CIC 2025 Conference

4th Coatings and Interfaces Online Conference
21-23 May 2025 | Online

coatings MDPI

Development of Self-Cleaning Cementitious Panels with Nano-TiO_2 and Micro-ZnO: Aesthetic and Photocatalytic Impacts of Epoxy Resin Application

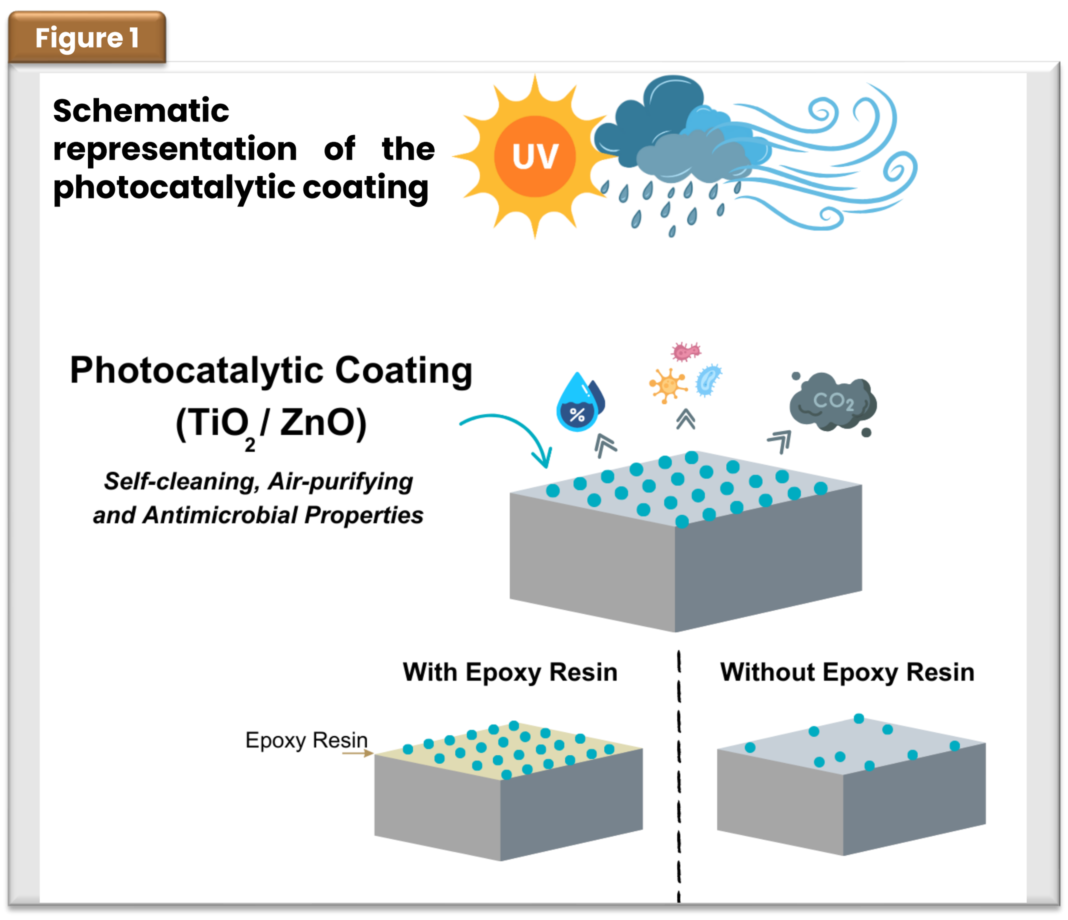
Fabíula Lessa[1]*, Orlando Lima Jr[1,2], Élida Margalho[1,2], Behzad Zahabizadeh[3], Vítor Cunha[3], Eduardo Pereira[3], Aires Camões[4], Iran Rocha Segundo[5] and Joaquim Carneiro[1]

[1] University of Minho, Centre of Physics of Minho and Porto Universities
[2] University of Minho, Department of Civil Engineering, ISISE, ARISE
[3] University of Minho, ISISE, IB-S, Department of Civil Engineering
[4] University of Minho, CTAC, Department of Civil Engineering
[5] University of Lisbon, CERIS
*Correspondence: fplessa@hotmail.com

1 Introduction and Aim

Self-cleaning coatings based on nanomaterials like TiO_2 and ZnO are promising for building facades and heritage surfaces. However, their long-term effectiveness is challenged by particle loss due to rain, wind, and abrasion. Epoxy resin can potentially improve particle adhesion (Fig. 1) but may affect photocatalytic performance and visual appearance.

Figure 1



This research aims to develop self-cleaning cement-based panels functionalized with TiO_2 and TiO_2/ZnO, and to evaluate the impact of epoxy resin on their photocatalytic activity and aesthetic properties.

