PHOTOCATALYTIC CEMENT. POLLUTION REDUCTION AND PRESERVATION OF BUILDING COATINGS

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ABSTRACT

The environmental awareness of the promoters is one of the fundamental pieces to enable the sustainable development of our cities and it is also a vital work of the technicians involved in the building process to encourage and enliven this awareness among our customers.
We know the tools needed to provide housing systems to make them more efficient, by involving and implicating the promoter throughout the process. Furtehermore, we are able to design and build homes that contribute to improve the environment in which they are located, not only by reducing our own consumption but also through direct interaction processes on the boundary conditions as environmental decontamination.
In this way, we can create homes that become vectors of sustainability which in turn could lead to synergies in their environment. The property shown below has been designed by LAC-architecture and it is located in a peri-urban area of the city of Granada, with a mediterranean-continental climate in which there are alternating periods of temperatures below zero with others which are above 40 º C. Due to these conditions, the materials and systems that control the inner housing conditions are subjected to a very wide range of actions.
Attached to these systems, a photocatalytic cement based coating will be used and will be able to become a degradation source of the harmful organic and inorganic substances coming into contact with it. These substances are the NOX, SOX, NH3, CO, volatile organic compounds (VOCs), chlorinated organic compounds, aldehydes and aromatic polycondensation which are responsible for air pollution in our cities.

Keywords: dwelling, low consumption, environment, photocatalysis, decontamination.

1.- Introduction

Whenever a building is projected, we have a direct opportunity to act on improving the environmental conditions of the place in which the intervention is found. The complicity of promoters in this goal is essential since they will be responsible for realizing the improvements schemes studied and developed during the project. Besides a housing program, which in many cases will be proposed by the promoters, locations should be carefully analyzed to detect the strengths and threats which we can find in the environment. That will be how to include solutions that enhance or mitigate the potential problems that we will meet.

In the house we are going to deal with, we can see how its situation in a consolidated peri-urban area (Fig.1) provides variables that influence decisions on plant systems and coatings.

As discussed below, the coatings used in this house incorporate the photocatalytic principle. It is the first time that this material is used in a particular house in southern Spain, making this intervention a pioneer in the introduction of the material in this kind of works.

Fig. 1 “Situation of the house respect to nearby towns” Source: the author.

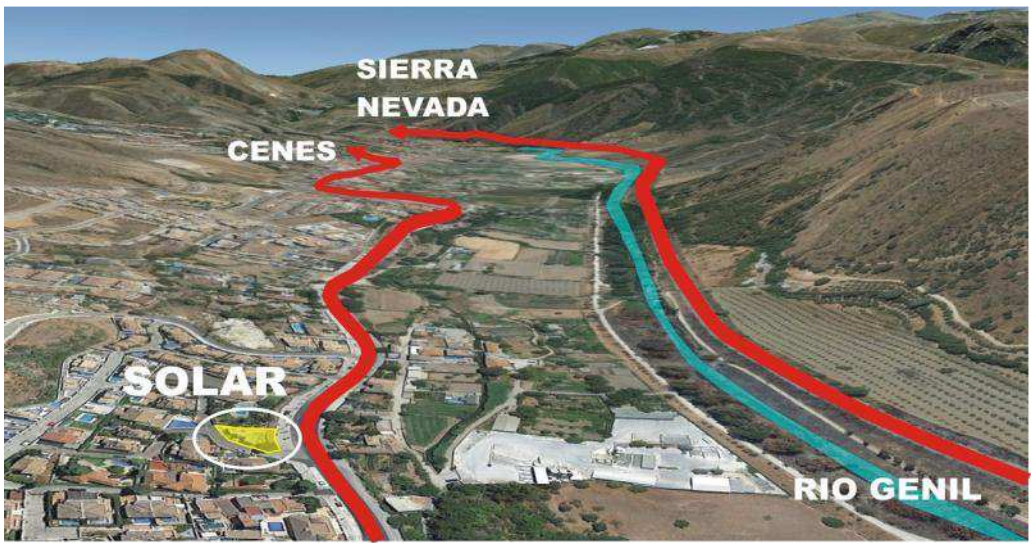

Fig. 2 “Relationship with the environment. Roads and green zones” Source: the author.

