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Self-Cleaning Façade Materials for Contemporary Forms

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Abstract
Modern architecture façades are increasingly characterized by striking geometries and diverse materials; however, their exterior surfaces are prone to dust, traffic pollutants and environmental degradation. Water, specialized tools and difficult accessibility, especially on higher or intricately designed buildings, can be part of regular facade maintenance. This paper looks at the application of self-cleaning surface technologies in modern building design, without the presumption of lower maintenance as an automatic consequence. The qualitative analysis of photocatalytic, hydrophilic and superhydrophobic mechanisms is combined with a systematic comparison of six constructed examples: Torre de Especialidades, Vanke Pavilion, Hospital Brive-la-Gaillarde, Infoscore, 570 Broome and Palazzo Italia. The illustrations include coated polymer modules, ceramics, glass, sintered stone and photocatalytic concrete. The assessment concludes that self-cleaning features are applicable for a variety of façade materials and architectural styles. But the cleaning efficiency depends on the illumination, precipitation, type of pollutants, the complexity of the surfaces and the durability of the coatings. The case evidence indicates a credible reduction of some cleaning duties, but does not prove a certain percent of water savings, or a documented decrease in deaths of workers. The manuscript proposes a framework of material, form, and exposure for the assessment of these technologies. Climate-specific field monitoring and life-cycle cost assessment are highlighted as key areas for future research. (Banerjee et al., 2015; Ćurčić, 2018; Wei et al., 2023)

keywords : Contemporary patterns; titanium dioxide; photo-catalytic reactions; water-attracting attributes; water-repellent traits; surface care; water conservation; self-cleaning exterior.

1. Introduction

The exterior of a structure is a crucial architectural component that serves as an environmental shield, necessitating ongoing upkeep. With modern design, the exterior façade has evolved from the relatively flat glass to folded ceramic textures, perforated panels and artistic concrete. The new possibilities for architectural expression are offered by these designs but they can also pose challenges regarding accessibility and maintenance. In polluted urban environments, particulate matter, organic deposits and biological growth can impact visual criteria and maintenance schedules. (Herzog et al., 2017; Mansour and Al-Dawery, 2017). The traditional ways of façade cleaning are water-fed cleaning, pressure cleaning, chemical cleaning, manual platforms or robotic platforms. The resources and risks fluctuate based on the composition and architecture of the structure. Self-cleaning surfaces are designed to reduce the adhesion of dirt, or to help in the removal of certain pollutants, using sunlight, rain and a specific surface chemistry. This is not just a matter of chemistry, but also the interplay of material, geometry and environmental

factors in their architectural significance. (Banerjee et al., 2015; Kim et al., n.d.) This research assesses this relationship by conducting a literature-based analysis of six cases documented in the current dissertation. It does not presume that a surface marketed as self-cleaning negates the need for routine inspection or cleaning.

Research problem

Self-cleaning materials have been applied to a range of contemporary façades, but project descriptions often combine architectural claims, laboratory mechanisms and anticipated maintenance benefits without comparable long-term field measurements. Architects consequently need a clear basis for assessing what is demonstrated and what remains uncertain. (Wei et al., 2023; Bersch et al., 2023).

Aim

To examine the integration of self-cleaning façade materials into contemporary architectural forms and evaluate their mechanisms, architectural compatibility and potential implications for sustainable maintenance.

Objectives

- Explain photocatalytic, hydrophilic and superhydrophobic self-cleaning mechanisms.
- Identify façade substrates and surface treatments used in documented contemporary projects.
- Compare six case studies by material, form, self-cleaning strategy and associated building functions.
- Assess the evidence and limitations relating to cleaning frequency, water use, labour exposure and maintenance cost.
- Develop design considerations and future research priorities for climate-sensitive application.

Research questions

How are self-cleaning mechanisms integrated into different contemporary façade materials and forms? Which environmental conditions enable or constrain their performance? What maintenance and resource-efficiency benefits can be reasonably inferred from the available documentation?

2. Literature and technical background

2.1 Photocatalytic surfaces

Titanium dioxide (TiO_2) is used as a photocatalytic component in façade coatings, treated glass and cementitious products. Under suitable illumination, photocatalytic reactions can degrade certain organic contaminants. Activity depends on formulation, irradiation, pollutants and environmental conditions; this does not establish universal pollutant removal or maintenance-free performance (Banerjee et al., 2015; Wei et al., 2023; Bento et al., 2025).

