Challenge Journal of Concrete Research Letters

Research Article

Photocatalytic activation of fibrous lightweight polymer concrete surfaces under artificial light source

Serdal Ünal [a], Mehmet Canbaz [a,*]

[a] *Department of Civil Engineering, Eskişehir Osmangazi University, 26480 Eskişehir, Türkiye*

ABSTRACT

In general, surface contamination of building materials is caused by pollution, which can be divided into human-made and natural sources. Building materials whose surfaces are exposed to pollutants from these sources for a long time show chemical and physical degradation and lose their function over time and their service life is shortened. Due to photocatalytic feature provided to the material surfaces, organic pollutants on the surface are degraded as a result of oxidation and reduction reactions under the influence of light. In this study, the self-cleaning performance was measured on the surfaces of fibrous lightweight polymer concretes with titanium dioxide (TiO_2) reinforcement incorporated into the structure. Perlite-based concrete specimens with TiO_2/resin ratios of 0%, 3%, 6% and 9% and fiber/resin ratios of 0%, 0.5% and 1% were prepared. When the results of the self-cleaning test with Rhodamine B dye were examined, the samples with a TiO_2/resin ratio of 9% had the highest degradation percentages of about 67%. This study shows that photocatalytic properties can be imparted to lightweight polymer concretes with different structures from conventional concrete by TiO_2 reinforcement.

ARTICLE INFO

Article history:

Received – September 5, 2024
Revision requested – September 30, 2024
Revision received – November 8, 2024
Accepted – November 19, 2024

Keywords:

Photocatalytic activation
Polymer concrete
Fiber
Self-cleaning

Citation: Ünal S, Canbaz M (2025). Photocatalytic activation of fibrous lightweight polymer concrete surfaces under artificial light source. *Challenge Journal of Concrete Research Letters*, 16(1), 15–24.

1. Introduction

Innovation in the construction industry and sustainability goals are driving the continuous evolution of materials science (Sui Pheng et al. 2019). Conventional concretes can have limitations in some applications, often due to their weight and various physical limitations (Seymour 2019). Concretes defined as lightweight concretes are concretes with a lower density than normal concretes. The density of these concretes is generally less than 1800 kg/m^3. The reason for the lower density of lightweight concretes is that these concretes are produced by using lightweight aggregates such as perlite, expanded clay, pumice or materials such as foam concrete. Such concretes can be preferred in both structural and non-structural applications (Khan et al. 2024; Thienel et al. 2020). Therefore, the search for lightweight and high performance alternatives has led to the development of polymer concretes (Nodehi 2022; Bedi et al. 2013). Polymer concretes are building materials that contain a variety of mineral and organic materials bound with resins, with optimized mechanical and chemical properties. These materials offer advantages such as light weight, high durability, and modifiability, providing a wide range of applications in construction (Sarde and Patil 2019). Cement-based concretes typically achieve a compressive strength of 30–35 MPa and a flexural strength of 7–8 MPa, whereas polymer concretes exhibit significantly higher strengths, reaching 90–100 MPa in compression and 20–25 MPa in flexure (Ulu 2024; Cakir 2022).

The use of polymer concretes in the field of building materials is increasing. Polymer concretes can be used in many different areas of use such as drainage channels,

* *Corresponding author.* Tel.: +90-222-239-3750 ; E-mail address: mcanbaz@ogu.edu.tr (M. Canbaz)
ISSN: 2548-0928 / DOI: https://doi.org/10.20528/cjcrl.2025.01.002

cable channels, tunnel coating elements, precast structural elements, wear-resistant ground roads, countertops, wall tiles, exterior coating elements, pool elements, and machine tool beds. In addition to its ability to be less labor-efficient, polymer concrete has higher mechanical strength and higher chemical resistance then classical concrete (Ulu 2024). Today, new studies are being carried out to reinforce polymer concretes, add various fibers and improve their physical properties (Kiruthika et al. 2021; Güler 2024; Rebeiz et al. 2004). The use of fibers in concrete aims to enhance its tensile strength by improving load-bearing capacity and bridging cracks, thereby preventing their propagation (Şengel et al. 2022).

The use of photocatalytic materials in construction building materials is rapidly expanding. Failure to protect the exterior surface of materials such as concrete, exterior paints, grouts, tile mosaics, plaster materials and coatings and the harboring of microorganisms can lead to serious problems (Haider et al. 2019). TiO_2 photocatalysis has become a real practical technology after the mid-1990s, especially in the field of building materials (Hashimoto 2005). The Jubilee Church in Rome, Italy, is the first building to contain self-cleaning concrete (Cedillo-Gonzalez et al. 2018). Self-cleaning properties are emerging as an important aspect to increase the sustainability of modern building materials (Ćurčić 2019; Folli et al. 2012). Contamination and staining on the surface of building materials are both aesthetically problematic and increase maintenance costs. Therefore, the self-cleaning ability of materials is of great importance in terms of reducing maintenance costs and achieving long-term cost-effectiveness (Zailan et al. 2017). Self-cleaning refers to the removal of contaminants and stains accumulated on the surface over time, and this process is usually achieved by additives with photocatalytic properties (Dikkar et al. 2021; Zhao et al. 2015). Titanium dioxide (TiO_2) plays an important role in this context. When exposed to UV light, TiO_2 oxidatively degrades contaminants, allowing the surface to be cleaned, thus maintaining the appearance and performance of the material for a long time (Beeldens 2006). This property increases the resistance of materials to environmental pollutants, reduces maintenance requirements and thus provides a cost-effective application (Ünal and Canbaz 2022). The generation of electron-hole pair for TiO_2 photocatalysis can be written as follows in Eq. (1) (Guo et al. 2019).

$$\mathrm{TiO_2} + hv \rightarrow h^{+}(\mathrm{TiO_2}) + e^{-}(\mathrm{TiO_2}) \quad (1)$$

