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Effect of Insufficient Curing on the Properties of Cement-Sand Mortar under the Laboratory and Field Conditions

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Abstract:
Curing the cement-sand mortar or concrete is a mechanism of maintaining the suitable temeperature and relative humidity (RH) so that there is adequate hydration of cement particles, leading to short-term and long-term strength gain and better durability properties. It is the last process, wherin hardened mortar or concrete is kept moist through the application of water, or by any other means, for the sufficient period, especially during initial one to two weeks. On many construction sites, particluarly in deveoping countries, curing is grosssly negelcted in terms of frequency as well as duration. Under-curing leads to a low quality product in terms of strength and durability.
The experimental work was carried out to assess the effect of insufficient curing duration on the 28-day parameters of cement-sand mortar, such as denisty, mass loss, compressive strength and water absorption. In all, 60 mortar cubes were cast ; 10 smaples (30 cubes) for the laboratory exposure and 10 samples (30 cubes) for the field exposure. The temperature and RH of indoor and outdoor environnements were measured in the afternoon for the 28 days. Spray curing was carried out twice a day ; curing durations were : no curing, 3-d curing, 7-day curing, 14-day curing and 28-day curing. For both the exposure conditions, 28-day compressive strength exhibited continuous incearing trend as the curing duration was increased ; field cubes showed considerably higher values. For other parameters, no particluar trend was followed ; however, field conditions with higher temperature, within a certain limit, and higher RH were seen to be more conducive and desirable.
***Key Words**: Temperature; Relative Humidity; Mortar; Hydration; Compressive Strength; Mass Loss; Water Absorption; Density, etc.*

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I. INTRODUCTION

For the concrete to attain the desired mechanical properties and durability, curing is a vital process[1,2,3,4]. As per American Concrete Institute (ACI), curing governs the temperature and humidity of freshly cast concrete and enhances hydration reaction of cement particles to ensure the long-term performance of concrete[2,5,6]. The purpose of curing in early ages is to reduce the water loss from the concrete so that the strength can be achieved in the initial days[7,8]. Curing is essential to prevent permeability loss, plastic shrinkage and enhance abrasion resistance[9]. The moment water comes in contact with the cement particles, hydration reaction starts leading to increases in the temperature[10]. It is important to maintain appropriate humidity and temperature for obtaining the desired concrete properties[11].

The loss of water takes place from the surface, exposed to the prevailing environmental conditions, where environmental humidity is less than that inside the concrete mass, also resulting in decreased initial water-cement ratio, which occurs because of hydration[12, 13]. Usually, concrete structures are subject to dry conditions from an early age at construction sites. Concrete starts drying out from the first day till many more days[14,15]. Theoretically, normal concrete has water-cement ratio > 0.42, which is sufficient for the complete hydration process[10,16]. However, practically on sites, in regions with high temperature and low relative humidity, major water loss occurs from the surface[17]. Inadequate curing takes place on many construction sites; however, it especially occurs for the vertical members, inclined members, regions where water is in scarce amount or inaccessible for the continuous curing[18,19,20] and where curing cannot be supervised properly.

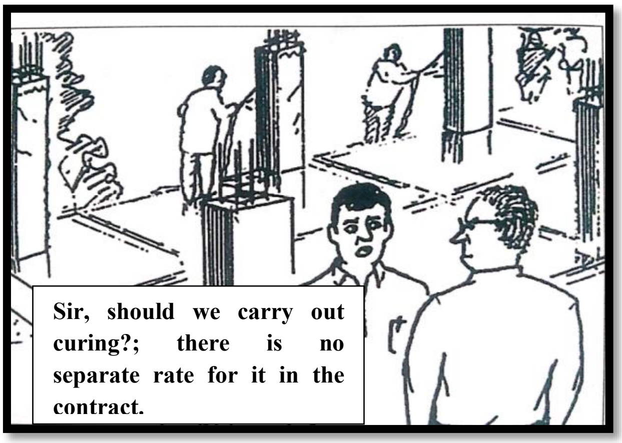

Fig. 1: Courtesy: Ambuja Knowledge Centre Booklet

Curing for the adequate duration is highly essential in high performance concrete due to its low water-cement ratio. The cement particles may attain a final degree of hydration, which may be less than 50%. If proper curing does not take place, internal relative humidity drops rapidly; hydration process ceases[21]. It can lead to early-age cracking owing to volumetric changes through self-desiccation. The water evaporation results in tensile stresses inside the concrete mass; sometimes, tensile stress exceeds tensile strength. High performance concrete usually consists of supplementary cementitious materials; this requires prolonged curing. Owing to curing for insufficient period, cementitious materials hydrate under sealed conditions; empty pores are formed within the concrete due to hydration products occupying less volume than the reacting materials i.e. cement and water.

