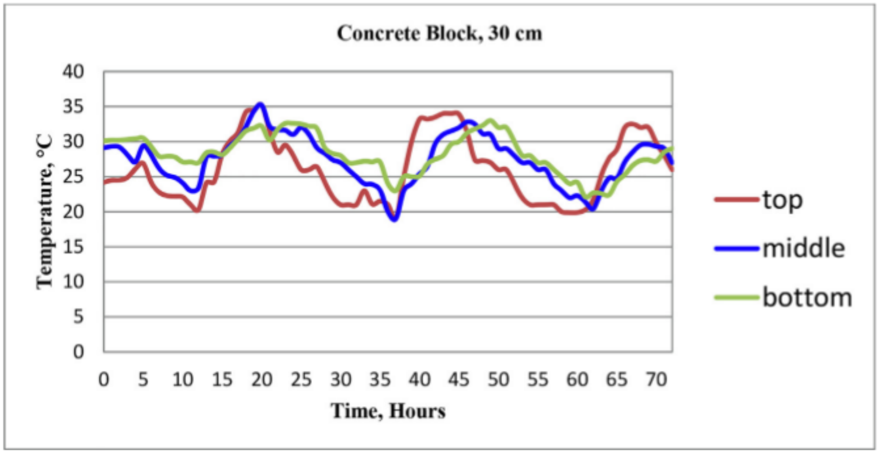

Fig. 6. Temperature distribution in 30 cm thick concrete block.

Table 6
Temperature variation data.

Time	Ambient Temperature, °C	20 cm.			25 cm.			30 cm.			Differential Temperature, °C		
		TOP	Middle	Bottom	Top	Middle	Bottom	Top	Middle	Bottom	20CM	25CM	30CM
12:00 AM	28	29	32	31	29	29	34	29	31	36	−2	−5	−7
2:00 AM	26	27	30	32	27	30	34	27	31	34	−5	−7	−7
4:00 AM	24	25	25	30	24	26	30	25	28	30	−5	−6	−5
6:00 AM	24	23	27	27	23	27	30	23	28	27	−4	−7	−4
8:00 AM	26	29	28	30	29	28	27	29	28	26	−1	2	3
10:00 AM	28	32	30	30	31	29	25	32	29	27	2	6	5
12:00 PM	31	33	33	31	32	32	26	32	32	28	2	6	4
2:00 PM	33	38	35	31	38	36	32	38	34	30	7	6	8
4:00 PM	32	36	32	30	36	34	32	36	35	31	6	4	5
6:00 PM	31	34	31	32	34	32	33	34	33	32	2	1	2
8:00 PM	30	30	29	28	31	29	34	30	31	33	2	−3	−3
10:00 PM	29	27	29	30	28	31	34	27	31	34	−3	−6	−7

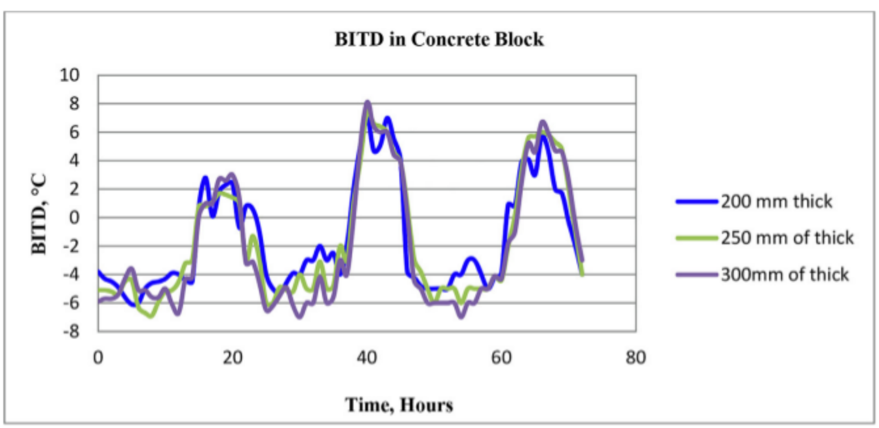

Fig. 7. Built-in temperature differential (BITD) of concrete blocks.

Table 7
Built-in temperature differential (BITD) of concrete blocks.

Concrete Block	Temperature Differential, °C		Suggested Temperature Differential, °C as per IRC-58:2015
	Positive	Negative	
20 cm	7	5	13.1
25 cm	6	7	14.3
30 cm	8	7	15.8

5. Conclusions

Present work is aimed at studying the temperature distribution across the depth of a concrete block. Based on the limited field study, the following conclusions may be drawn:

- There is a wide variation in the temperature distribution along the depth of the concrete block during rainfall season. The reason for the aforementioned wide variation may be attributed to the rainfall water meeting the top surface which is influencing the surface temperature.
- It has been observed that high intensity of heat radiation during the daytime is causing a surge in built-in temperature differential in camparision to the night.
- The 30 cm thick concrete block showing the maximum temperature differential has been noted. The reason for this may be ascribed to the thickness of concrete block in which temperature requires more time to vary from top to bottom and vice versa.

In summary, the temperature differentials obtained in the area under the study are substantially lower than the maximum recommended values by IRC-58:2015 irrespective of the block thickness. Hence, the temperature differential study may be given due consideration in the local region.

References

[1] A. Ojha, V. Chouhan, L. Gupta, S. Goswami, AIP Conf, Proc. 2204 (1) (2020) 020005.
[2] A. Ojha, L. Gupta, Urb. Challen. Emerg. Econ. (2018) 552–557.
[3] M. Dhananjay K. Abhilash G. J. Res. Eng. Civ. Str. Eng. 14 2014 5
[4] L. Gupta, A. Bellary, Mat. Tod. Proc. 5 (1) (2018) 2074–2081.
[5] C.L. Kapugamage, A. L. Amarasiri, W. P. S. Dias, D.M.C.S.D Bandara, H. M. Riyaz, P. S. P. Bandusena, Wom. Car. Adv. Tra. Dev. (2008) 335.
[6] L. Gupta, A. Patil, A. Ojha, Int. J. Res. Eng. Tech. 5 (3) (2016) 32–36.
[7] N. Suresh, M. Manjunatha, Ind. Conc. J. (2016) 69.
[8] S.P. Rajput, Mat. Tod. Proc. 5 (9) (2018) 17540–17547.
[9] L. Gupta, G. Suresh, Int. Cong. Exhi. Sust. Civi. Infrast.: Innov. Infrast. Geotech. (2017) 249–261.
[10] X. S Hou, X. K Li, B Peng., G. H. Deng, Adv. Mat. Res. 723 (2013) 163-170.
[11] G.K. Kamalakara, S.M. Naik, B.K.S. Kumar, S.K. Vijaykumar, W.B. Siddharam, M. Sushmitha, Intl. J. Res. Anal. Rev. 5 (2) (2018) 1022–1028.
[12] L. Gupta, G. Suresh, Ind. High. 4 (2016) 44.
[13] V.B. Math, A. Sheregar, G. Kavitha, Eur. J. App. Eng. Scient. Res. 4 (2) (2015) 35–43.
[14] A. Tiwari, S. Singh, R. Nagar, J. Cl. Prod. 135 (2016) 490–507.
[15] L. Gupta, R. Kumar, Int. Cong. Exhi. Sust. Civi. Infrast.: Innov. Infrast. Geotech. (2018) 124–134.

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