International Journal of Environmental & Agriculture Research (IJOEAR)
ISSN: [2454-1850]
[Vol-12, Issue-10, October- 2026]
Website: www.ijoear.com
Journal DOI: 10.25125/agriculture-journal

Non-Destructive Testing of Concrete Specimens Using Thermography

Vanya Georgieva[1*]; Galina Dineva[2]; Dimitar Georgiev[3]

Department of Agricultural Engineering, Faculty of Agriculture, Trakia University, 6000 Stara Zagora, Bulgaria
*Corresponding Author

Received:- 21 September 2026/ Revised:- 01 October 2026/ Accepted:- 19 October 2026/ Published: 31-10-2026
Copyright @ 2026 International Journal of Environmental and Agriculture Research
This is an Open-Access article distributed under the terms of the Creative Commons Attribution Non-Commercial License (https://creativecommons.org/licenses/by-nc/4.0) which permits unrestricted Non-commercial use, distribution, and reproduction in any medium, provided the original work is properly cited.

Abstract— *The present study evaluates the surface temperature of concrete specimens subjected to an aggressive environment using passive infrared thermography. Specimens of ordinary concrete (OC) and sulfate-resistant concrete (SRC) were analyzed. The maximum, minimum and average surface temperatures, as well as the temperature range (ΔT), were determined for each specimen. A statistically significant effect of the storage environment on the average surface temperature (Tavg) was established ($F(1,8) = 22.93$; $p = 0.001$; $\eta p^2 = 0.741$). The obtained results confirm the applicability of thermography as a comparative non-destructive method for monitoring changes in the surface thermal behavior of concrete specimens.*

Keywords— concrete elements, infrared camera, surface temperature, aggressive environment.

I. INTRODUCTION

Concrete is widely used as a structural material for the construction of floors, manure alleys, channels and other facilities in livestock buildings. Its condition is considered important for the durability of structures as well as for hygiene, movement safety and animal health. Concrete surfaces are required to provide mechanical resistance, ease of cleaning and sufficient slip resistance [1].

The operating environment in livestock buildings is characterized by high humidity and prolonged contact with manure, urine, feed residues and cleaning water. As a result, concrete is subjected to complex chemical and physical effects [2]. Changes in the cement matrix, increased porosity and gradual deterioration of the surface layer may be caused by organic acids, ammonium compounds, sulfates and manure decomposition products [3], [4]. Additional effects may be induced by microbial activity in the presence of moisture and organic matter [5].

For the assessment of these changes, methods that do not affect the integrity of the investigated elements are required [6]. Infrared thermography (IRT) is considered an applicable non-contact and non-destructive method in which infrared radiation emitted from the surface is converted into a temperature field. Differences in the thermal response of concrete may be associated with changes in thermal conductivity, heat capacity, density, porosity and moisture content [6], [7], [9], [12]. The method is applied to identify thermal anomalies associated with internal inhomogeneities, voids, delamination and changes in moisture conditions [8], [10], [11].

In passive infrared thermography, no additional thermal excitation is applied and the natural temperature response of the material is recorded. The obtained results may be influenced by moisture content, ambient temperature, air movement, measurement distance and measurement angle. Therefore, measurements are required to be performed under as uniform conditions as possible and the interpretation of the results should be based primarily on quantitative temperature parameters [6]–[8].

Based on the reviewed scientific literature, no studies involving the application of infrared thermography to concrete elements subjected to manure exposure were identified.

The aim of the present study was to perform a comparative assessment of the surface thermal behavior of ordinary and sulfate-resistant concrete specimens after storage in manure using passive infrared thermography.

II. MATERIALS AND METHODS

Cubic concrete specimens with dimensions of 150 × 150 × 150 mm were used in the study. Two types of concrete were investigated: ordinary concrete (OC) and sulfate-resistant concrete (SRC). For each concrete type, a control group (A) and an experimental group (B) were established. The experimental specimens were stored in semi-liquid manure for six months while the control specimens were maintained under laboratory conditions without exposure to external aggressive agents.

A Laserliner ThermoCamera HighSense infrared thermal imaging camera was used to perform non-contact measurements and quantitative analysis of the surface temperature field of the concrete specimens.

The main technical characteristics and measurement parameters used during the thermographic investigation are presented in Figure 1.