The land where this property has been built is located in an area with arboreal mass on one side and ways of high circulation on the other. The plant masses are linked to the nearby riverbed of the Genil while the roads are linking the city of Granada with

the municipality of Cenes de la Vega and the access to Sierra Nevada. Both tracks have high traffic densities. (fig.2)
Thus, we observe that the prevailing conditions on the plot are:

- Presence of sunlight. The plot has no adjacent buildings and two of its three edges onto a vial. We have lots of sunlight.
- Exempt design house, with all its facades exposed to the elements and the existence of air pollution from vehicle traffic.
- Close situation to parks, with the presence of consolidated gardens and the channel of the river Genil.
- Medium relative humidity from October to May and low in the rest of the year.

These conditions determined the actions to be included in the project and later work. At the same time, they were the ones who gave us the excuse to undertake new solutions that could improve the environmental conditions of the area and preserve the aesthetics of the house.
We knew about Richard Meier and Rafael Moneo´s interventions in some churches of Rome [1] and San Sebastián as cases of a successful use of this material. Also, we know about two other cases of this use in southern Spain but both of them belong to public promotions in the province of Málaga. However, there was nothing similar in the use of photocatalytic cement in a private home. We made a presentation of this material to the homeowner and he acceded to its use without any hesitation.
The functional housing program is developed at various levels and has a built surface of 238,23m^2. The LOW level with a total of 119,14m^2, has a direct entrance from the street.
Meanwhile the HIGH plant has a floor area of 119,09m^2 and a distribution which includes the bedrooms and bathrooms. A visual connection is present between the plants through the double height main lobby and the footbridge that crosses it. The presence of a skylight in the corner spaces emphasizes the hierarchy.

2.- Objectives

Besides the obvious goals of any property, to serve the basic needs of the inhabitants themselves, in this project we have tried to create a building with low consumption and decontaminating properties using the photocatalytic technology.
The city of Granada has a Mediterranean-continental climate, cool in winter with abundant frost and hot summers with highs of 35°C. The temperature variation is large throughout the year, often exceeding 20°C in a day. The rains, rare in summer, are mainly in winter and generally of minor importance for the rest of the year. These special characteristics are due in large part to its geographical position between mountain ridges of high altitude and elevation of 685m above the sea.

