A Sustainable Facade Treatment Through Self Cleaning Coating Agents: A Review

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Abstract Building façades play an essential role in building aesthetics and in shielding the structural system and contents from defects and deterioration due to exposure to a climate such as air pollution: The impact of air pollution on building facades can be defined as "discolouration, material degradation, and structural collapse." Abrasion, deposition and removal, direct chemical attack, indirect chemical attack, and decay are ways atmospheric contaminants deteriorate. This paper aims to investigate the type of coatings through self-cleaning agents for various types of building materials on building façades. Application of self-cleaning material, rather than repainting the entire building elevation, is becoming more practical to preserve clean facades for more extended periods. In particular, their presence eliminates indirect costs associated with repair activities over the house's life, providing quick and cost-effective access to the envelope surfaces. Furthermore, their existence reduces indirect costs related with maintenance operations throughout the life of the building by allowing for fast and cost-effective access to the exterior surfaces throughout construction.

Keywords Façade material · Deterioration · Cleaning process · Self-cleaning material · Façade treatment

1 Introduction

Façades; the first aesthetical feature of a building that distinguishes one building from another, have to fulfil the fundamental aspects like defence against fire and burglary, climatic impact, and environmental pollution. The development of facades has made it more practical, providing designers with the ability to produce high-performance solutions, which are visually pleasing and exciting for both internal and external and It is necessary to keep facade materials in a generally clean condition

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throughout time in order to ensure that the proper functioning of the envelope components is preserved [1]. Research shows that high density architecture has attracted a lot of attention regarding the effect of outdoor pollutants and globally especially in big cities. Moreover, having bad air quality is one of the most significant factors contributing to deterioration of building façades in most high-density urban contexts. A viable alternative for mitigating the effect of this deterioration is to incorporate a self-cleaning substance into the paints used on the facades of the particular contaminated buildings. Cleaning processes in these situations will be greatly simplified by the use of effective self-cleaning coatings, which are designed to take advantage of the combination chemical-physical behaviour of treated surfaces [2–6]. Rather than repainting the whole building repeatedly, it is becoming more practical to use self-cleaning materials to maintain cleaner facades over a more extended period [7]. Self-treatment coatings are increasingly becoming an integral part of the global strategy for bacterial pathogen protection. This paper would discuss the application of coatings to the self-cleaning treatment of building façades. Examining the latest generation of release-based coatings, emphasising the threats and uncertainties they create. Recent methods for controlling self-treatment and release of façade materials, imparting multi-functionality, and enhancing the long-term durability of building materials/façade finishes are illuminated in particular (Fig. 1).

A case study was conducted on the facades of many buildings in Cairo, Egypt and Beirut, Lebanon to examine the outer characteristics of the buildings. The facades of the buildings show trace of pollution and marks of stain. These instances are prevalent in a large number of buildings in these areas. Due to their flexibility on the substrate and the ability to preserve the original aesthetical look of such buildings with almost no effort and meagre cost, self-cleaning materials have found wide acceptance in building, especially for building preservation [8].

Another example is Talaat Harb Square, Cairo's central squares downtown. Due to air pollutants and pollen, Egypt faces significant façades destruction. The surface would be clean as the coating decomposes the chemical compounds on the surface. A component of the inorganic pollutants can remain on the surface after the molecules decompose, easily washed down by rain or other cleaning methods [9]. This square is considered an important and historic downtown centre of Cairo, with distinctive

Fig. 1 Example of exterior stained façade in Cairo, Egypt

Fig. 2 Example of an exterior limestone cladding coated with a self-cleaning coating that resists algae growth (**c**) and (**d**) [9]

architecture surrounding and identifying its central position. Trying to fix the issue of erosion, the Egyptian government paints façades every few years. The government's primary goal is to retain a better urban look for this critical square. Unfortunately, it returns after a short period. Figure 2 shows the same buildings in 2007 to 2015. Therefore, self-cleaning agents is one of the key solutions in reducing cost for building maintenance as well as to preserve the building facades especially for fragile and exquisite building materials and features.

2 Types of Coatings

2.1 Paint

Paints serving defensive or decorative functions and their need for our goods as well as buildings remain as critical as in the past. Developing waterborne structures focused on polymer dispersions practically revolutionised traditional internal and external used paints. It's no surprise that there's much interest in nanostructured paints with suspended nanoparticles or nanotubes that are applied as liquids and then hardened on the materials' surface [10]. Today, nano paints come in many forms and have been developed with many different needs in mind. Typical objectives include improved scratch and abrasion resistance, hardness, glossiness, and colour steadfastness.