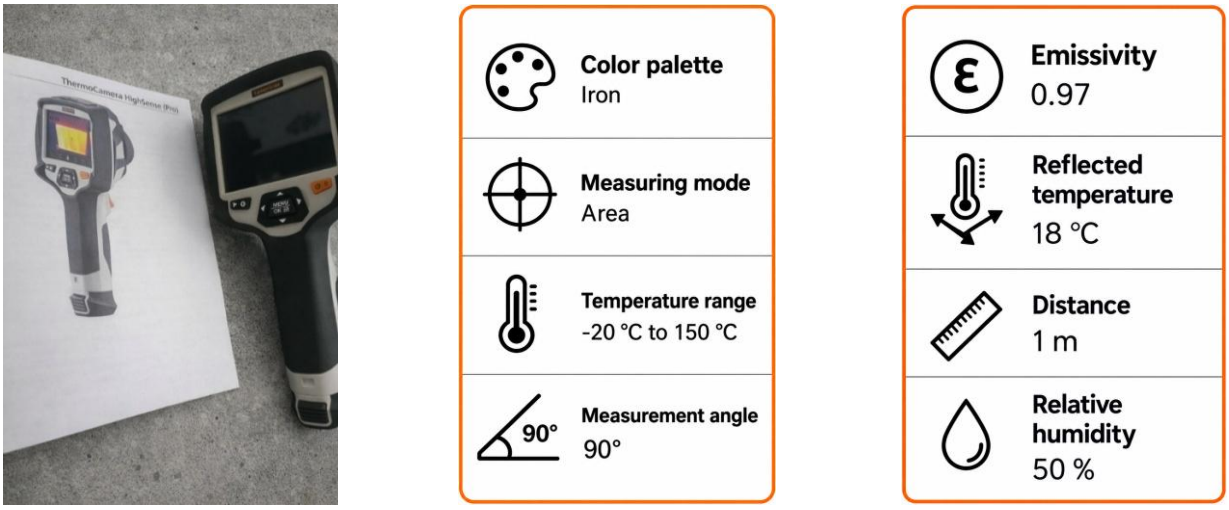


FIGURE 1: Infrared thermal imaging camera used and main parameters of the thermographic measurements.

Before each thermographic examination, a visual comparison between the control and experimental specimens was performed. The distance between the camera and each concrete specimen was approximately 1 m with a measurement angle of approximately 90° and an emissivity coefficient of ε = 0.97. Eight consecutive thermal images of the upper surface were recorded for each specimen. The maximum (Tmax), minimum (Tmin) and average (Tavg) surface temperatures were obtained from each thermogram. The temperature range was additionally calculated as $\Delta T = T_{max} - T_{min}$.

The thermograms and temperature profiles along the diagonal D–D′ (Fig. 2) were processed using Laserliner QuickReporting Editor Plus software. Statistical analysis was performed using IBM SPSS Statistics 27 through two-way analysis of variance (ANOVA) with each individual concrete cube considered an independent experimental unit.

Research hypotheses:

- H1 – The average surface temperature (Tavg) is affected by the storage environment.
- H2 – The magnitude of this effect is dependent on the type of concrete used.

III. RESULT AND DISCUSSION

The preliminary visual assessment showed that the control specimens were characterized by a relatively light-colored and more uniform surface while darker and non-uniform coloration and local changes in surface texture were observed in the experimental specimens. At this stage, no clearly pronounced macroscopic cracks, delamination or significant material loss were detected. Therefore, the visual assessment was considered preliminary and should be interpreted together with the thermographic and statistical results.

The average temperature parameters of all independent specimens, including Tmax, Tmin, Tavg and ΔT, are presented in Table 1.

TABLE 1

MEAN TEMPERATURE PARAMETERS OF ALL INVESTIGATED CONCRETE SPECIMENS

Concrete type	Group	Cube	Tmax (°C)	Tmin (°C)	Tavg (°C)	ΔT (°C)
OC	Control	1	15.71	14.01	14.51	1.7
OC	Control	2	18.11	16.41	17.01	1.7
OC	Control	3	19.81	18.31	18.81	1.5
OC	Experimental	1	20.51	18.91	19.81	1.6
OC	Experimental	2	21.01	19.61	20.21	1.4
OC	Experimental	3	21.01	19.61	20.11	1.4
SRC	Control	1	17.71	15.91	16.41	1.8
SRC	Control	2	15.21	13.41	13.91	1.8
SRC	Control	3	13.11	11.11	11.71	2
SRC	Experimental	1	20.91	19.71	20.11	1.2
SRC	Experimental	2	20.71	19.21	19.71	1.5
SRC	Experimental	3	20.21	18.71	19.21	1.5

Note: The presented values are arithmetic means calculated from eight consecutive thermographic measurements for each independent concrete cube.