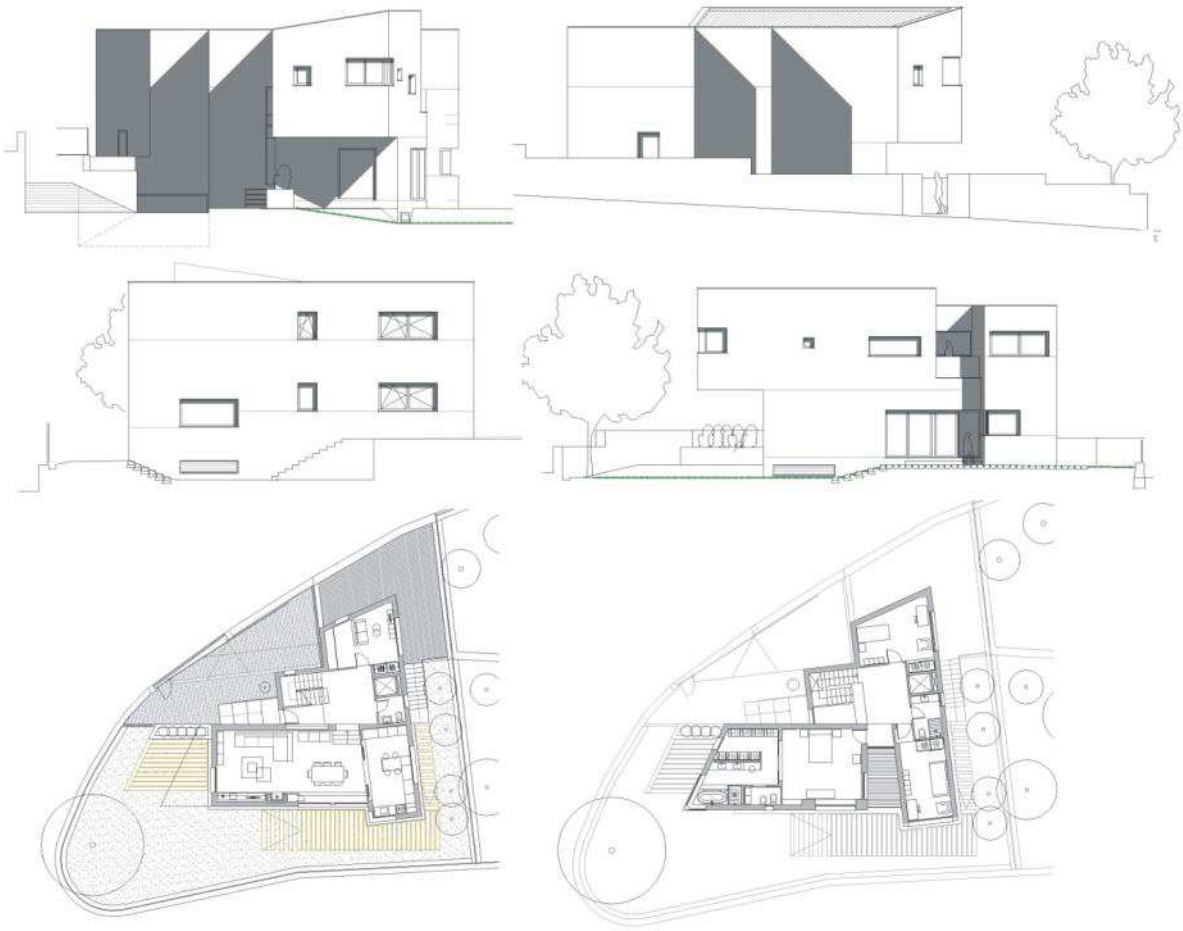

Fig. 3 “Façades and plans of the house” Source: the author.

In 2012 it was the fourth sunniest city in Spain, with 3.016 hours of sunshine, as it is clear from the data available to the National Institute of Statistics. According to the CTE HE the city is classified with C·3 while according to the average annual daily global solar radiation contained in the Atlas of Solar Radiation in Spain corresponds to the climate zone V with a value of 5.20kWh/m^2 (sum value of 3.63kWh/m^2 corresponding to direct radiation and 1.57kWh/m^2 a diffuse radiation).

The first point was to achieve low power consumption and reduced emissions that will be around 7.69kgCO_2/m^2year. We did it following some easy guidelines to implement in any home in new plant and which will be indicated in paragraphs 3.1 to 3.9 below.

We took adventage of the presence of a large-sized walnut on the western edge of the plot to increase shaded areas in the garden which was protected from the setting sun during the summer. Similarly, the fall of its leaves caused the opposite effect during the winter so that the presence of the walnut becomes an ally in the climatization housing.

On the other hand, besides the thermal behaviour of the building, we were worried about the exposed situation to environmental pollution caused by the proximity of the road already mentioned. This exposure could cause the premature degeneration of the house finish so that photocatalytic cements were used in its external cladding. As explained above, this coating is able to become a source of degradation of harmful organic and inorganic substances that come into contact, such as NOX, SOX, NH3, CO, volatile organic compounds (VOCs), chlorinated organic compounds, aldehydes and aromatic polycondensates responsible for air pollution. [2]