However, as shown in Fig. 3, finishes are frequently low-quality finishes, resulting in unplanned maintenance and extra costs. The new regulatory and scientific study focused on metal surfaces. Studying the regularities of structure-forming and coating properties on porous substrates, and developing guidelines to improve quality, would enhance the quality of protective and decorative coatings and ensure maintenance-free life. Coatings used for building facades, performing aesthetic preventive roles should have a high-quality look, i.e. should be defect-free (inclusions, stains, sharkskin, strokes and scratches, waviness). Passive coatings can detect bacteria from adhering to surfaces and destroy bacteria as they contact them. Surface roughness, wettability, and conductivity are both physical and chemical properties of the coating that have a significant impact on bacterial activity [11].

Fig. 3 Example powder coating for metallic trends for façade

2.1.1 Example of Paints Products

(i) **Epoxy paints**

Much of epoxy paints are operating as the two-component framework (2K) and used for many applications, much of it for painting; concrete, steel frame, and wooden grounds as a primer and finish often coating metal surfaces, fuel pipes and tanks. One of the important coating missions is coating pipelines and tanks for water and gasoline.

(ii) **Polyurethane paints**

As epoxy, its function relies typically on the 2K system with high wash-ability weathering and chemical resistance, making it ideal for applying steel, wooden, and concrete surfaces. As currently described, polyurethane is graded based on the polyol used in its manufacture, which impacts the properties of PU. Still, it is commonly known for its abrasion resistance, durability, strength, chemical resistance, and weather resistance [12].

(iii) **Aluminium Paints**

It's a metallic paint used for defence purposes, the base material in aluminium paint is aluminium powder. Aluminium paint is used to coat woodwork and metal surfaces. This paint is recommended for its weather resistance and water resistance. It is extremely heat resistant as well as corrosive resistant. it relies on aluminium paste as a pigment, which makes it corrosion resistance

(iv) **Varnish**

It's a colourless paint used for protection and disappearing the primed surface underneath it and often has a yellowish tint. Historically, natural resin solutions, which are secretions of plants, were used to create the first varnishes. It has been stated that the amines occurring in the structure of solvent-based varnishes become yellow

over time due to the effects of oxidation; however, these substances that produce yellowing have not been used in the manufacturing process of water-based varnishes [13]. Varnishes are used to preserve wooden surfaces, paintings, and a variety of other ornamental items from the elements. Varnish preserves and improves the look of hardwood floors as well as wood panelling and trim in the interior of buildings and furniture. It was found that there is a significant connection between overall change in wood colour and resistant characteristics after thermal treatment [14].

2.2 Self Repelling Paints/Coatings

Nanotechnology is a relatively new field in materials science, though it has grown significantly in nature, it is concerned with the boundary between atoms and molecules and the macro universe, where the properties are essentially determined by the fundamental behaviour of atoms [15]. If nanotechnology can be implemented creatively, it resulted in drastic increase in material efficiency and new technologies in the building industry. According to modern research, the lotus leaf utilises nanotechnology to produce a self-cleaning, non-wetting, super-water-repellent, or superhydrophobic [16, 17] (Fig. 4).

The lotus leaf's self-cleaning potential is its unique surface structure. A lotus leaf's nanostructure consists of different cone-like protrusions [11, 19–21]. As a result, the lotus leaf powerfully repels water that brings soil off the leaf, enabling the lotus to stay clean despite rising in turbid water [22]. This is commonly recognised as "lotus impact," mimicking various substrates utilising certain newly created coating materials (Fig. 5).