The obtained data showed differences between the control and experimental specimens for both concrete types. For ordinary concrete (OC), the average surface temperature (Tavg) ranged from 14.51 to 18.81 °C in the control group and from 19.81 to 20.21 °C in the experimental group. For sulfate-resistant concrete (SRC), a wider temperature range was observed in the control specimens from 11.71 to 16.41 °C. After storage in the aggressive environment, Tavg increased to 19.21–20.11 °C. Along with the increase in Tavg, a tendency towards lower maximum temperature differences (ΔT) was observed, particularly in SRC. This indicated a more uniform surface temperature field at the time of measurement. The observed differences could not be independently interpreted as a measure of the degree of deterioration but could serve as a comparative indicator of changes in the surface thermal response.

For a more detailed illustration of the changes in the surface temperature field, representative thermograms and temperature profiles along the diagonal D–D′ (Fig. 2), obtained and processed using Laserliner QuickReporting Editor Plus, are presented.

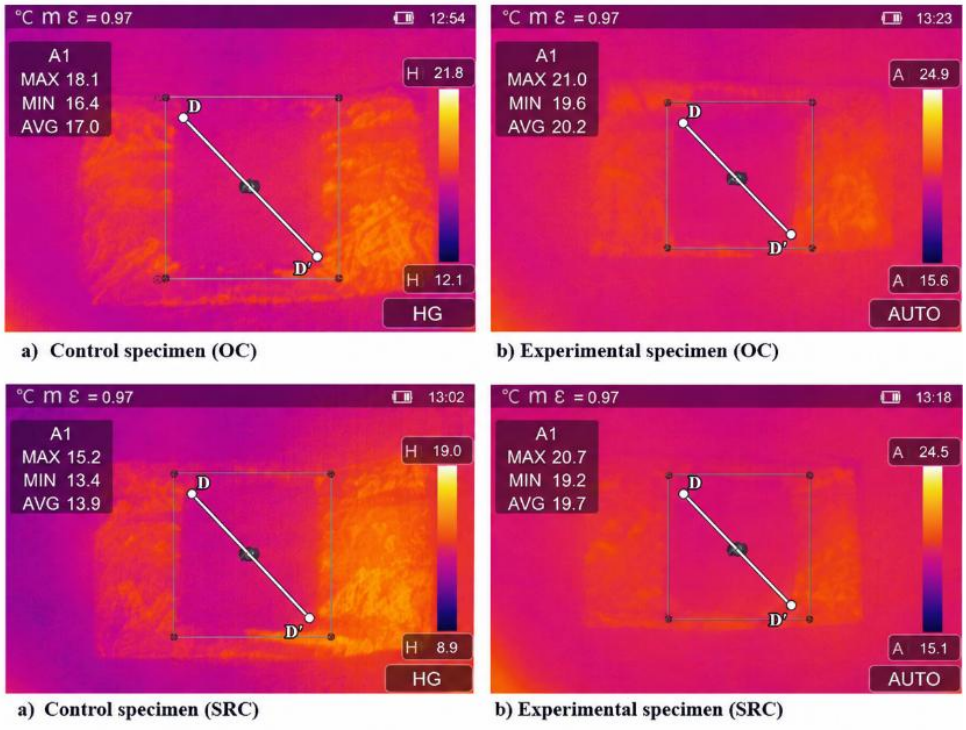


FIGURE 2: Representative thermograms of ordinary concrete (OC) and sulfate-resistant concrete (SRC) specimens: (a) control specimens and (b) experimental specimens.

As shown in Figure 2, a shift in the temperature field towards higher values was observed in the experimental specimens of both concrete types. For the representative pair of OC specimens, an increase in the average surface temperature from 17.0 to 20.2 °C was recorded while for SRC an increase from 13.9 to 19.7 °C was observed. Therefore, a more pronounced temperature change was observed for SRC in the thermographic images. The thermograms were used for illustrative purposes and confirmed the direction of the observed changes. However, statistical conclusions should be based on the results obtained from all independent specimens.

The temperature profile along the diagonal D–D′ for a representative pair of OC specimens is presented in Figure 3.