If the reactions are briefly summarized; super oxygen (O_2•), hydroxy (•OH), peroxy (HO_2•) radicals are synthesized as a result of the reactions of the water and oxygen molecule groups on the surface and the trapping of gaps and electrons. These radicals thus produced realize photocatalytic redox reactions. The super oxygens, hydroxy and peroxy groups formed as a result of these oxidation and reduction reactions on the material surfaces break down the organic compounds on the material surface into harmless products. This photomineralization can be shown in a simple way as in Eq. (2) (Carp et al. 2004).

$$\text{organic compounds} \xrightarrow{\text{semiconductor}} \mathrm{CO_2} + \mathrm{H_2O} + \text{mineral acid} \quad (2)$$

There are many studies on the use of concrete and resins in combination with fibers to produce different composite materials; however, there are no studies on materials lightened by perlite, showing photocatalytic properties and containing different proportions of fibers. There is also growing interest in studies on self-cleaning of various building material surfaces. Measuring the self-cleaning performance of materials such as the composite material produced in this study is one of the first studies in this field. In this study, the effects of TiO_2 and fibers were investigated in detail to improve the self-cleaning ability of polymer concrete. In addition, the use of perlite and fibers aims to improve the physical properties of polymer concrete and make it lighter. Perlite is known for its low density and high insulating capacity, while fibers can increase the tensile strength of the concrete matrix and reduce the risk of cracking (Topçu and Işıkdağ 2008; Cojocaru et al. 2023). The combination of TiO_2, perlite and fibers aims to optimize both the functional and structural performance of the material. The focus of the research is on the effects of different TiO_2-resin-fiber ratios on the self-cleaning performance of polymer concretes. Specimens were prepared with different TiO_2/resin ratios (0%, 3%, 6%, 9%) and fiber/resin ratios (0%, 0.5%, 1%). The data obtained showed that the self-cleaning capacity improved significantly with increasing TiO_2 content; in particular, the specimens with 9% TiO_2/resin ratio showed the highest performance. These results demonstrate how careful optimization of the proportions of additives used in the development of polymer concretes can be effective in improving material performance and environmental sustainability. The results offer potential improvements for both the building materials industry and environmental protection.

2. Experimental Study

2.1. Materials

The construction materials in this study were used in a previous research and their structural characteristics were provided by Ünal and Canbaz (2024).

- Binder: Polyester type resin was used as a binder in the study. The polyester used is TP100 type of Turkuaz Polyester (Kocaeli, Türkiye) brand. Casting-type orthophthalic based unsaturated polyester resin was used as binder. The mechanical, physical and chemical properties of the polyester resin are shown in Table 1.

Hardeners are accelerators or heat-activated chemicals that regulate the curing of polyester resin. They initiate cross-linking reactions between the resin and reactive monomers. In this way, solidification of the resin is provided. Methyl ethyl ketone peroxide (Mek Peroxide) of Turkuaz Polyster was used as hardener in the experimental study.

Accelerators are used in the curing of unsaturated polyester resins with organic peroxides at room temperature. Accelerator activates the hardener and enables the reaction to start. In the experimental study, cobalt octoate from Turkuaz Polyster was used as accelerator.

Table 1. Properties of polyester resin.

Viscosity Cps	Appearance	Exothermic heat, °C	Specific weight, kg/m³	Working time, min.	Tensile str., MPa	Bending str., MPa	Hardness Barcol
350–500	Clear, liquid	175	1.17	10–15	50–60	85–95	40–42

- Fiber: Polypropylene fibers obtained from Şişecam Company (İstanbul, Türkiye) were used in the study. The chemical and physical properties of the fibers used in the blend are given in Table 2.
- TiO_2: The TiO_2 used in production is in the anatase phase and was sourced from Refsan (Kütahya, Türkiye). As the purity of the material is very high, no additional purification was required. The properties of the powders used in the initial stage, as reported by the manufacturers, are shown in Table 3.
- Perlite: Perlite obtained from Uzay Perlit Company (İstanbul, Türkiye) was used in the study. The chemical and physical properties of the fibers used in the blend are given in Table 4. The granulometry of the expanded perlite used in the study is shown in Fig. 1.

Table 2. Properties of fiber.

Fiber diameter, µm	Clipping length, mm	Moisture content, %	Type of binder	Amount of binder, %
13	4.5–6.0	0.07	Silane	0.7 ± 0.2

Table 3. Properties of TiO_2.

Phase	Average grain size, µm	Purity, %	Fineness, m²/g	Density, kg/dm³
Anatase	5	> 99	82	4.21

Table 4. Properties of perlite.

Specific weight, kg/m³	Average grain size, mm	SiO_2, %	Al_2O_3, %	Na_2O, %	K_2O, %	MgO, %	PH
50–60	0–3	74	14	3	5	0.5	7

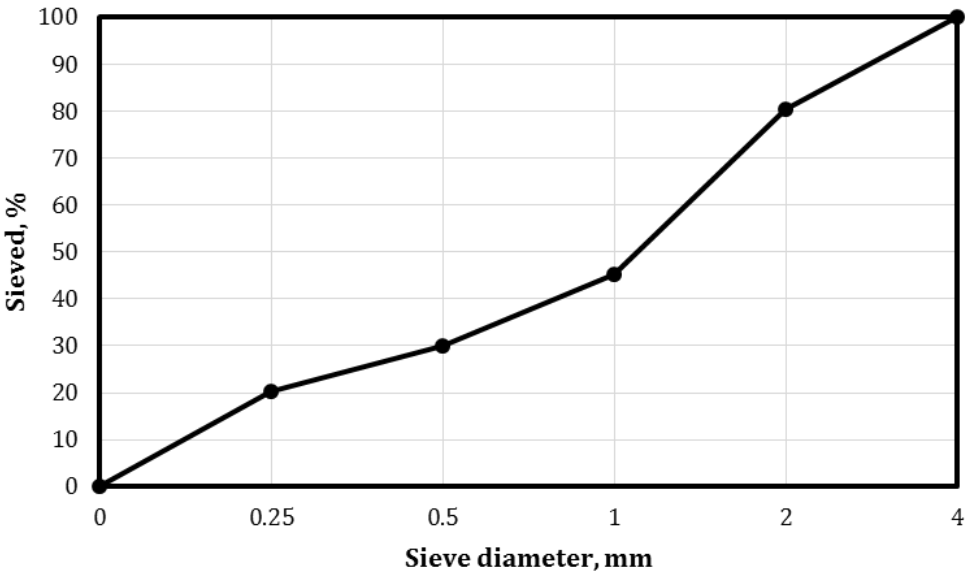

Fig. 1. Granulometry of expanded perlite used in the study.