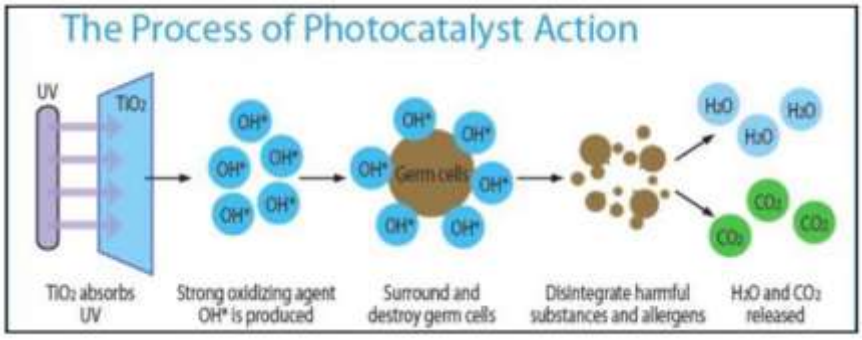


Figure 1. Photocatalytic self-cleaning cycle. Reproduced from Ćurčić (2018, p. 427, Fig. 2); original source cited there as [14].

2.2 Hydrophilic and Superhydrophilic surfaces

Hydrophilic surfaces spread water out rather than forming discrete droplets. Rain can provide a more uniform coating on susceptible surfaces and this can help wash off dislodged particles. Light-induced hydrophilicity can also be exhibited by photocatalytic coatings. Cleaning by rain may be restricted in areas of little rainfall or where the surface is protected. (Bento et al., 2025; Banerjee et al., 2015)



Figure 2. Self-cleaning glass: soiling, photocatalysis and hydrophilic action. Reproduced from Ćurčić (2018, p. 428, Fig. 3); original source cited there as [17].

2.3 Superhydrophobic surfaces

Superhydrophobic surfaces have high water repellency , often associated with micro- or nanoscale texture. Water droplets may roll across the surface and carry away loosely attached particles, an effect commonly compared with lotus leaves. Abrasion, surface contamination and loss of texture can reduce effectiveness; superhydrophobicity and photocatalysis should not be treated as identical mechanisms. (Banerjee et al., 2015).

2.4 Maintenance, water and safety

The presentation identifies water-based, mechanical, chemical, steam, low-water and robotic cleaning approaches. Their water and labour requirements vary considerably. A useful comparison would estimate annual cleaning-water demand as façade area multiplied by water used per unit area per cleaning event and by the number of events per year. Any claimed savings require matched baseline and post-installation measurements. Similarly, general powered-access fatality statistics cannot be interpreted as façade-cleaning fatalities or used to quantify a safety benefit from self-cleaning materials. (Kim et al., n.d.; Mansour & Al-Dawery, 2017).

3. Methodology

The study uses a qualitative, descriptive comparative design. First, mechanisms were classified as photocatalytic, hydrophilic or superhydrophobic using the technical descriptions and research-paper names listed in the presentation. Second, six architectural examples were selected because they represent different material substrates and envelope configurations. Third, each project was coded for material, self-cleaning strategy, façade form and secondary architectural function. Finally, recurring patterns and limitations were synthesised into design considerations. (Banerjee et al., 2015; Ćurčić, 2018).

The evidence base is secondary project documentation collected in the supplied slide deck. No original surface tests, rainfall measurements, maintenance records, cost quotations or worker-safety observations were supplied. Numerical claims in the presentation are therefore treated as project descriptions requiring source confirmation, rather than independent performance results. This approach is appropriate for identifying design patterns but cannot establish causality or quantified savings.

4. Architectural case studies

4.1 Torre de Especialidades, Mexico City

The Torre de Especialidades at Hospital Manuel Gea González has a geometrically patterned secondary screen of proSolve370e modules developed by Elegant Embellishments. The components are formed from polymer (ABS-based) rather than conventional ceramic tiles and receive a TiO_2-containing photocatalytic surface treatment. The screen combines architectural shading and increased exposed surface area with an intended air-pollution mitigation function. Published promotional pollutant-removal equivalences should not be treated as independently measured site outcomes (LaufsED, n.d.; Centre for Public Impact, n.d.).



Figure 3. Torre de Especialidades, Mexico City: photocatalytic lattice façade. Reproduced from Ćurčić (2018, p. 433, Fig. 10); original sources cited there as [30, 31].