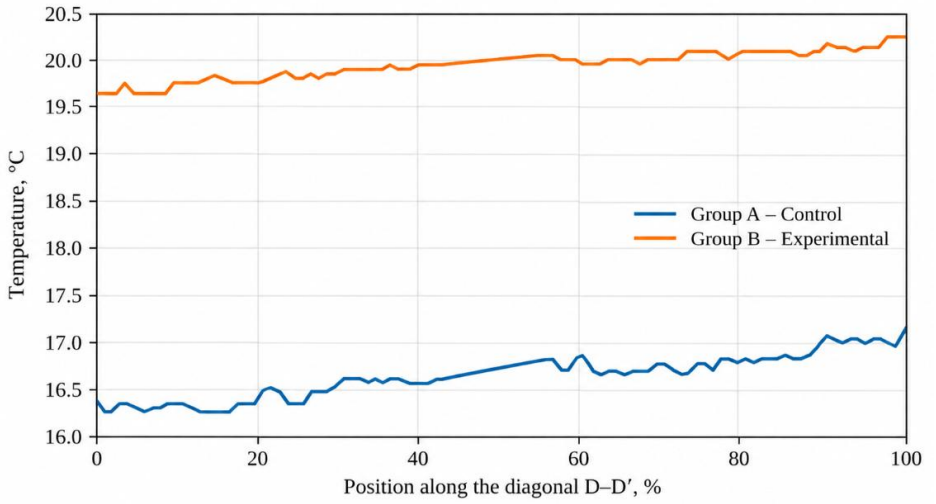


FIGURE 3: Temperature profile along the diagonal D–D′ for representative ordinary concrete (OC) specimens.

For OC, the temperature profile of the experimental specimen was consistently shifted above that of the control specimen along the entire diagonal. An average temperature difference of approximately +3.32 °C was observed along the profile. This was consistent with the difference in Tavg obtained from the representative thermograms. The shapes of both curves remained relatively similar. This indicated that the observed change was mainly associated with an overall increase in temperature rather than an isolated local deviation.

The temperature profile along the diagonal D–D′ for a representative pair of sulfate-resistant concrete (SRC) specimens is presented in Figure 4.

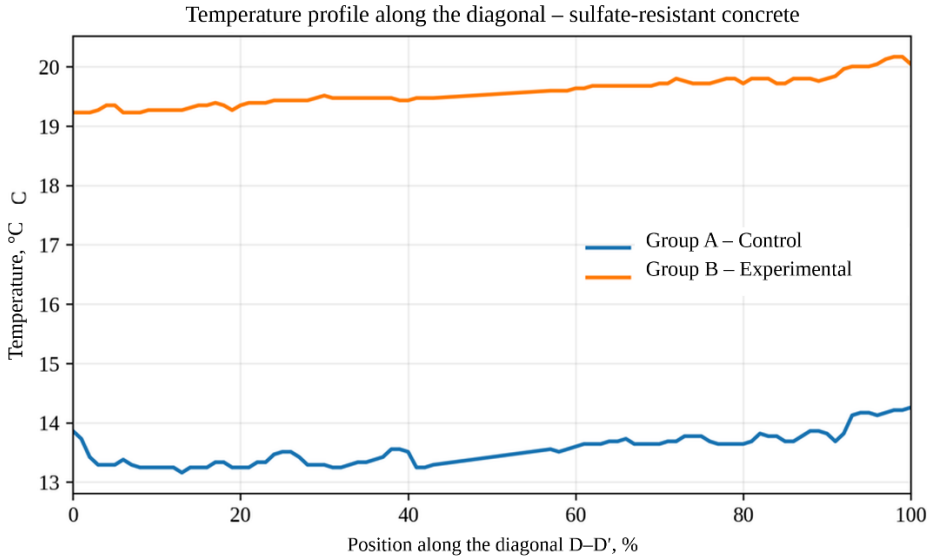


FIGURE 4: Temperature profile along the diagonal D–D′ for representative sulfate-resistant concrete (SRC) specimens.

For SRC, a greater difference between the control and experimental temperature profiles was observed along the entire diagonal. The average temperature difference between the profiles was approximately +6.03 °C. This was consistent with the greater increase in Tavg observed for SRC and supported the hypothesis that the aggressive environment may induce a more pronounced thermal response due to possible interactions involving the additives used in sulfate-resistant concrete.

The mean values and standard deviations of Tmax, Tmin, Tavg and ΔT for each group are summarized in Table 2.

TABLE 2

MEAN VALUES AND STANDARD DEVIATIONS OF SURFACE TEMPERATURE PARAMETERS BY GROUP

Concrete type	Group	n	Tmax, °C mean ± SD	Tmin, °C mean ± SD	Tavg, °C mean ± SD	ΔT, °C mean ± SD
OC	Control	3	17.88 ± 2.06	16.25 ± 2.15	16.78 ± 2.16	1.63 ± 0.12
OC	Experimental	3	20.85 ± 0.29	19.38 ± 0.40	20.05 ± 0.21	1.47 ± 0.12
SRC	Control	3	15.35 ± 2.30	13.48 ± 2.40	14.01 ± 2.35	1.87 ± 0.12
SRC	Experimental	3	20.61 ± 0.36	19.21 ± 0.50	19.68 ± 0.45	1.40 ± 0.17

Note: n – number of independent concrete cubes in each group; SD – standard deviation.