2.2. Method and tests

The first step in specimen production was to produce control specimens. In the production stage, perlite and polyester were prepared for production in separate containers. Hardener was added to the polyester at a rate of 2% of resin and accelerator at a rate of 1%. All components were mixed until a homogeneous mixture was obtained. The mixture was poured into 4x4x16 cm metal moulds after thorough compaction to avoid voids. The surfaces of the moulds were lubricated with mould oil before casting. The mixture was allowed to set for 30-40 minutes. At the end of the setting process, the moulds were opened and the specimens were prepared for the experiment after 1 day.

For the production of the additive specimens, polyester was mixed with perlite by adding hardener and accelerator before mixing with perlite. The mixture was then poured into the container with perlite to obtain a homogeneous mixture. TiO_2 (0% - 3% - 6% - 9%) and fibers (0% - 0.5% - 1%) were then added to the mixture in different proportions to the resin and thoroughly mixed. The resulting mixture was poured into metal moulds lubricated with moulding oil and again thoroughly compacted to avoid voids. Table 5 shows the mixing ratios of the concrete specimens. Since the polymerization time can reach 7 days depending on the type of resin, the tests were carried out 7 days after production.

The photocatalytic tests were carried out according to the UNI 11259 standard. Rhodamine B dye, the preferred pollutant in this standard, is the most commonly used pollutant in photocatalytic colour tests. A solution with a concentration of 50 mg/dm^3 was prepared with Rhodamine-B powder (UNI 11259 2008). For colorimetric measurements, a spectrophotometer using the L^*a^*b (CIE) colour system (directional 65°/10° and diffuse 8°/d sphere geometry) was preferred (Ünal and Canbaz 2022). In this colour system, $\pm a$ is green-red, $\pm b$ is blue-yellow and L is lightness (Durmuş 2020; McGrath et al. 2017). In the study, measurements were taken at five different points on each sample surface and the results were averaged. Colorimetric measurements were taken at the beginning, 4 hours and 26 hours. The 4 hour and 26 hour self-cleaning performance was calculated using the formulas in Eqs. (3) and (4). The self-cleaning experiments were repeated a total of 3 times on the same surfaces of the same specimens to study the long-term effects. In this way, the loss of self-cleaning performance over long periods was also analyzed. The UNI 11259 (2008) standard requires R_4>25% after 4 hours and R_{26}>50% after 26 hours.

Table 5. Mix proportion of photocatalytic fibrous lightweight polymer concrete.

Perlite/Polyester resin	Accelerator/Polyester resin	Hardener/Polyester resin	TiO_2/Polyester resin	Fiber/Polyester resin
0.11	0.01	0.02	0/0.03/0.06/0.09	0/0.005/0.01

$$R_4 = [(a_0 - a_4)/ a_0)] \times 100 \quad (3)$$

$$R_{26} = [(a_0 - a_{26})/ a_0)] \times 100 \quad (4)$$

a_0 : Colour coordinate value a, before illumination with UV lamp
a_4 : Colour coordinate value a, after 4 hours of UV irradiation
a_{26} : Colour coordinate value a, after 26 hours of UV irradiation
R_4 : Degradation rate after 4 hours of UV irradiation
R_{26} : Degradation rate after 26 hours of UV irradiation (UNI 11259 2008)

ΔE is the colour difference in the CIELAB colour space between an object of the same size observed by a CIE standard observer in the same neutral environment. ΔE is calculated using the following Eq. (5) (Zhang and Guo 2021):

$$\Delta E = [(\Delta L)^2 + (\Delta a)^2 + (\Delta b)^2]^{1/2} \quad (5)$$

ΔE : Colour difference
ΔL : Difference between the coordinates of L
Δa : Difference between the coordinates of a
Δb : Difference between the coordinates of b

3. Discussion

3.1. Properties of fresh SCC

In the analysis of the results, the changes in the a colour coordinate, as defined in the UNI 11259 standard, were first studied. Fig. 2 shows the degradation rates obtained using Eqs. (1) and (2) as a result of colorimetric measurements on fiber-free specimens. Fig. 2 provides that the specimens with 9% TiO_2 achieved the highest colour coordinate change with 36.92% at the end of 4 hours in the first experiment. After the 9T0F specimen, the best performance was achieved by the 6T0F specimen with 6% TiO_2. Both the 6T0F and 9T0F specimens met the requirement of being above the 25% limit at the end of 4 hours as specified in the UNI 11259 standard. The 3T0F and 0T0F specimens were below the 25% limit. When analysing the self-cleaning performance after 26 hours, the 9T0F specimen reached the highest value with 66.15%. 6T0F reached 60.65% after 26 hours. Both specimens met the requirement to be above the 50% limit at the end of 26 hours, as specified in the UNI 11259 standard. Specimens 3T0F and 0T0F remained below the 50% limit after 26 hours. It can be said that 9T0F and 6T0F specimens showed self-cleaning properties in the first test.