In this experimental work, an attempt has been made to investigate the effect of no curing, spray curing for 3, 7, 14 and 28 days on the density, compressive strength, mass loss and water absorption of (70.6 x 70.6 x 70.6) mm cement-sand mortar cubes at 28 days, under the laboratory and field (under the sun) conditions, at the prevailing temperature and the relative humidity.

II. MATERIALS USED

i) OPC 53 cement with specific gravity of 3.15, conforming to Indian Standard, IS 12269: 2013[22].
ii) Fine aggregates, conforming to zone II of IS 383: 2016 with specific gravity of 2.74 [23].
iii) Potable mixing and curing water, conforming to IS 456: 2000 (Reaffirmed 2005)[24].

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III. METHODOLOGY

The fine aggregates were brought to the saturated surface dry (SSD) condition. Cement and sand were mixed at a volumetric proportion of 1: 3, with a water-cement ratio of 0.4. The mixture was filled in to (70.6 x 70.6 x 70.6) mm cube moulds and vibrated on a vibrating machine. Totally 60 cubes were cast; 30 for the laboratory exposure and 30 for the field exposure. Each sample consisted of a set of 3 specimens for arriving at the average values. Spray curing was done twice a day; in the morning and in the evening.

Fig. 2: Moulds Filled with Cement-Sand Mortar

Table No. 1: Details of Cube Casting for the Laboratory Conditions

Density, Mass Loss & Compressive Strength at 28 Days		**Water Absorption at 28 Days**		**Remarks**
28DWCL	Cubes cast: (3 x 5) = 15	28DWCLWA	Cubes cast: (3 x 5) = 15	Without curing
3DSCL		3DSCLWA		Spray curing for 3 days
7DSCL		7DSCLWA		Spray curing for 7 days
14DSCL		14DSCLWA		Spray curing for 14 days
28DSCL		28DSCLWA		Spray curing for 28 days

Table No. 2: Details of Cube Casting for the Field Conditions

Density, Mass Loss & Compressive Strength at 28 Days		**Water Absorption at 28 Days**		**Remarks**
28DWCF	Cubes cast: (3 x 5) = 15	28DWCFWA	Cubes cast: (3 x 5) = 15	Without curing
3DSCF		3DSCFWA		Spray curing for 3 days
7DSCF		7DSCFWA		Spray curing for 7 days
14DSCF		14DSCFWA		Spray curing for 14 days
28DSCF		28DSCFWA		Spray curing for 28 days

Fig. 3: Spray Curing Being Done

Fig. 4: Specimens Placed in the Field (Under the Sun)

IV. EXPERIMENTAL INVESTIGATIONS

4.1 Temperature and Relative Humidity Values for 28 Days

The temperature and relative humidity values for the laboratory as well as the field conditions were noted on a daily basis at 12.30 pm till 28 days.

4.2 Density at 28 Days

The average density (kg/m^3) of a set of 3 cubes was calculated as (Cube Mass) / (Cube Volume)

4.3 Mass Loss at 28 Days

The average mass loss for a set of 3 cubes was calculated as [(Initial Mass – Final Mass) / Initial Mass] x 100%.

4.4 Compressive Strength at 28 Days

The mortar cubes, which were used for density and mass loss determination, were placed and centered in the compressive testing machine; load was uniformly and steadily applied, starting from zero with the rate of 35 MPa/minute. IS: 4031(Part 6) – 1988 (Reaffirmed 2019)[25] was referred for the testing. The average value for 3 cubes was reported as compressive strength.

Compressive Strength = [(Failure Load) / (Cross-Sectional Area, 70.6 x 70.6)] N/mm^2 or Mpa.