The trends identified above (Table 1) were confirmed by the statistical analysis of the data. For ordinary concrete (OC), the mean Tavg increased from 16.78 to 20.05 °C, corresponding to an absolute difference of 3.27 °C and a relative increase of 19.5%. For sulfate-resistant concrete (SRC), an increase in Tavg from 14.01 to 19.68 °C was observed, representing a difference of 5.67 °C or 40.4%. In the experimental groups, considerably lower standard deviations were observed compared to the control groups. Therefore, the storage environment was associated not only with an increase in the mean surface temperature but also with more consistent temperature values among the individual specimens.

A comparison of the mean surface temperatures of both concrete types depending on the storage environment is presented in Figure 5. The values are illustrated as group means for the control and experimental specimens.

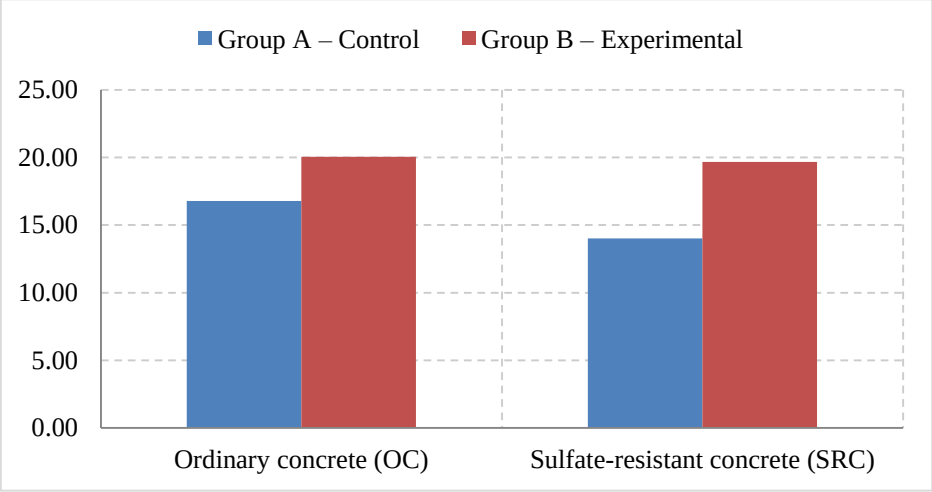


FIGURE 5: Comparison of mean surface temperature (Tavg) by concrete type and storage environment.

For both concrete types, a higher mean surface temperature (Tavg) was observed in specimens stored in the aggressive environment compared to the control specimens. For ordinary concrete (OC), an increase in Tavg from 16.78 °C in the control group to 20.05 °C in the experimental group was recorded, representing a difference of 3.27 °C. For sulfate-resistant concrete (SRC), an increase in mean Tavg from 14.01 °C to 19.68 °C was observed, corresponding to a difference of 5.67 °C.

As shown in the graph, the effect of the storage environment was observed for both concrete types, with a more pronounced temperature change recorded for SRC. This indicated that after six months of storage in the aggressive manure environment, an increase in the surface temperature response was observed.

The boxplot diagram of Tavg according to the storage environment is presented in Figure 6. This provides a summarized representation of the data distribution.

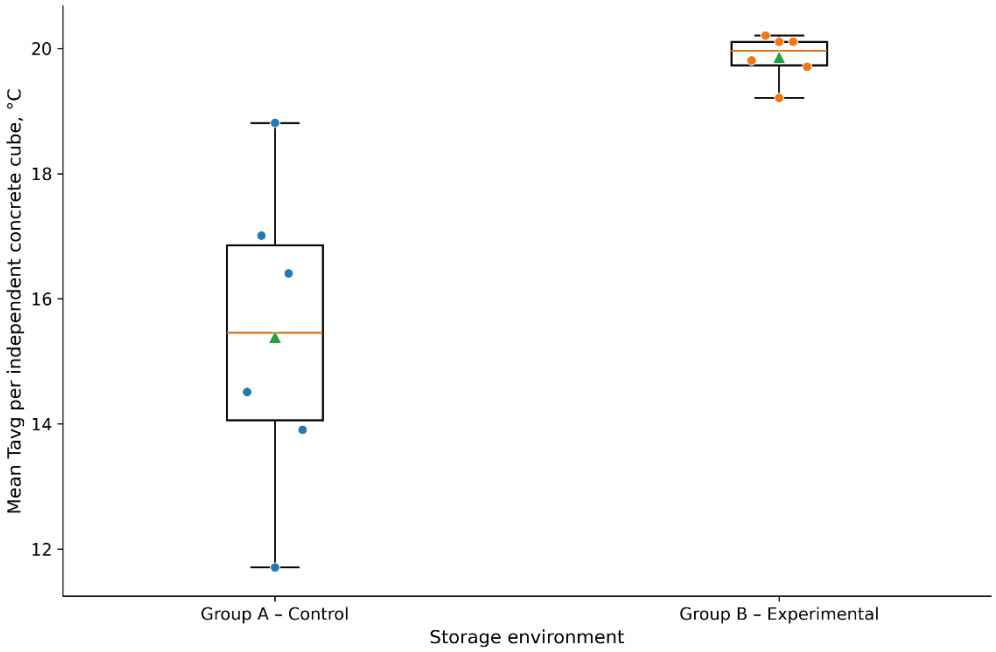


FIGURE 6: Distribution of mean surface temperature (Tavg) by storage environment.