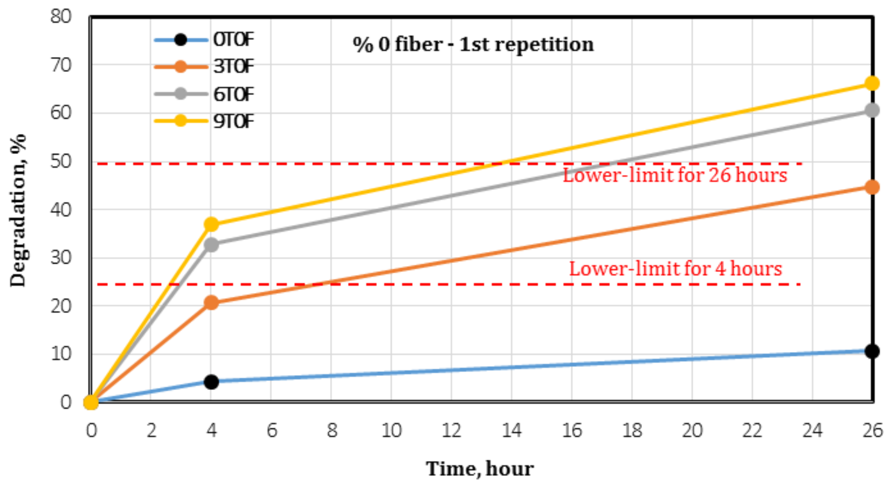

Fig. 2. Degradation of fiber-free specimens at the 1st repetition.

Fig. 3 shows the results of the 2nd and 3rd self-cleaning tests on the fiber-free specimens. The tests were carried out at 1 month intervals to examine the long term effects. Analysis of Fig. 3 shows that the 9T0F and 6T0F specimens performed very well in the repeat tests. In both repeat tests, 9T0F specimens gave the highest results. In the 3rd repeat test, the 9T0F specimen, which achieved a maximum colour coordinate change of 66.67% at the end of 26 hours, did not lose its self-cleaning performance over long periods. The 6T0F spec-imen reached a degradation rate of 60.65% after 26 hours in the first test. In the 3rd self-cleaning test, it is seen that it reached 55% at the end of 26 hours. Therefore, it can be said that the specimens containing 6% TiO_2 tend to show lower performance in the long term than the specimens containing 9% TiO_2. The control sample 0T0F without TiO_2 and fiber achieved an average degradation rate of 10% in all tests. The self-cleaning performance of the 3T0F specimens was below the UNI 11259 limits.

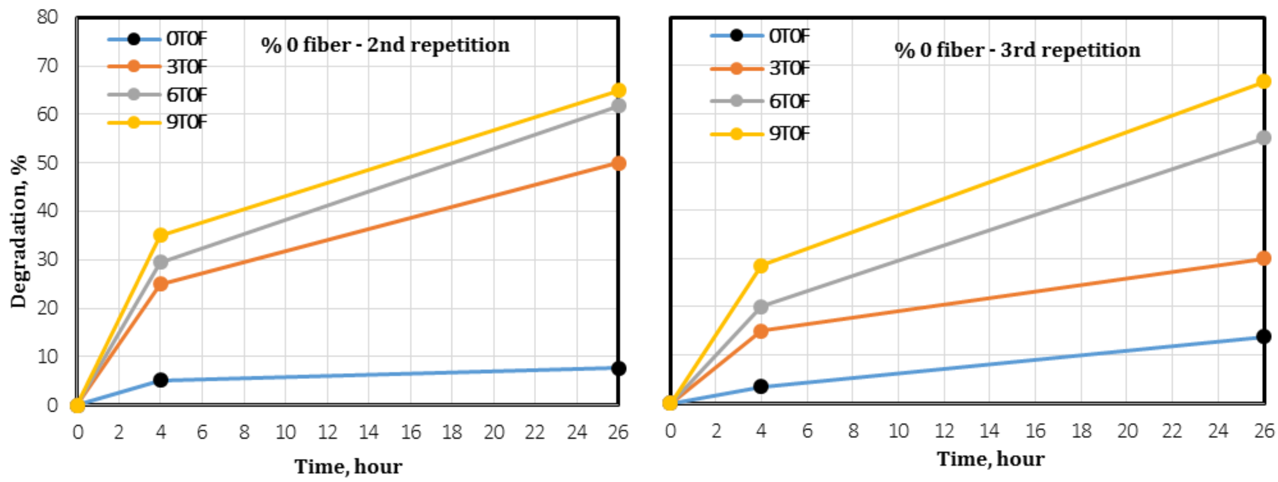

Fig. 3. Degradation of fiber-free specimens at 2nd and 3rd repetitions.

Fig. 4 shows the results of the first self-cleaning test on samples containing 0.5% fiber. Looking at the first test results, it can be seen that there is not much difference between the specimens containing 0.5% fiber and no fiber. In this case, it is clear that a small amount of fiber additive does not make a significant difference to the self-cleaning performance. As with the fiber-free samples, the specimens containing 0.5% fiber had the highest self-cleaning rate at 4 hours and 26 hours, and the specimens containing 9% TiO_2 had the highest self-cleaning rate. The 9T0.5F specimens achieved a degradation rate of 35.48% after 4 hours and 64.51% after 26 hours. With the results obtained, the 9T0.5F and 6T0.5F specimens were above the UNI 11259 limits, while the 3T0.5F and 0T0.5F specimens were below the UNI 11259 limits.

Fig. 5 shows the results of the second and third self-cleaning tests on samples containing 0.5% fiber. Looking at the results of the second test, it can be seen that there are no significant differences in values from the first test. In the second test it can be seen that the 9T0.5F specimens achieved the highest rate of degradation at the end of 4 hours and 26 hours. The 9T0.5F specimens achieved 30.43% degradation rate after 4 hours and 65.21% degradation after 26 hours. After 9T0.5F, the most effective ingredient was 6T0.5F. 6T0.5F specimens achieved

30.32% degradation rate after 4 hours and 60% degradation rate after 26 hours. The 3T0.5F and 0T0.5F specimens were below the lower limits specified in the UNI 11259 standard. 0T0.5F, which does not contain TiO_2 in its structure, reached a maximum degradation rate of 12% after 26 hours. This percentage was obtained due to the heat generated by the artificial UV source on the concrete surface. Therefore, according to the test results obtained, it can be said that the specimens without TiO_2 in their structure do not have self-cleaning properties.