4.5 Water Absorption at 28 Days

After 28 days, mortar cubes were placed in an oven at 105^{0}C for 24 hours. The cubes were then taken out; they were cooled at the room temperature and weighed (W_1). They were then immersed in the fresh and clean water. They were removed from the water after 24 hours of water absorption; the surface was air-dried and weighed again (W_2). Average value of 3 cubes was considered.

$$\text{Water absorption (\%)} = [(W_2 - W_1) / W_1] \times 100\%$$

V. RESULTS AND DISCUSSION

5.1 Temperature and Relative Humidity Values for 28 Days

Table No. 3: Temperature and Relative Humidity Values for 28 Days

Days	Temp. ^{0}C (Lab.)	Temp. ^{0}C (Field)	RH % (Lab.)	RH % (Field)	Days	Temp. ^{0}C (Lab.)	Temp. ^{0}C (Field)	RH % (Lab.)	RH % (Field)
1	30.94	36	32	50	*15*	30.27	38	42	55
2	31	33	31	52	*16*	31	35.71	62	60
3	31.61	33	31	60	*17*	31	37	61	75
4	32	35	32	53	*18*	30.17	36.67	48	90
5	31.61	32	41	65	*19*	27.00	41.32	46	57
6	31.61	36.76	37	70	*20*	29.71	37.89	62	68
7	36.72	39.71	50	93	*21*	31	40.67	43	59
8	32	31.66	31	79	*22*	25	38.23	43	70
9	29.44	32	51	70	*23*	29.81	37.98	60	55
10	32.11	39	44	73	*24*	31.24	35.71	54	59
11	30.50	40	40	70	*25*	30.68	34	53	67
12	31.17	35.76	28	67	*26*	30.55	35.8	62	57
13	31.78	33.37	30	60	*27*	30.72	37.76	56	60
14	30.11	31.94	42	57	*28*	30.32	35.45	60	69

For the laboratory exposure, the minimum and maximum temperatures were 25 ^{0}C and 36.72 ^{0}C respectively; the average value being 30.75 ^{0}C. For the field conditions, the minimum and maximum temperatures were 31.66 ^{0}C and 41.32 ^{0}C respectively; the average value being 36.12 ^{0}C.

For the laboratory conditions, the minimum and maximum RH values were 28% and 62% respectively; the average value being 45.42%. For the field exposure, the minimum and maximum RH values were 50% and 93% respectively; the average value being 65%.

High temperature with low RH usually results in rapid drying, cracking and poor strength; High temperature with high RH poses moderate risk, but still requires the controlled curing; moderate temperature combined with moderately high RH is good for hydration, strength and durability; Low temperature with low RH may result in delayed strength and potential freeze damage and low temperature with high RH leads to slowing down of hydration, however, there is a low risk of drying and cracking.

5.2 Density at 28 Days

Table No. 4: Average Density Values at 28 Days

Lab.	Avg. Density (kg/m^3)	Field	Avg. Density (kg/m^3)
28DWCL	2057.14	28DWCF	2124.75
3DSCL	1980.95	3DSCF	2148.56
7DSCL	1910.47	7DSCF	2170.47

14DSCL	2008.56	14DSCF	2135.23
28DSCL	2012.37	28DSCF	2166.66

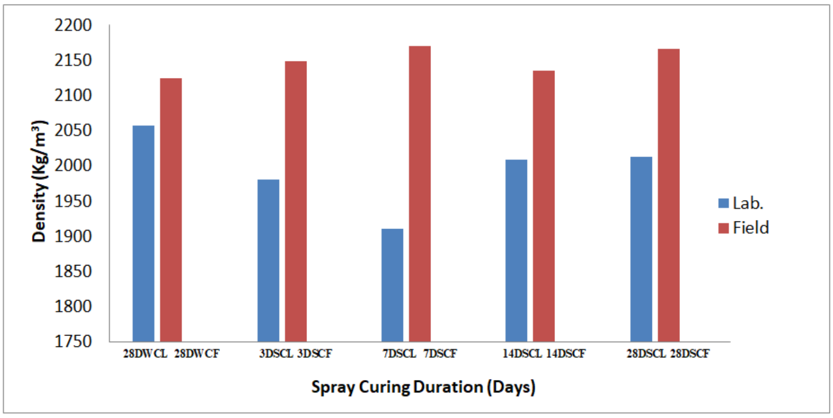

Fig. 5: Average Density Values at 28 Days

For the laboratory exposure, 7-day spray cured cubes exhibited the least density; the highest value was witnessed for the cubes without curing as indicated in Table 4 and Fig. 5. No particular pattern was followed; density depends upon factors like extent of compaction, cube dimensions, etc.