The boxplot diagram showed a clear shift in the distribution towards higher surface temperatures in the experimental specimens. A wider range and greater dispersion of values were observed in the control group while a more compact distribution was recorded in the experimental group. This graphical pattern was consistent with the expectations for H1 and suggested a statistically significant main effect of the storage environment.

The profile of mean Tavg values by group is presented in Figure 7, allowing the possible interaction between concrete type and storage environment to be assessed.

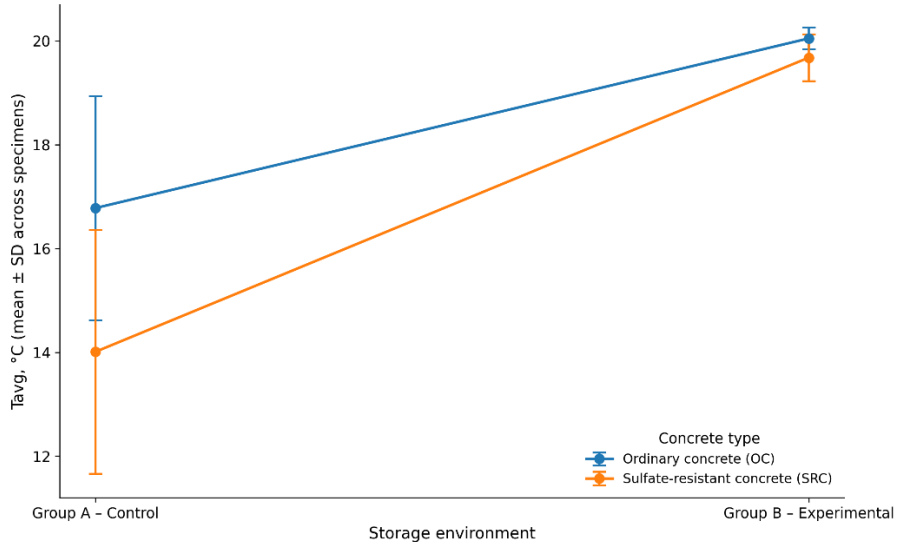


FIGURE 7: Mean surface temperature (Tavg ± SD) of ordinary concrete (OC) and sulfate-resistant concrete (SRC) specimens according to the storage environment.

An upward trend from the control to the experimental environment was observed for both lines in Figure 7, confirming the overall effect of storage in the aggressive environment. The SRC line started at a lower initial temperature and showed a greater increase. However, the differences between the slopes of the two lines did not provide clear graphical evidence of a statistically significant interaction. Therefore, the graph suggested a possible trend rather than conclusive evidence supporting H2.

A boxplot diagram showing the distribution of Tavg for each combination of concrete type and storage environment is presented in Figure 8, providing additional information to the interaction profile.

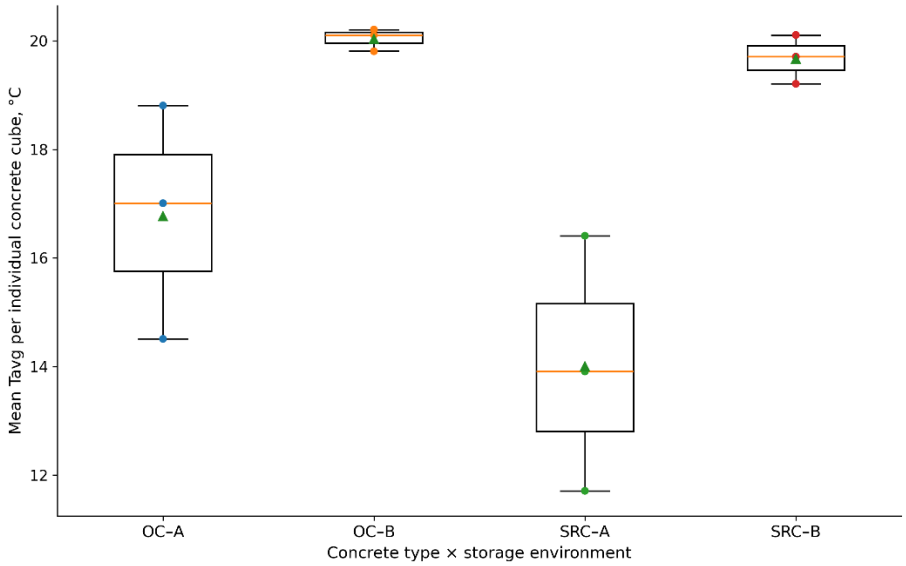


FIGURE 8: Distribution of mean surface temperature (Tavg) according to concrete type and storage environment.