4.2 Vanke Pavilion, Milan

Designed by Studio Libeskind for Expo Milano 2015, the Vanke Pavilion uses more than 4,000 three-dimensional glazed porcelain stoneware tiles developed with Casalgrande Padana. Manufacturer and architectural accounts identify the cladding as Bios Self-Cleaning and describe photocatalytic air-purification functionality. This confirms an architectural application on a complex curving form, not a quantified long-term reduction in washing or atmospheric pollution (ArchDaily, 2015; Casalgrande Padana, n.d.).



Figure 4. Vanke Pavilion, Milan: ceramic façade panels and details. Reproduced from Ćurčić (2018, p. 431, Fig. 7); original source cited there as [24].

4.3 Hospital Brive-la-Gaillarde, France

The Brive-la-Gaillarde hospital renovation employs a ventilated double-skin glass façade with SGG BIOCLEAN glazing on the outer layer. The façade includes access walkways, solar-control elements and rainwater-guiding details intended to support the glazing's self-cleaning function. Project documentation establishes this design integration but does not provide independently measured annual cleaning-water savings (Ćurčić, 2018; Technal, 2014).



Figure 5. Brive-la-Gaillarde Hospital: renovated façade and self-cleaning glass. Reproduced from Ćurčić (2018, p. 429, Fig. 5); original sources cited there as [20, 21].

4.4 Infoscore, Baden-Baden, Germany

The Infoscore office extension in Baden-Baden uses approximately 200 m² of SGG BIOCLEAN glass, according to Ćurčić (2018). The vertically installed glazing is exposed to rainfall, allowing dirt to be washed from its treated surface. The published account explicitly notes that periodic cleaning is still necessary; no measured comparison of maintenance frequency or water use is supplied (Ćurčić, 2018).



Figure 6. Infoscore, Baden-Baden: building and BIOCLEAN glass façade detail. Reproduced from Ćurčić (2018, p. 428, Fig. 4); original sources cited there as [18, 19].

4.5 570 Broome, New York

The 570 Broome residential tower in New York uses Neolith sintered-stone façade panels. Architectural reporting identifies a PURETi titanium-dioxide-based treatment intended to provide photocatalytic and hydrophilic functions. The manufacturer confirms Neolith's use on the façade, while the coating description comes from architectural reporting. Neither source establishes a measured before-and-after reduction in cleaning water or pollutant concentrations (Architectural Digest, 2018; Neolith, n.d.).



Fig. 9 a) The rendering of 570 Broome in New York City [28]
b) 570 Broome in New York City - Neolith paneling with Pureti coat [27]

2.5. Self-cleaning concrete facades

Figure 7. 570 Broome, New York: tower and sintered-stone façade. Reproduced from Ćurčić (2018, p. 432, Fig. 9); original sources cited there as [27, 28].

4.6 Palazzo Italia, Milan

Palazzo Italia at Expo Milano 2015 employs an articulated external skin made from i.active BIODYNAMIC photocatalytic cementitious panels incorporating Italcementi's TX Active technology. Published project descriptions report approximately 9,000 m² of cladding and more than 700 panels. These figures describe the constructed façade; they do not measure pollutant removal or maintenance savings (ARQA, 2015; ANSA, 2015).



Figure 8. Palazzo Italia, Milan: photocatalytic concrete façade. Reproduced from Ćurčić (2018, p. 434, Fig. 11); original source cited there as [32].

5. Comparative analysis

Project	Substrate	Form / assembly	Additional design relevance
Torre de Especialidades	TiO_2-coated polymer modules	Lattice screen	Shading; airflow interaction
Vanke Pavilion	Ceramic panels	Three-dimensional skin	Expressive geometry
Brive hospital	Self-cleaning glass	Ventilated double skin	Thermal buffering; ventilation
Infoscore	Coated glass	Rain-exposed glazing	Rain-assisted surface cleaning
570 Broome	Sintered stone	Cladding panels	Alternative stone-like substrate
Palazzo Italia	Photocatalytic concrete	Sculptural envelope	Material-integrated complex form

The cases establish material and formal diversity, but not a performance ranking. Differences in climate, coating chemistry, building use and documentation prevent a valid quantitative comparison of cleaning efficiency.

6. Findings and discussion

6.1 Material versatility and form

Across the six projects, self-cleaning technologies are documented on TiO_2-treated polymer screens, ceramic cladding, glass, sintered stone and concrete. The projects show that treated surfaces can be integrated into screens, ventilated skins, panelised cladding and irregular envelopes. They establish material and formal diversity, but not comparative cleaning efficiency (Ćurčić, 2018; ArchDaily, 2015; Neolith, n.d.; ARQA, 2015).