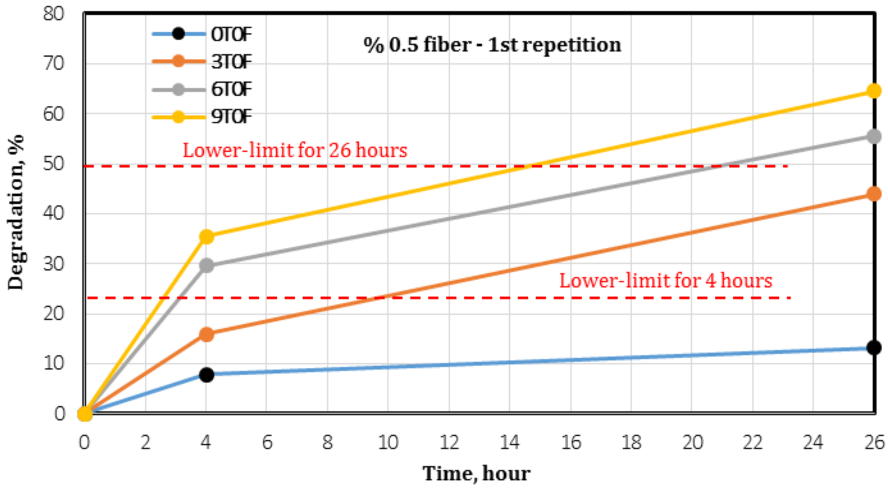

Fig. 4. Degradation of specimens containing 0.5% fiber at the 1st repetition.

When the results of the third self-cleaning test on the specimens containing 0.5% fiber are examined, the most significant difference is observed in the 6T0.5F specimen. At the end of 26 hours, the degradation rate of the 6T0.5F sample, which was 60% in the 2nd test, decreased to 50% in the 3rd test. Although the 50% degradation rate is within the UNI lower limit, it is worrying for its long-term performance. The specimens containing 9% TiO_2 did not lose performance in the long term. Another notable situation in the 3rd self-cleaning test was the 3T0.5F specimens. After 26 hours, the degradation rate of the 3T0.5F specimen, which was 41.93% in the 2nd test, decreased to 25% in the 3rd test. This shows that as the TiO_2 content decreases, the self-cleaning performance continues to decrease in the long term.

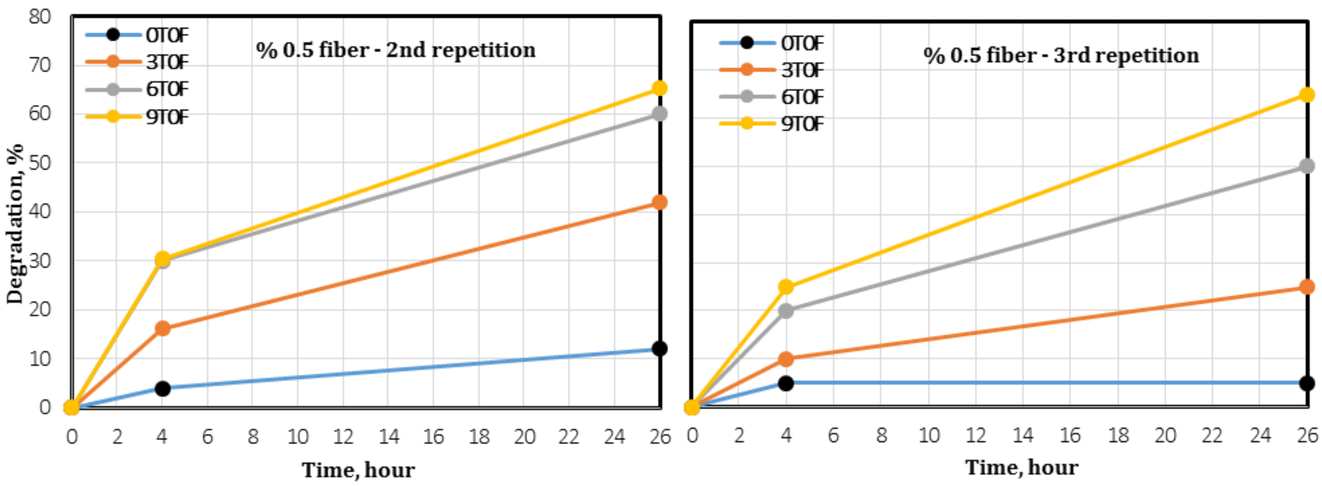

Fig. 5. Degradation of specimens containing 0.5% fiber at 2nd and 3rd repetitions.

Fig. 6 shows the first test results showing the self-cleaning performance of the specimens containing 1% fiber. As can be seen from the graph, there is a slight decrease in the self-cleaning rate as the fiber content increases. For example, 9T0F with no fiber content achieved a 66.15% degradation rate after 26 hours in the first test, while 9T1F with 1% fiber content achieved a 58.62% degradation rate after 26 hours in the first test. Fibers are not resistant to UV radiation and may show some expansion due to the temperature generated on the surface and internal structure by the light from the UV source, thus limiting the TiO_2's effective area. Nevertheless, 9T1F and 6T1F exceeded the UNI 11259 lower limit after 4 and 26 hours. 3T1F and 0T1F specimens were below the UNI limits at both 4 hours and 26 hours.

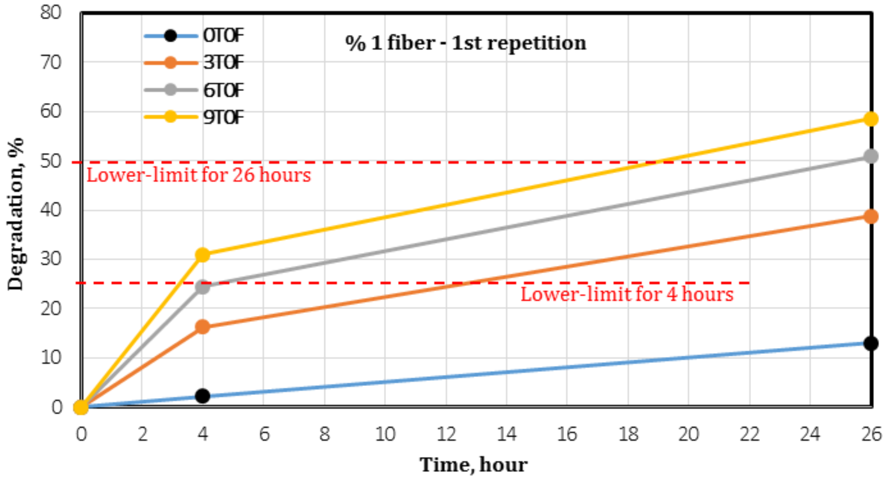

Fig. 6. Degradation of specimens containing 1% fiber at the 1st repetition.