2 Materials and Methods

Epoxi resin aplication + Photocatalytic functionalization

Substrates: White and gray cementitious panels

Epoxy Resin: Applied prior to photocatalyst deposition (PF) in selected samples

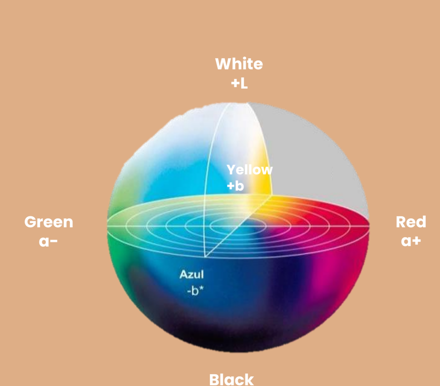
Coatings:
Spray: TiO_2 (16 g/L, 20 mL)
Dip: TiO_2 + ZnO (70:30, 16 g/L, 20 mL)

Spray coating

Dip coating

Aesthetic evaluation of the substrate – with and without epoxy resin

Spectrophotometric analysis/ Digital Image Processing
Comparison Prior (PF) and After (AF) Functionalization

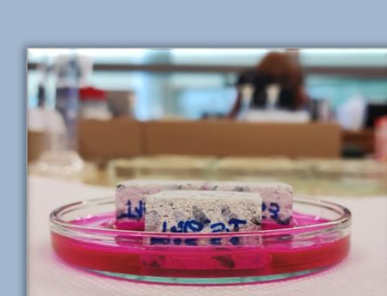


Color variation:
$\Delta E = ((\Delta a)^2 + (\Delta b)^2 + (\Delta L)^2)^{0.5}$

Colorimetric assessment (CIELAB ΔE) prior and after functionalization

Characterization analysis (SEM/ EDS)

Assessment of photocatalytic efficiency with and without resin



"Pollution" with Rhodamine B

Degradation under simulated UV light (60, 180, 540 min)

Spectrophotometric analysis/ Digital Image Processing
(Assessment of photocatalytic efficiency)

Acknowledgements

This research was financed by the Portuguese Foundation for Science and Technology FCT/MCTES through national funds (PIDDAC) under the projects NanoAir PTDC/FISMAC/6606/2020 (doi.org/10.54499/PTDC/FIS-MAC/6606/2020), UIDB/04650 Centre of Physics of Minho and Porto Universities (CF-UM-UP), UIDB/04029/2020 (doi.org/10.54499/UIDB/04029/2020), and under the Associate Laboratory Advanced Production and Intelligent Systems ARISE under reference LA/P/0112/2020. This research is also financed by national funds through FCT – Foundation for Science and Technology, under grant agreement 2023.02795.BD (doi.org/10.54499/2023.02795.BD), as well as by doctoral grant PRT/BD/154269/2022 financed by FCT, with funds from POR Norte-Portugal 2020 and the State Budget under the MIT Portugal Program. Iran Rocha Segundo would like to acknowledge the FCT for funding with reference 2022. 00763.CEECIND (doi.org/10.54499/2022.00763.CEECIND/CP1718/CT0006) and also would like to acknowledge the financial support of the FCT, through the UIDB/04625/2025 project of the CERIS research unit.