6.2 Environmental exposure as a design variable

Performance is not a fixed property of the material alone. Light access affects photocatalytic activity, while rain exposure influences the removal of loosened dirt from hydrophilic surfaces. Sheltered recesses, deeply folded geometries and prolonged dry spells may reduce the practical cleaning effect. Material selection should be assessed together with façade orientation, shading, rainfall patterns, pollution type and access for occasional cleaning. (Banerjee et al., 2015; Wei et al., 2023; Bersch et al., 2023).

6.3 Water conservation: plausible but unquantified

If self-cleaning surfaces reduce the frequency or intensity of washing, they may lower operational water demand. However, the source presentation does not supply comparable measured cleaning schedules and water-use records for the six buildings. The paper therefore does not claim a specific saving. A future study should compare similar façades over time using litres per square metre per cleaning cycle, annual cleaning frequency and local rainfall. (Kim et al., n.d.; Mansour & Al-Dawery, 2017).

6.4 Worker access and costs

Reducing cleaning frequency could reduce some high-level access operations, but this remains a potential consequence rather than a measured safety result. The slide deck includes powered-access incident figures that encompass broader work categories; they cannot support a causal claim about self-cleaning façades. Financial assessment must also include initial material or coating premiums, application, inspection, durability, recoating and replacement alongside any cleaning savings. (Kim et al., n.d.).

6.5 Water scarcity

Water scarcity can increase the desirability of reducing discretionary façade washing. Therefore, self-cleaning façades should be assessed as a potential water-efficiency measure in areas experiencing water stress (Banerjee et al., 2015; Bersch et al., 2023).

7. Design implications

- Match the cleaning mechanism to the actual pollutant and climate, rather than specifying “self-cleaning” as a generic label.
- Evaluate the interaction of surface treatment, façade geometry, sunlight, rainfall and sheltered areas.
- Retain safe access for inspection and occasional cleaning; do not assume maintenance-free operation.
- Request independently documented durability, coating compatibility and performance data from suppliers.
- Use life-cycle comparisons covering water, labour, access equipment, coating renewal and embodied impacts.

8. Limitations

This is a secondary-source review of six selected projects, not an experimental or statistically representative study. The presentation contains incomplete citations, unverified project-specific quantities and some inconsistent location data. Without primary maintenance records or standardised exposure tests, the study cannot calculate cleaning efficiency, pollutant removal, net water savings, payback periods or accident reductions. The case descriptions should be checked against authoritative project and manufacturer sources before publication.

9. Conclusion

The six architectural examples demonstrate the integration of functional surface technologies with diverse contemporary façade materials and geometries. Applications include photocatalytically treated polymer screens, sculptural ceramics, glass assemblies, sintered-stone cladding and expressive cementitious panels. The principal contribution of this review is architectural: surface functionality and formal experimentation can be pursued together, although project-specific performance must be separately measured (Ćurčić, 2018; ArchDaily, 2015; Neolith, n.d.; ARQA, 2015).

The environmental case is promising but conditional. Self-cleaning surfaces may lessen certain deposits and reduce reliance on conventional washing, yet their effectiveness depends on light, rain, contaminants, detailing and long-term durability. Water conservation, reduced worker exposure and cost savings are credible hypotheses for testing, not outcomes established by the six case descriptions. Future decisions should be based on climate-specific monitoring and whole-life assessment. In this qualified sense, self-cleaning façade materials represent a useful direction for more maintainable and resource-conscious contemporary architecture. (Banerjee et al., 2015; Bento et al., 2025; Wei et al., 2023).

10. Future research

Further work should test coated and untreated reference panels under comparable conditions in Indian hotdry, warm-humid, composite and cold climates. Useful measures include surface soiling, water contact angle, photocatalytic activity, rainfall, UV exposure, cleaning-water consumption (L/m²/year), coating degradation and total maintenance cost. Studies spanning dry spells and high-rainfall periods would help determine when passive cleaning works well and when conventional cleaning remains necessary.

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28. Source-verification note: Project material and assembly descriptions were cross-checked with published architectural, manufacturer, engineering or project sources. Claims about pollutant removal, cleaning-water savings, service life and maintenance costs are not independently established by these case studies. Supplier statements should be identified as such, not presented as experimental findings.