For the field exposure, least density value was exhibited by the cubes without curing. Highest value was seen for the cubes with 7 days of spray curing; followed by 28-day spray cured cubes with slightly lesser value.

For all the cases, the density values of cubes exposed to the field conditions were greater than that of the cubes placed inside the laboratory. Referring table 3 of section 5.1, the higher temperature, combined with the greater RH for the field exposure resulted in a denser matrix.

5.3 Mass Loss at 28 Days

Table No. 5: Average Mass Loss at 28 Days

Lab.	Avg. Mass Loss (%)	Field	Avg. Mass Loss (%)
28DWCL	0.18	28DWCF	0.58
3DSCL	0.18	3DSCF	0.26
7DSCL	0.44	7DSCF	0.26
14DSCL	0.23	14DSCF	0.45
28DSCL	0.28	28DSCF	0.35

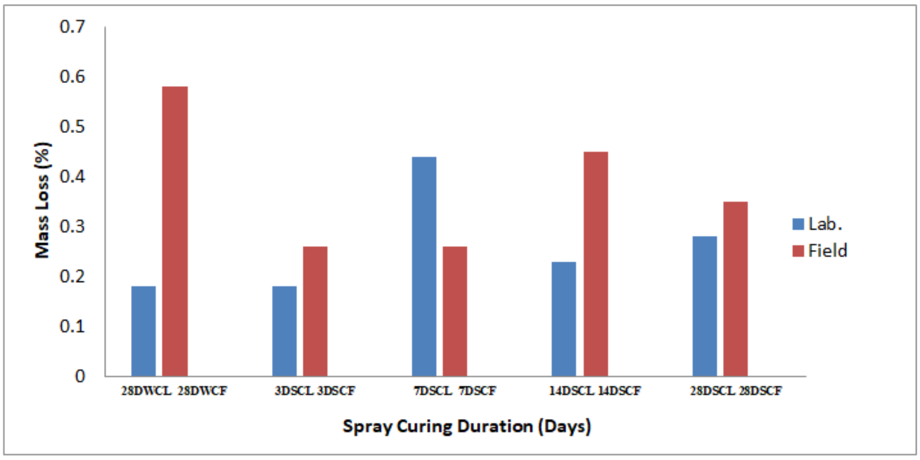

Fig. 6: Average Mass Loss Values at 28 Days

Referring table 5 and fig. 6, no particular trend for the mass loss due to evaporation was observed. However, the mass loss values for field samples were more than that for the laboratory samples. Though RH was higher for the field conditions, temperatures were also on the higher side; this led to accelerated moisture evaporation from the mortar cubes resulting in the greater mass loss.

5.4 Compressive Strength at 28 Days

Table No. 6: Average Compressive Strength at 28 Days

Lab.	Avg. Comp. Strength (Mpa)	Strength Gain (%)	Field	Avg. Comp. Strength (Mpa)	Strength Gain (%)
28DWCL	10.23	39.96	28DWCF	20.45	46.47
3DSCL	14.40	56.25	3DSCF	25.10	57.04
7DSCL	15.36	60.00	7DSCF	28.20	64.09
14DSCL	20.16	78.75	14DSCF	42.95	97.61
28DSCL	25.60	100	28DSCF	44.00	100