3 Results and Discussion

Figure 2

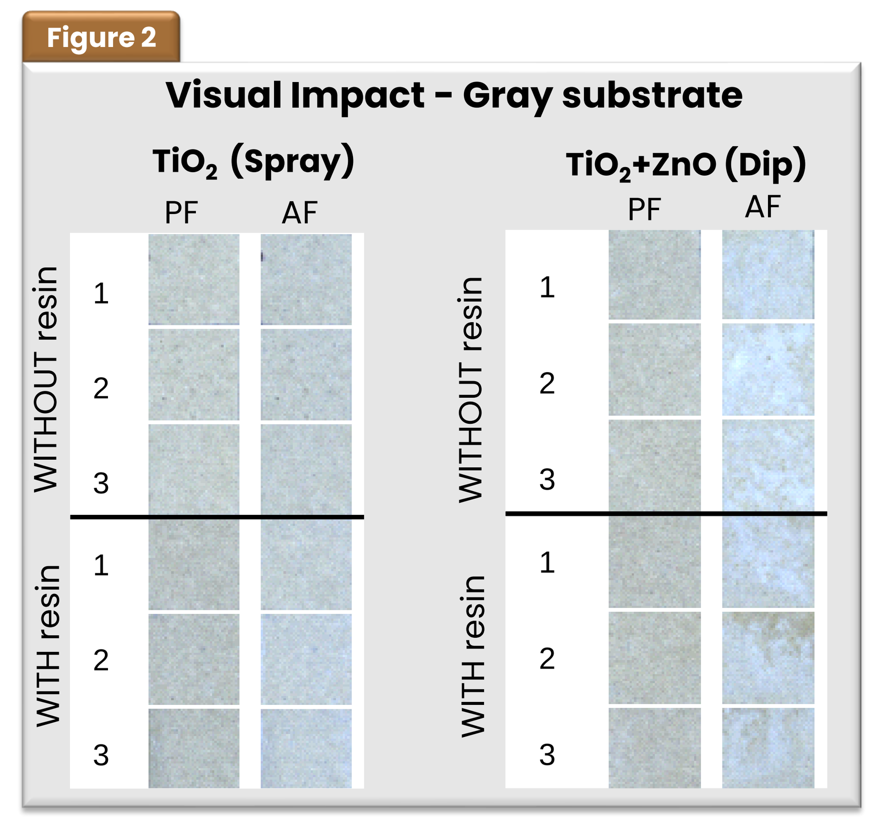


Figure 3

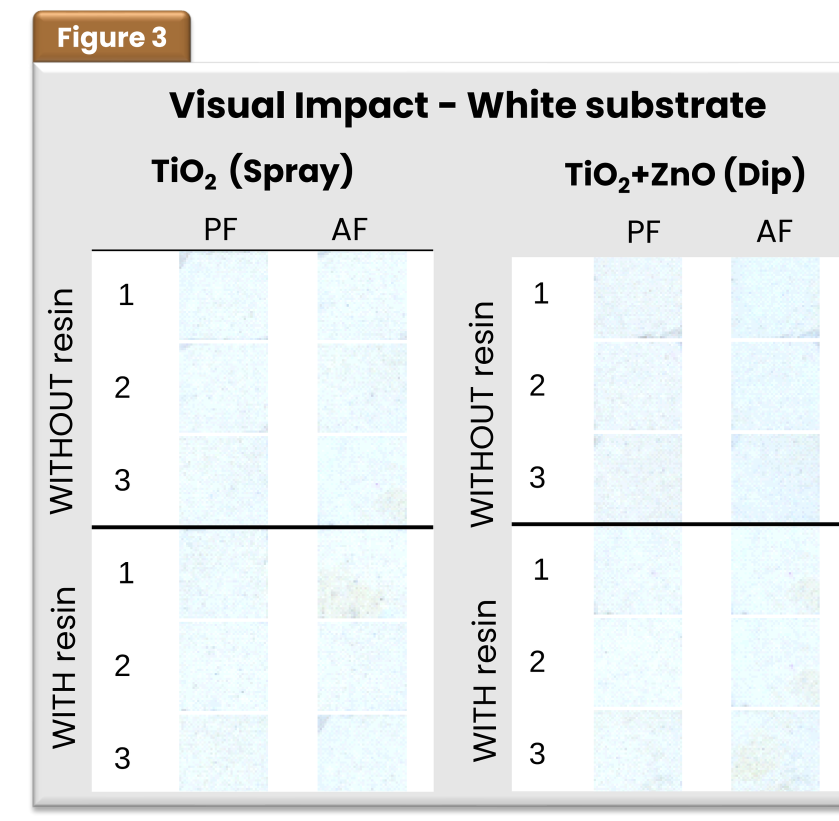
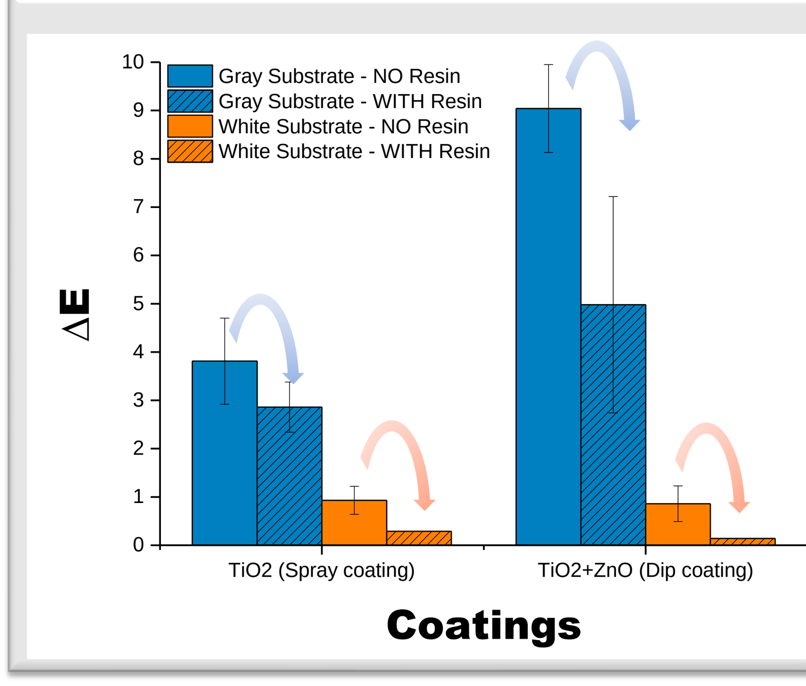