Figure 8 shows that the lowest values were observed in the SRC-A group while the highest values were recorded in the OC-B and SRC-B groups, where the two experimental combinations were found to be close to each other. Under control conditions, considerably greater dispersion among the specimens was observed, particularly for SRC. This may explain why the interaction between concrete type and storage environment did not reach statistical significance despite the greater temperature increase observed for SRC.

Before the interpretation of the two-way model, the assumptions of normality and homogeneity of variances were examined. No statistically significant deviation from normality was detected by the Shapiro–Wilk test ($W = 0.891$; $p = 0.122$) and no significant heterogeneity of variances was established by Levene's test ($F = 2.358$; $p = 0.148$). Considering the small number of independent specimens ($n = 3$ per group), the obtained results were interpreted with caution. However, the application of two-way ANOVA was considered appropriate.

The results of the two-way analysis of variance (ANOVA) for Tavg are presented in Table 3 to statistically evaluate hypotheses H1 and H2.

TABLE 3
TWO-WAY ANALYSIS OF VARIANCE (ANOVA) OF TAVG FOR 12 INDEPENDENT CONCRETE CUBES (N = 12)

Effect	SS	df	MS	F	p	ηp²
Concrete type	7.363	1	7.363	2.821	0.132	0.261
Storage environment	59.853	1	59.853	22.932	0.001	0.741
Concrete type × environment	4.32	1	4.32	1.655	0.234	0.171
Error	20.88	8	2.61	—	—	—

Note: SS – sum of squares; df – degrees of freedom; MS – mean square; F – F-statistic; p – level of statistical significance; ηp² – partial eta squared. Results were considered statistically significant at p < 0.05.

The results presented in Table 3 showed a statistically significant main effect of the storage environment on the average surface temperature (Tavg), $F(1,8) = 22.93$; $p = 0.001$; $\eta p^2 = 0.741$. Therefore, H1 was statistically supported. Storage in the aggressive environment was associated with changes in the surface temperature of the concrete specimens. An increase in mean Tavg from 15.40 °C in the control specimens to 19.86 °C in the experimental specimens was observed, corresponding to a difference of +4.47 °C or approximately +29.01%.

No statistically significant main effect of concrete type was established ($p = 0.132$). Similarly, the interaction between concrete type and storage environment was not statistically significant, $F(1,8) = 1.655$; $p = 0.234$; $\eta p^2 = 0.171$. Therefore, H2 was not statistically supported despite the greater increase observed for SRC (+5.67 °C; +40.4%) compared to OC (+3.27 °C; +19.5%).

The conducted study demonstrated that passive infrared thermography can be successfully applied as a comparative non-destructive method for monitoring changes in the surface thermal behavior of concrete specimens subjected to an aggressive environment. The differences established between the control and experimental specimens indicated a clear influence of the storage environment on the thermal response of concrete. An increase in the average surface temperature was observed for both investigated concrete types after six months of storage in semi-liquid manure.

The statistically significant effect of the storage environment on the average surface temperature (Tavg) was confirmed by the statistical analysis. However, the dependence of the observed temperature changes on concrete type was not statistically demonstrated with the present sample size. The greater temperature change observed for sulfate-resistant concrete (SRC) should be considered a trend that requires further investigation over a longer period.

The obtained results indicated that additional information on the condition of the concrete surface layer could be provided by thermographic analysis. However, temperature changes should not be interpreted independently as a direct measure of the degree of deterioration. For a more comprehensive assessment, the obtained results should be compared with data from other non-destructive and physical-mechanical tests.

IV. CONCLUSION

Based on the conducted study, the following main conclusions were drawn:

- High technical repeatability was demonstrated by passive infrared thermography, with a coefficient of variation of Tavg below 1.1% for all investigated concrete specimens.
- After six months of storage in an aggressive manure environment, statistically significant changes in the surface temperature parameters were established. A pronounced effect of the storage environment on Tavg was recorded, $F(1,8) = 22.93$; $p = 0.001$; $\eta p^2 = 0.741$.
- An increase in the average surface temperature (Tavg) from 16.78 to 20.05 °C was observed for ordinary concrete and from 14.01 to 19.68 °C for sulfate-resistant concrete. However, a statistically significant interaction between concrete type and storage environment was not established. Therefore, the greater temperature change observed for sulfate-resistant concrete may be considered a possible response associated with its specific composition and interactions with the aggressive environment.
- The observed temperature changes cannot be independently considered a quantitative indicator of the degree of concrete deterioration. The obtained results may provide preliminary information on the general condition of the concrete specimens. Further investigations using additional testing methods are required to evaluate changes in their mechanical properties.