Fig. 7 shows the second and third test results showing the self-cleaning performance of the samples containing 1% fiber. Analyzing the second test results, it can be seen that the 9T1F and 6T1F samples performed above the UNI limits at both 4 and 26 hours. In the second test, 9T1F showed the highest self-cleaning performance. While 9T1F achieved 32% degradation after 4 hours, it achieved 60% degradation after 26 hours. 6T1F achieved 28% degradation after 4 hours and 52% degradation after 26 hours. With these results, it can be said that the 1st and 2nd test results are close to each other. 3T1F and 0T1F specimens were below the UNI 11259 limits, as in the other tests.

Looking at the third test results showing the self-cleaning performance of the samples containing 1% fiber, the most remarkable performance was achieved in 6T1F. The degradation rate, which was about 25% at the end of 4 hours in the 1st and 2nd test results, decreased to 20% in the 3rd repeat test. The degradation rate, which was approximately 52% at the end of 26 hours in the 1st and 2nd test results, decreased to 40% in the 3rd repeat test. Looking at the results obtained in the 3rd test, it can be said that the 6T1F sample with 1% fiber has lost its self-cleaning ability in the long term. Looking at all the results obtained in general, it can be seen that the use of 9% TiO_2 is ideal for fibrous lightweight polymer concretes in both the short and long term. Specimen 3T1F, which does not contain TiO_2 and contains 3% TiO_2, remained below the UNI lower limits in the 3rd test. From these results it can be seen that the fibrous lightweight polymer concretes without TiO_2 and with 3% TiO_2 did not show self-cleaning properties in any of the tests.

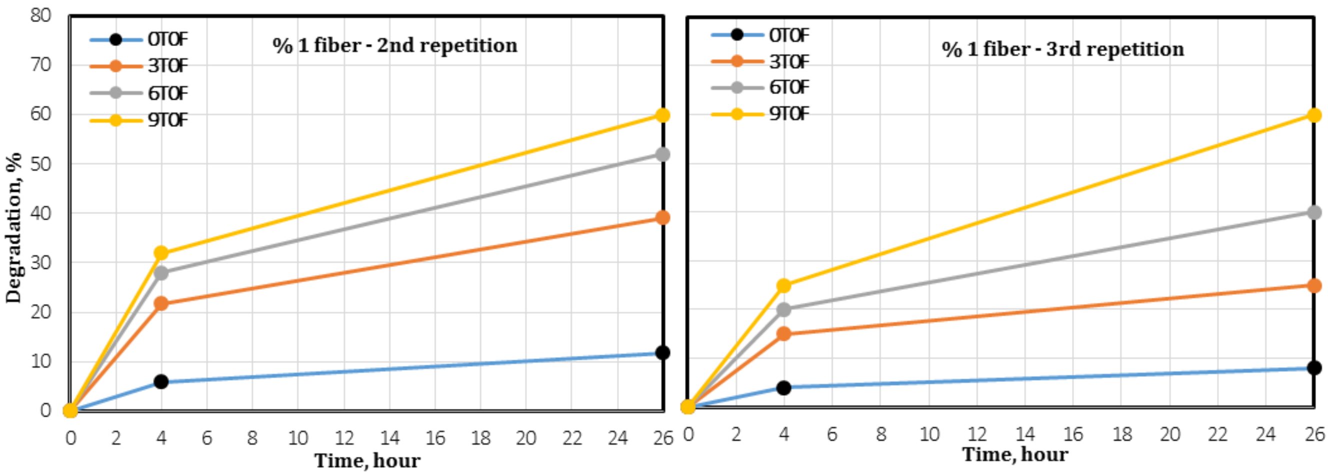

Fig. 7. Degradation of specimens containing 1% fiber at 2nd and 3rd repetitions.

Fig. 8 shows the results of the first, second and third self-cleaning tests on fiber-free specimens. The values obtained are the average of the values obtained in all the tests. The ΔE value is obtained from the changes in L, a, b coordinates using Eq. (3) and expresses the total colour change. Fig. 8 shows that 9T0F with 9% TiO_2 achieved the highest ΔE value at the end of 4 hours and 26 hours. 9T0F reached 12 at the end of 4 hours and 18 ΔE value at the end of 26 hours. The ΔE value between 0-2 indicates that there is no significant change in the colour structure. It was found that the ΔE of the 0T0F specimen without TiO_2 was also in this range. The ΔE range of the 6T0F was between 9T0F and 3T0F specimens.

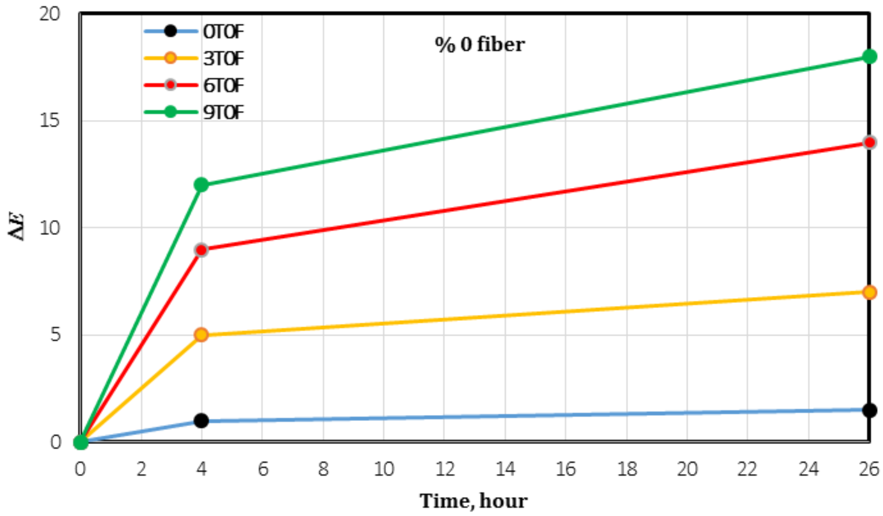

Fig. 8. Δ*E* values of fiber-free specimens.