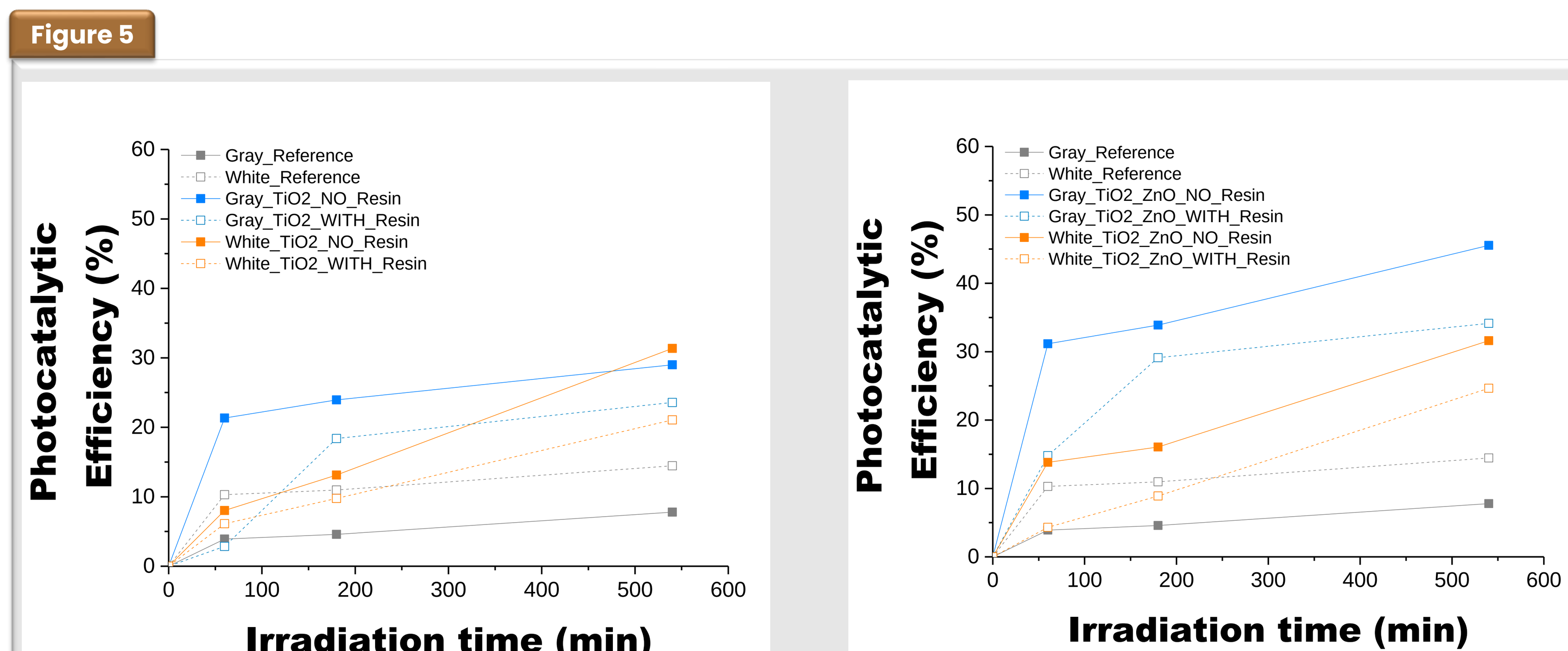
Figure 4



Aesthetic Impact (ΔE)

- ΔE between 0.14 and 9.04 → minimal aesthetic alteration* .
- Resin reduced visual impact, especially on gray surfaces.
- Higher ΔE with dip coating due to increased particle content.
- Resin reduces aesthetic impacts (↓ΔE): possible reduction of the effective area of the photocatalyst**.

Figure 5



Photocatalytic Performance

- Resin reduced efficiency in all cases (↓25–84%).
- Best performance: Gray panel with TiO_2/ZnO, no resin (~45%).
- Resin possibly limits active surface exposure**.

*Munafò et al., 2015; Miliani et al., 2007; Goffredo et al., 2015.
**Kumar, 2017; I. R. Segundo et al. 2022.

4 Conclusions

The photocatalytic coatings contributed to self-cleaning, promoting a significant increase in photocatalytic efficiency without causing a significant aesthetic impact on the surfaces. The application techniques, spray and dip coating, showed differences in terms of uniformity and thickness, which influenced the final performance. The use of epoxy resin preserves aesthetics but significantly compromises photocatalytic efficiency—up to 84% in some cases. Further research should explore alternative binders and surface treatments that maintain transparency and catalytic activity. These treatments should also be assessed for their long-term durability and resistance to wear.

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