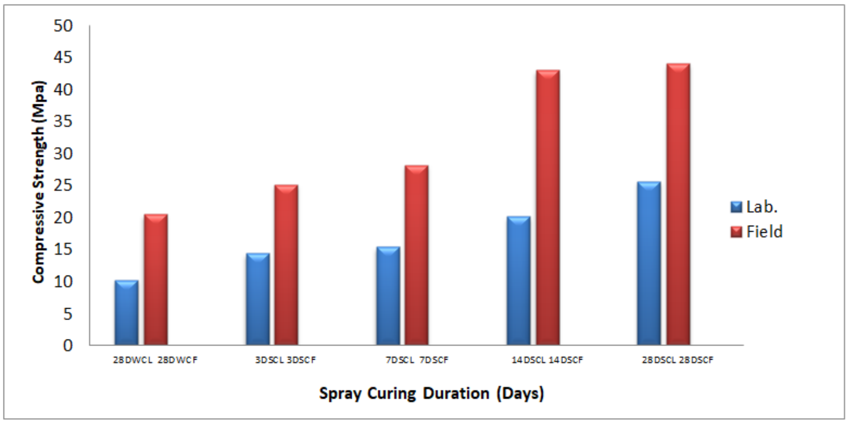

Fig. 7: Average Compressive Strength at 28 Days

Table 6 along with fig. 7 clearly depict that, as the curing duration is increased, there is an increasing trend in the compressive strength for both the exposure conditions. Considering 28-day spray cured strength as 100% strength, it was witnessed for the laboratory exposure that the samples without curing could attain only 40%, 3-day spray cured samples attained 56%, 7-day spray cured samples exhibited 60% and 14-day spray cured samples gained 80% strength. Similarly, for the field exposure, cubes without curing attained 46%, 3-day spray cured samples attained 57%, 7-day spray cured samples reached 64% and 14-day spray cured samples gained 98% strength.

This clearly indicates that ensuring curing for the sufficient duration for keeping the matrix moist and within the suitable temperature range is a vital consideration. If no curing is done, there may be 50 to 60% strength loss. If a very short duration curing is done, say for 3 days, the matrix can lose up to 40 to 50% of its potential compressive strength due to inadequate hydration. This is because hydration is most active during the initial 7 days. Practically, 28 days curing is not possible on the construction sites. However, curing for more than 7 days till 14 days is highly beneficial.

For all the cases, compressive strength values of field exposed samples were almost double of that of samples placed in an indoor environment. The higher temperature and humidity facilitate in accelerated cement hydration, resulting in faster strength attainment. Higher temperatures, within a certain range, enhance the rate at which cement hydrates due to quicker chemical reactions between cement and water. Greater humidity facilitates concrete to be in moist state for a longer period, thereby enhancing the degree of hydration. On the contrary, lower temperature and humidity result in slow down of hydration, delayed setting and strength gain.

5.5 Water Absorption at 28 Days

Table No. 7: Average Water Absorption at 28 Days

Lab.	Avg. Water Absorption (%)	Field	Avg. Water Absorption (%)
28DWCLWA	3.21	28DWCFWA	1.87
3DSCLWA	7.18	3DSCFWA	1.18
7DSCLWA	9.64	7DSCFWA	1.72
14DSCLWA	8.66	14DSCFWA	1.59
28DSCLWA	7.36	28DSCFWA	2.15

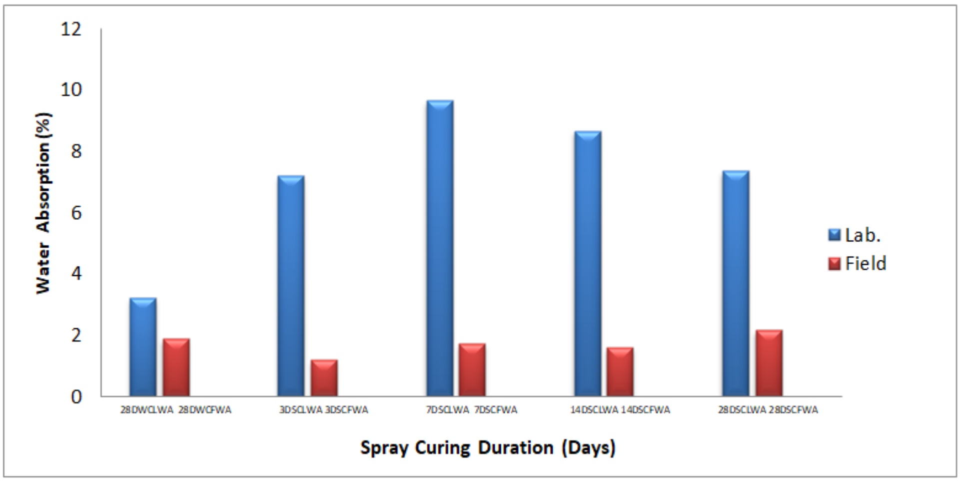

Fig. 8: Average Water Absorption at 28 Days

For both the exposure conditions, no particular pattern for the water absorption was followed. However, for all the cases, water absorption values of field samples were lower than the corresponding values of indoor samples. Referring table 4 of section 5.2, the greater density values for the field samples indicate lesser porosity of matrix, thereby reducing the water absorption. Curing the matrix at a higher temperature (up to a certain limit), combined with greater RH results in the denser matrix, thereby enhancing the long-term durability.