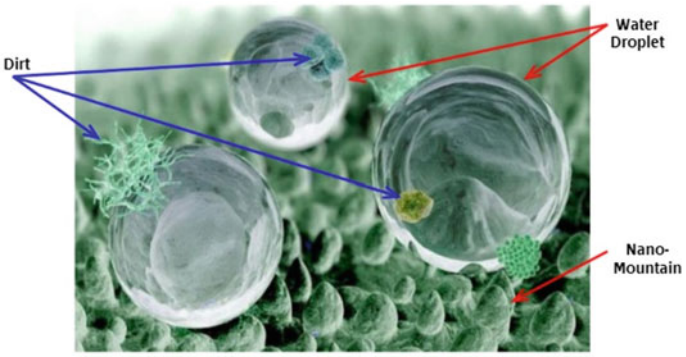

Fig. 4 Water drops suspended on nanostructured lotus leaf [18]

Fig. 5 Comparison of conventional and nano lotus leaf bio mimicked coating (adapted from European Consumers Choice 2017)

2.3 Photocatalyst Coating

Photocatalysts are materials that, under sunlight, it decomposes hazardous compounds such as titanium oxide (TiO_2). It is mainly used as a photocatalyst. TiO_2 stage anatase has the most significant photocatalytic effect among polymorphs. Photocatalytic coatings, using a coating that produces reactive radical species with a solid antimicrobial range, give an alternate way of surface disinfection [23].

Conventionally, in the end of the façade assembly process or on present façade surfaces, photocatalytic coatings in anti-bacterial coating (paints, plasters or spray-clear coatings) demonstrated suitable air purification and quick durability [24–27]. One of the most successful photocatalytic approach used to treat various organic oxide compounds, including dyes and phenol. According to [28] (2009), these reactive organisms behave as antimicrobial surfaces: these compounds are generally known as light-activated antimicrobials (LAAAs). The oxidation of organic materials involves complex processes depending on radical hydroxyl details, based on the photodegradation mechanism of organic compounds using TiO_2. This carries generate free hydroxyl radicals that may interact with organic compounds in secondary reactions (Fig. 6).

2.4 Anti Bacterial Coating

Antimicrobial coatings utilise chemicals to hinder pathogen growth by cell membrane perturbation. In layman's terms, an antimicrobial coating is a surface application of a chemical agent that can prevent bacterial infection micro-organisms. Besides increasing surface durability, appearance, corrosion resistance, etc., these coatings often guard against harmful disease-causing microbes. There are several ways to strengthen anti-bacterial and antimicrobial surfaces using nano products. One

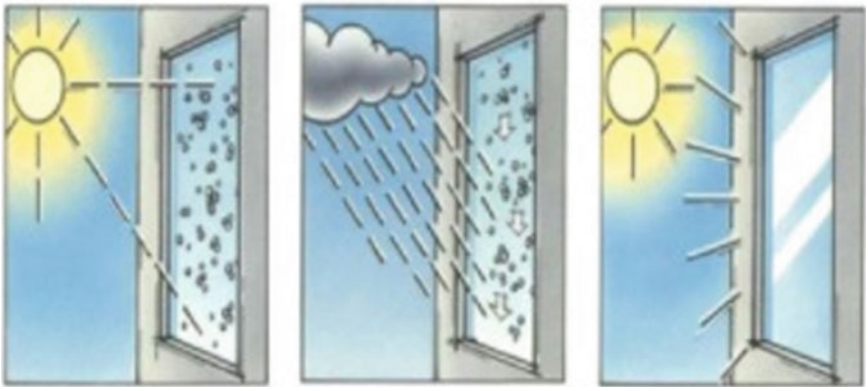

Fig. 6 The basics of how photocatalysis surfaces execute [29]

approach uses copper or silver nanoparticles trapped in another matrix, such as coatings on certain raw materials or directly integrated into bare material surfaces. This technique takes advantage of copper's antimicrobial properties long-established, but this has been significantly improved, thanks to the far wider surface area of nanoparticles. The upper layer achieves hydrophobic function, significantly reducing surface tension and molecular attraction. The lower layer ensures the surface coating speed. It cannot reverse this layer. Once added into cracks, it cannot be extracted. Unlike standard coating schemes, Nano-based anti-graffiti coatings are permanent and stay in effect long after removing writing from walls.

3 Analytical Study to Distinguishing the Application of Nano-coating for Building Components

(i) Floor

It may be used as floor finishing material to manufacture water-repellent flooring for improved service life. Water involves certain flooring materials' corrosion processes. Water repellence reduces water infiltration into flooring materials and thereby increases floor system life span with higher durability.

(ii) Wall Concrete Brick

Nano lotus leaf biomimicked coating may be added to the exterior walls or façades of buildings, minimising humidity due to water sorption and obtaining a dust-free, self-cleaning wall surface.