Fig. 9 shows the results of the first, second and third self-cleaning tests on specimens containing 0.5% fiber. The values obtained are the average of the values obtained in all the tests. From Fig. 9, it can be seen that 9T0.5F with 9% TiO_2 reached the highest Δ*E* value after 4 hours and 26 hours, as in the samples without fiber. 9T0.5F reached a Δ*E* value of 13 at the end of 4 hours and 17 at the end of 26 hours. When the test results were examined, it was found that increasing the fiber content from 0% to 0.5% was not very effective in changing the Δ*E* values of the specimens. It was found that the Δ*E* of the 0T0.5F specimen without TiO_2 was within the 0-2 limit.

Fig. 10 shows the Δ*E* results of the samples containing 1% fiber. It can be seen that the specimens with the highest colour change was the specimen with 9% TiO_2. As the fiber content increased, the Δ*E* values of the specimens containing 9% TiO_2 decreased slightly. The Δ*E* values of the fiber free sample 9T0F at the end of 4 hours and 26 hours were 12 and 18 respectively. However, the Δ*E* values of 9T1F specimens with 1% fiber content were 11 and 16 respectively. The fiber structure is not resistant to UV radiation and the high coefficient of expansion slightly reduced the Δ*E* value.

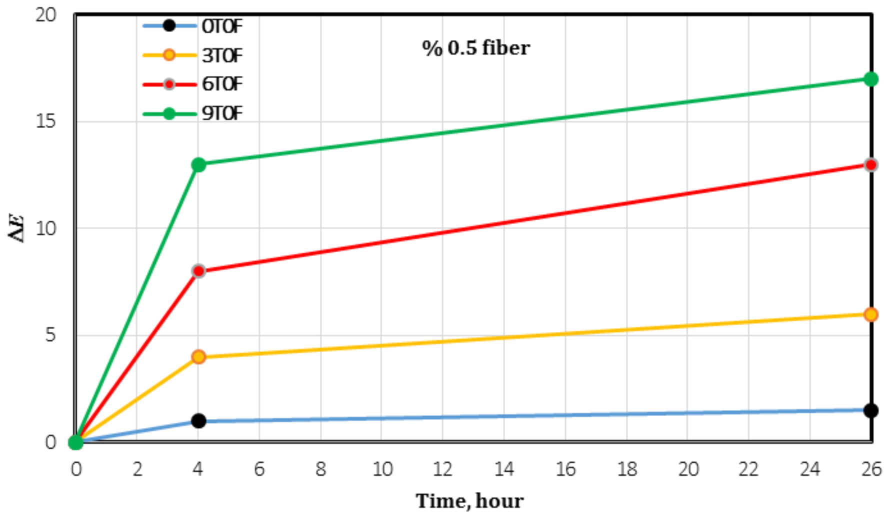

Fig. 9. *ΔE* values of specimens containing 0.5% fiber.

4. Conclusions

The conclusions of the study are summarized as:

- While increasing the fiber ratio from 0% to 0.5% did not cause any change in the *a*-coordinate in the first tests, increasing the fiber ratio to 1% caused a decrease in the *a*-coordinate change of up to 10%.
- The increase in fiber content affected the specimen which containing 3% and 6% TiO_2 most in the long term. When comparing the 3rd tests, they showed decreases of up to 15% due to the fiber increase.
- The specimens that did not show a decrease in performance in both short and long term were the specimens containing 9% TiO_2.
- When all the contents were compared, the specimens with 9% TiO_2 exceeded the limits set by the UNI 11259 standard in all the tests. The specimens with 9% TiO_2 reached the highest degradation rate of

36.92% after 4 hours and 66.67% after 26 hours. 18 ΔE value and a high colour change was obtained.

Looking at the overall results, the increase in fibre content has a slightly negative effect on the self-cleaning performance. However, considering its contribution to mechanical properties, it is recommended to use 1% fiber. It is recommended to use 9% TiO_2 in lightweight polymer concretes with photocatalytic properties to obtain permanent self-cleaning performance in short and long term. In this field, measuring the self-cleaning performance with different photocatalysts at different mixing ratios is recommended for future studies.

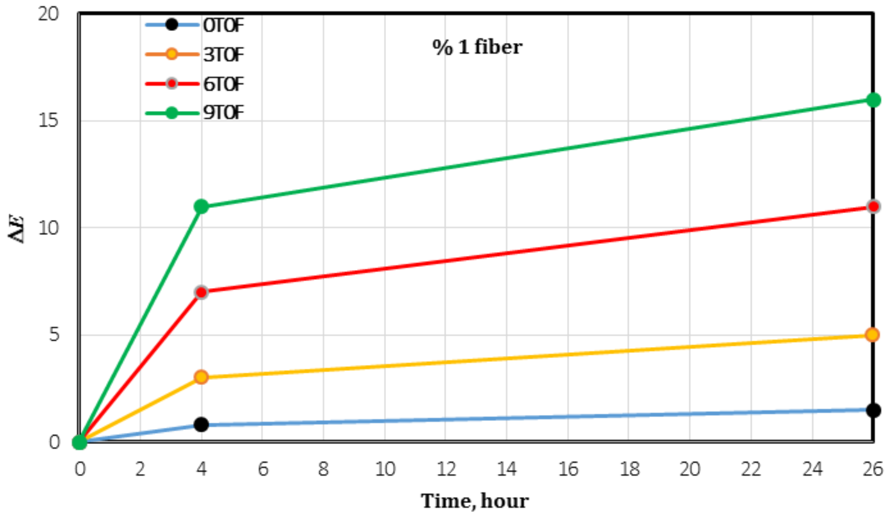

Fig. 10. *ΔE* values of specimens containing 1% fiber.