Table No. 8: Ranking of Parameters (Highest Value – 1 and Lowest Value -5)

Lab.	Den	ML	CS	WA	Field	Den	ML	CS	WA
28DWCL	1	4	5	5	28DWCF	5	1	5	2
3DSCL	4	4	4	4	3DSCF	3	4	4	5
7DSCL	5	1	3	1	7DSCF	1	4	3	3
14DSCL	3	3	2	2	14DSCF	4	2	2	4
28DSCL	2	2	1	3	28DSCF	2	3	1	1

Den- Density, ML-Mass Loss, CS- Compressive Strength and WA- Water Absorption

Referring table 8, no particular trend was observed for the various parameters, except for the compressive strength values which continuously showed an increasing trend with greater curing duration. This shows that compressive strength is not the direct function of other parameters under consideration. Matrix has a complex behavior under the load.

VI. CONCLUSIONS

Curing for the insufficient duration results in significant strength loss. Curing must be carried out vigorously at least up to 14 days. Curing beyond 14 days is beneficial for the continuous strength gain. Curing at high temperature (up to certain limit) and high relative humidity enhances the compressive strength considerably. If better quality mortar or concrete is produced by selecting proper ingredients, but if the duration and frequency of curing are not given due importance, all the efforts put for manufacturing a better product will be a wasteful exercise. Curing the mortar or concrete adequately is a must for the short-term and long-term benefits. This would lead to the sustainable construction practice and development.

REFERENCES

[1]. P. Ge, W. Huang, H. Zhang, W. Quan, and Y. Guo, "Study on calculation model for compressive strength of water saturated recycled aggregate concrete," KSCE Journal of Civil Engineering, Vol. 26, No. 1, pp. 273–285, Sep. 2021, https://doi.org/10.1007/s12205-021-0286-4.

[2]. G. Zhang, C. Li, H. Wei, M. Wang, Z. Yang, and Y. Gu, "Influence of humidity on the elastic modulus and axis compressive strength of concrete in a water environment," Materials, Vol. 13, No. 24, p. 5696, Dec. 2020, https://doi.org/10.3390/ma13245696.

[3]. D. Shen, C. Liu, M. Wang, X. Jin, and H. Tang, "Prediction model for internal relative humidity in early-age concrete under different curing humidity conditions," Construction and Building Materials, Vol. 265, p. 119987, Dec. 2020, https://doi.org/10.1016/j.conbuildmat.2020.119987.