Fig. 7 The most relevant metrics and sustainability requirements arising from the use of nano coatings in architectural facades in line with the comparative empirical analysis

(iii) Glass

Water droplets roll off quickly with soil, and nano lotus leaf biomimicked coating would not absorb dust due to its strong water repellence. Buildings painted with a bio mimicked nano lotus leaf coating substance can self-clean through rain and remain dry due to the lotus effect. As water droplets slip down, they hold the dust particles as they do on the wall, keeping the windows self-cleaned.

(iv) Drainage System

This one-of-a-kind coating often resists the building surface development of fungus, mildew, and algae. It may be added from outside windows for self-cleaning. Nano lotus leaf bio mimicked coating may be added as a water-repelling coating on pavements for fast drainage, enabling them to dry quickly throughout the rainy season, thereby contributing to safe driving and increased durability.

(v) Pavement

For similar purposes, it may also be used for safe walking on the sidewalk; but, it must be assured that the friction property of the concrete surface is not compromised by the presence of bio mimicked nano-lotus leaf coating. Nano lotus bio mimicked coating may be used on the building's roof to accelerate the drainage of snow-melt water or rainwater, thereby reducing algae or bacterial growth and thereby (Figs. 7; Table 1).

4 Conclusion

In the standards and benchmarks of the sustainability of architectural facades, there have a few points that can be focused on these issues:-

- self-cleaning coatings represent a durable coating over the existence of the structure, minimize maintenance costs and prolong building lifespan.
- The self-cleaning coating often represents the interior air quality and allows for unrestricted design versatility.
- Easy-to-clean coatings increase the reliability of coating materials' performance and service of the building.

- Application on Nano paint coatings could provide a long-term anti-graffiti solution for a building within this uses of Nano paint coatings improve the quality of life and could act as a more sustainable building materials which can work in different climatic conditions and weather.

Table 1 Analytical study distinguishing the application of various nano paint coatings used in the architecture façade to make them sustainable

Properties	• **Anti Bacterial Coating** To incorporate copper or silver nanoparticles onto another material, such as coatings in various necessary materials or directly mixed with surfaces of essential material. Such a strategy favours bacteria but has already been documented • **Self Repelling Paints** The lotus surface produced from the nanotechnology sector is a hydrophobic surface that works on removing and separating water from surface areas • **Photocatalysis** Hydrophilic surfaces working on destroying particles of dust and dirt and making them loose on surfaces [27]
Advantages	• **Anti-bacterial coating** Since ions prevent cell division, weaken cell membranes and walls, and contain the transference of enzymes from the feeding substrate, bacteria have a slight possibility of surviving. Hence, by utilising this process, bacterial elimination can be achieved indefinitely without chemical materials. Silver nanoparticles minimise the need for chemical detergents and the amount of time it takes to scrub [12] • **Self Repelling Paints** The use of the Lotus Effect remains for a long time, as facades are still practical after five years. Cleanly and a drop in maintenance requirements, the merits of these surfaces are mainly reflected • **Photocatalysis** In coating, organic contamination on the surface is decomposed, making the surface clean. Once the particles decompose, a portion of inorganic pollutants may be quickly cleaned off the ground using rain or washing methods
Disadvantages	• **Anti-bacterial coating** There are many defined favourites of types, concentrations and shapes, as well as the distribution of the volume of nanoparticles to microbes for high potency; it is nevertheless important to note that all microbes with similar composition are not affected; more studies on the types of microbe activities that can breathe are required • **Self Repelling Paints** Limited drops of water nearly often result in the formation of water droplets in the formation of drywalls or areas, leaving the surface dusty rather than clean. The composition of these materials cannot survive solid mechanical corrosion • **Photocatalysis** Self-cleaning surfaces by photocatalysis usually are more efficient in the open air than in enclosed spaces if the required requirements are met, including ultraviolet light, oxygen, and air humidity. It is suggested that it be used only on the building's exterior facades and not inside

(continued)

Table 1 (continued)

Usage	• **Anti-bacterial** Support maintenance strategies related to healthcare situations. It is using silver nanoparticle technology in buildings that are exposed to microbes and fungi regularly • **Self Repelling Paints** To make the most use of self-cleaning facades, thus reducing maintenance costs. Also, coating roof tiles in a house that is only washed regularly [30] • **Photocatalysis** Coating granite and marble walls to prevent the adhesion of dust and dirt

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