Acknowledgements

None declared.

Funding

The authors received no financial support for the research, authorship, and/or publication of this manuscript.

Conflict of Interest

The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this manuscript.

Author Contributions

All of the authors made substantial contributions to conception and design, or acquisition of data, or analysis and interpretation of data; were involved in drafting the manuscript or revising it critically for important intellectual content; and gave final approval of the version to be published.

Data Availability

The datasets created and/or analyzed during the current study are not publicly available, but are available from the corresponding author upon reasonable request.

References

Bedi R, Chandra R, Singh SP (2013). Mechanical properties of polymer concrete. *Journal of Composites*, 2013(8), 948745.

Beeldens A (2006). An environmental friendly solution for air purification and self-cleaning effect: the application of TiO_2 as photocatalyst in concrete. *Proceedings of Transport Research Arena Europe–TRA*, Göteborg, Sweden, 1-9.

Cakir F (2022). Effect of curing time on polymer concrete strength. *Challenge Journal of Concrete Research Letters*, 13(2), 54-61.

Carp O, Huisman CL, Reller A (2004). Photoinduced reactivity of titanium dioxide. *Progress in Solid State Chemistry*, 32, 33-177.

Cedillo-González EI, Barbieri V, Falcaro P, Torres-Martínez LM, Juárez-Ramírez I, Villanova L, Siligardi C (2018). Influence of domestic and environmental weathering in the self-cleaning performance and durability of TiO_2 photocatalytic coatings. *Building and Environment*, 132, 96-103.

Cojocaru A, Isopescu DN, Maxineasa SG (2023). Perlite concrete: a review. *IOP Conference Series: Materials Science and Engineering*, 1283(1), 012003.

Ćurčić AA (2019). Photocatalytic self–cleaning facades in achitectural design. *Facta Universitatis, Series: Architecture and Civil Engineering*, 16(3), 425-436.

Dikkar H, Kapre V, Diwan A, Sekar SK (2021). Titanium dioxide as a photocatalyst to create self-cleaning concrete. *Materials Today: Proceedings*, 45, 4058-4062.

Folli A, Pade C, Hansen TB, De Marco T, Macphee DE (2012). TiO_2 photocatalysis in cementitious systems: Insights into self-cleaning and depollution chemistry. *Cement and Concrete Research*, 42(3), 539-548.

Guo Q, Zhou C, Ma Z, Yang X (2019). Fundamentals of TiO_2 photocatalysis: concepts, mechanisms, and challenges. *Advanced Materials*, 31(50), 1901997.

Güler E (2024). The effect of dust sugar filter waste on soil dynamic parameters and liquefaction. *Journal of Material Cycles and Waste Management*, 26(4), 1-19.

Haider AJ, Jameel ZN, Al-Hussaini IH (2019). Review on: Titanium dioxide applications. *Energy Procedia*, 157, 17-29.

Hashimoto K, Irie H, Fujishima A (2005). TiO_2 photocatalysis: a historical overview and future prospects. *Japanese Journal of Applied Physics*, 44(12R), 8269.

Khan SA, Hussain F, Khushnood RA, Amjad H, Ahmad F (2024). Feasibility study of expanded clay aggregate lightweight concrete for nonstructural applications. *Advances in Civil Engineering*, 2024(1), 8263261.

Kiruthika C, Prabha SL, Neelamegam M (2021). Different aspects of polyester polymer concrete for sustainable construction. *Materials Today: Proceedings*, 43, 1622-1625.

Nodehi M (2022). Epoxy, polyester and vinyl ester based polymer concrete: a review. *Innovative Infrastructure Solutions*, 7(1), 64.

Sarde B, Patil YD (2019). Recent research status on polymer composite used in concrete-an overview. *Materials Today: Proceedings*, 18, 3780-3790.

Rebeiz KS, Serhal SP, Craft AP (2004). Properties of polymer concrete using fly ash. *Journal of Materials in Civil Engineering*, 16(1), 15-19.

Seymour H (2019). The Multinational Construction Industry. Taylor & Francis, Routledge.

Sui Pheng L, Shing Hou L, Pheng LS, Hou LS (2019). The economy and the construction industry: A study at the firm level. In: *Construction Quality and the Economy*, Springer Nature, 21-54.

Şengel H, Kınık K, Erol H, Canbaz M (2022). Effect of waste steel tire wired concrete on the mechanical behavior under impact loading. *Challenge Journal of Structural Mechanics*, 8(4), 150-158.

Thienel KC, Haller T, Beuntner N (2020). Lightweight concrete–From basics to innovations. *Materials*, 13(5), 1120.

Topçu İB, Işıkdağ B (2008). Effect of expanded perlite aggregate on the properties of lightweight concrete. *Journal of Materials Processing Technology*, 204(1-3), 34-38.

Ulu A (2024). Effect of resin amount on the damping properties of polymer concrete. *Challenge Journal of Concrete Research Letters*, 15(2), 47-55.

Ünal S, Canbaz M (2022). Effect of industrial wastes on self-cleaning properties of concrete containing anatase-TiO_2. *Revista de la Construcción*, 21(3), 493-505.

Ünal S, Canbaz M (2024). Mechanical properties of lightweight photocatalytic marbelite. *Challenge Journal of Structural Mechanics*, 10(4), 159-165.

Zailan SN, Mahmed N, Abdullah MMAB, Sandu AV, Shahedan NF (2017). Review on characterization and mechanical performance of self-cleaning concrete. *MATEC Web of Conferences*, 97, 01022.

Zhang S, Guo Y (2021). Measurement of gem colour using a computer vision system: A case study with jadeite-jade. *Minerals*, 11(8), 791.

Zhao A, Yang J, Yang EH (2015). Self-cleaning engineered cementitious composites. *Cement and Concrete Composites*, 64, 74-83.