RECOMMENDATION

Passive infrared thermography may be applied as a comparative non-destructive method for monitoring changes in the surface thermal behavior of concrete specimens. However, the obtained results should be interpreted in combination with other non-destructive and destructive testing methods.

ACKNOWLEDGEMENT

The authors express their sincere appreciation to all individuals who provided professional assistance and support in the organization and conduct of the experimental investigations as well as in the preparation of the present scientific publication.

CONFLICT OF INTEREST

The authors declare that there are no conflicts of interest related to the research, authorship and publication of this manuscript.

REFERENCES

[1] Kuisma, R., Kymäläinen, H.-R., Hellstedt, M., Jauhiainen, P., Määttä, J., & Sjöberg, A.-M. (2008). Properties and cleanability of new and traditional surface materials in cattle barns: A field study. *Agricultural and Food Science*, *17*(3), 227-239.

https://doi.org/10.2137/145960608786118839

[2] Svennerstedt, B., De Belie, N., Braam, C. R., Lenehan, J. J., Richardson, M., & Sonck, B. (1999). *Durability of building materials and components in agricultural environment* (Report 119). Swedish University of Agricultural Sciences, Department of Agricultural Biosystems and Technology.

[3] Chikhi, A., Rebai, B., Benaddi, H., Tidjani, M., Lakhemissi, T., Abdelhak, B., & Hadji, M. (2024). Impact of aggressive environments on the mechanical and physico-chemical properties of concrete. *Studies in Engineering and Exact Sciences*, *5*(2), e9846.
https://doi.org/10.54021/seesv5n2-402

[4] Hilbig, H., Gutberlet, T., & Beddoe, R. E. (2024). Acid attack on hydrated cement: Effect of organic acids on the degradation process. *Materials and Structures*, *57*, Article 83. https://doi.org/10.1617/s11527-024-02360-8

[5] Wang, D., Guan, F., Feng, C., Mathivanan, K., Zhang, R., & Sand, W. (2023). Review on microbially influenced concrete corrosion. *Microorganisms*, *11*(8), Article 2076. https://doi.org/10.3390/microorganisms11082076

[6] Pozzer, S., Omidi, Z., El Refai, A., López, F., Ibarra-Castanedo, C., & Maldague, X. (2024). Passive infrared thermography for subsurface delamination detection in concrete infrastructure: Capabilities. *Construction and Building Materials*, *419*, Article 135542. https://doi.org/10.1016/j.conbuildmat.2024.135542

[7] Pozzer, S., El Refai, A., López, F., Ibarra-Castanedo, C., & Maldague, X. (2024). Passive infrared thermography for subsurface delamination detection in concrete infrastructure: Inference on minimum requirements. *Computers & Structures*, *305*, Article 107529. https://doi.org/10.1016/j.compstruc.2024.107529

[8] Cheng, C., Chen, D., Shao, S., Na, R., Cai, H., Zhou, H., & Wu, B. (2025). Revealing the impact of depth and surface property variations on infrared detection of delamination in concrete structures under natural environmental conditions. *Buildings*, *15*(1), Article 10. https://doi.org/10.3390/buildings15010010

[9] Shrestha, P., Avci, O., Rifai, S., Abla, F., Seek, M., Barth, K., & Halabe, U. (2025). A review of infrared thermography applications for civil infrastructure. *Structural Durability & Health Monitoring*, *19*(2), 193-231. https://doi.org/10.32604/sdhm.2024.049530

[10] Yang, F., Zeng, X., Xia, Q., Yang, L., Cai, H., & Cheng, C. (2025). Early detection and analysis of cavity defects in concrete columns based on infrared thermography and finite element analysis. *Materials*, *18*(7), Article 1686. https://doi.org/10.3390/ma18071686

[11] Abdulridha, A. A., Alzubaidi, L., & Alver, N. (2026). Integration of artificial intelligence techniques with infrared thermography for defect detection in concrete structures: A systematic review. *Measurement*, *267*, Article 120491.
https://doi.org/10.1016/j.measurement.2026.120491

[12] Wciślik, W., & Wciślik, S. (2026). Infrared thermography for defect detectability in structural health monitoring of concrete structures: Heat transfer physics, resolution limits, and AI-assisted diagnostics. *Materials*, *19*(12), Article 2596.
https://doi.org/10.3390/ma19122596.