[4]. T. Gereziher Atsbha and S. Zhutovsky, "Investigating the effect of hybrid curing on mechanical and durability properties of normal-strength concrete," Construction and Building Materials, Vol. 369, p. 130536, Mar. 2023, https://doi.org/10.1016/j.conbuildmat.2023.130536.
[5]. G. H. Guo, Y. F. Bai, and T. Wang, "Analysis of dynamic load level of high-speed heavy vehicle imposed on uneven pavement," in Applied Mechanics and Materials, Vol. 138-139, pp. 146–152, Nov. 2011, https://doi.org/10.4028/www.scientific.net/amm.138-139.146.
[6]. L. Liu, S. Zhao, J. Xin, and Z. Wang, "Simplified analysis of thermal cracks in low-heat Portland cement concrete," Advances in Civil Engineering, Vol. 2022, No. 1, p. 76305, Apr. 2022, https://doi.org/10.1155/2022/7630568.
[7]. A. A. Raheem, A. A. Soyingbe, A. J. Emenike, "Effect of curing methods on density and compressive strength of concrete", International Journal of Applied Science and Technology, Vol. 3, No. 4, pp. 55-64, 2013.
[8]. R. S. Unnithan, S. Anil, "Review on Self Curing Concrete", International Journal of Engineering and Technology, Vol. 4, No. 5, pp. 1022-1024, 2017.
[9]. G. Espinoza-Hijazin, A. Paul, M. Lopez, "Concrete containing natural pozzolans: new challenges for internal curing", Journal of Materials in Civil Engineering, Vol. 24, No. 8, pp. 981-988, 2011.
[10]. G. Espinoza-Hijazin, M. Lopez, "Extending internal curing to concrete mixtures with W/C higher than 0.42", Construction and Building Materials, Vol. 25, No. 3, pp. 1236-1242, 2011.
[11]. Z. Shen, H. Zhu, and X. Meng, "The influence of curing methods on the performance of recycled concrete powder artificial aggregates and concrete," Construction and Building Materials, Vol. 435, p. 136908, Jul. 2024, https://doi.org/10.1016/j.conbuildmat.2024.136908.
[12]. A. A. Bashandy, N. N. Meleka, M. M. Hamad, "Comparative Study on the Using of PEG and PAM as Curing Agents for Self-Curing Concrete", Challenge Journal of Concrete Research Letters, Vol. 8, No. 1, pp. 1-10, 2017
[13]. J. Zhang, J. Wang, Y. Han, "Simulation of moisture field of concrete with pre-soaked lightweight aggregate addition", Construction and Building Materials, Vol. 96. pp. 599-614, 2015.
[14]. D. Mohamad, S. Beddu, S. N. Sadon, N. L. M. Kamal, Z. Itam, K. Mohamad, W. M. Sapua, "Self-curing Concrete using Baby Diapers Polymer", Indian Journal of Science and Technology, Vol. 10 No. 4, 2017.
[15]. S. Zhutovsky, K. Kovler, "Influence of water to cement ratio on the efficiency of internal curing of high-performance concrete", Construction and Building Materials, Vol. 144, pp. 311-316, 2017.
[16]. O. Idowu, L. Black, "Effect of Improper Curing on Concrete Performance", 34th Cement and Concrete Science Conference, University of Sheffield, UK, September 14-17, 2014.
[17]. K. N. Rahal, "Effects of improper moist curing on flexural strength of slabs cast under hot weather conditions", Construction and Building Materials, Vol. 110, pp. 337-345, 2016.
[18]. M. S. R. Chand, P. S. N. R. Giri, G. R. Kumar, P. R. Kumar, " Paraffin wax as an internal curing agent in ordinary concrete", Magazine of Concrete Research, Vol. 67, No. 2, pp. 82-88, 2015.
[19]. M. I. Mousa, M. G. Mahdy, A. H. Abdel-Reheem, A. Z. Yehia, "Mechanical properties of self-curing concrete (SCUC)", HBRC Journal, Vol. 11, No. 3, pp. 311-320, 2014.
[20]. K. B. Subramanian, A. Siva, S. Swaminathan, A. M. G. Ajin, "Development of High Strength Self Curing Concrete Using Super Absorbing Polymer", International Journal of Civil, Environmental, Structural, Construction and Architectural Engineering, Vol. 9, No. 12, pp. 1536-1541, 2015.
[21]. J. Justs, M. Wyrzykowski, D. Bajare, P. Lura, "Internal curing by superabsorbent polymers in ultra-high performance concrete", Cement and Concrete Research, Vol. 76, pp. 82-90, 2015.
[22]. Indian Standard, IS 12269: 2013, "Ordinary Portland Cement 53 Grade-Specification (First Revision)", Bureau of Indian Standards, New Delhi, India.
[23]. Indian Standard IS 383: 2016, "Coarse and Fine Aggregate for Concrete- Specification (Third Revision)", Bureau of Indian Standards, New Delhi, India.
[24]. Indian Standard, IS 456: 2000 (Reaffirmed 2005), "Plain and Reinforced Concrete- Code of Practice (Fourth Revision)", Bureau of Indian Standards, New Delhi, India.
[25]. Indian Standard, IS 4031 (Part 6):1988 (Reaffirmed 2019), "Methods of Physical Tests for Hydraulic Cement, Determination of Compressive Strength of Hydraulic Cement", Bureau of Indian Standards, New Delhi, India.