As we know the surfaces exposed to the atmosphere are stained by deposition of organic pigmented compounds. In our case the main source of these compounds will

be the exhaust pipes of motor vehicles and to a lesser extent from daily activities. The presence of roughness on the exterior finish of the building would be a factor that would increase the chances of premature aging, so another of the conditions imposed at the finish was the total absence of roughness.
We knew the use of photocatalytic cement in cobblestone pavements (Bergamo) and coatings of Vodafone town of Milan [3] [5] or the church Dives in Misericordia of Richard Meier in Rome (fig. 4). This project won the international competition "50 Churches for Rome 2000" promoted by the Vicariate of Rome. It is characterized by three huge structures built with prefabricated concrete elements with photocatalytic cement that simulate three huge white sails. [1]

Fig. 4 "Dives in Misericordia Church. Richard Meier. "Source: Panoramio

Closer, we had the example of the Church of Jesu, Rafael Moneo (fig.5). Located near the Urumea River in the district of San Sebastian Loyola, is another example of the enormous success in the durability of the photocatalytic cement. So the coating used in housing provides a double effect of decontamination and durability, desirable in all interventions. Later we will see the result in the house executed in Granada.

3.- Systems applied

The required standards that were set in the project were finally fulfilled during the execution of the work based on the application of the following systems in the house:

- Insulation with 10cm of XPS plates in facades and roofs. The placement is made of two layers of successive plates with alternate gaskets to prevent accidental appearance of open joints that could become a thermal bridge. We obtain design values of transmittance of 0.32W/m²K.
- Design of the enclosure made to eliminate all thermal bridges housing. Only the ones associated to the placement of doors and windows have been allowed, minimizing them and modeling their behavior by THERM software application that allowed us to make an analysis of heat transfer by these building blocks and adjust the phi value. This application has been developed by the Lawrence Berkeley National Laboratory (LBNL)
- Use of frames with thermal break through polyamides 27mm outer glass sheet 5+5 low emission with air camera of 16mm and 6mm inner glass. Above 16mm of air camera convection phenomena occur within the same air which

makes impossible to improve the insulating capacity. The incorporation of glass with low-emissivity coating on double glazing reduces energy losses heating or cooling through the glass to less than 50% of a basic double glazing U reaching values of between 2.6W/m²K and 1.4 W/m²K [7]

Fig. 5 “Iesu church. Rafael Moneo.” Source: arkitekturaz.wordpress.com

- Using blinds on the largest windows as elements of consumption reduction. We show that proper use of blinds can be seen as a 10% saving in energy consumption of a home, so it becomes fundamental.
- Recirculating hot water system to reduce water consumption at points further away from the boiler. The system is operated by a switch in the bathroom that makes hot water available for immediate use without having to waste everything which is in the pipeline supply.
- Installation of solar panels attached to a gas condensing boiler of high efficiency. This system will assume at least a contribution of between 65 and 70% of the demand for hot water and heating (higher than indicated by the CTE·HE4 for the climate zone IV values) [6]. The heating is projected with an underfloor heating system thermostatically controlled separately in each habitable living space. Installing underfloor heating in the screeds of inertia of the plants provides high thermal stability to reduce material consumption over long periods of use, as it is predictable in the winter months.
- HVAC fan coil units type of class A with nominal values of EER of 3.66 and COP of 4.62 in each habitable room.
- Use of landscaping as a conditioning resource in summer. The arrangement of windows and skylight located in the stairwell will cause internal movements of air from the shaded areas into housing.
- Use of photocatalytic cements to reduce the pollution of the environment and preserve the conditions of the finish of the facades. Thus, maintenance of the aesthetic housing conditions will be greatly reduced.

Besides all these systems is understood that an appropriate use of the building by the owner is essential to ensure that the final consumption is reduced to the estimated levels. Attached to this proper use, there should be a preventive maintenance program that makes all systems running at peak capacity.

4.- Brief introduction to the photocatalysis

The photocatalytic products have been developed to provide a solution that respects the environment in the construction market and are becoming increasingly useful in order to build environmentally friendly buildings assets and environmental material.
Under its aesthetic qualities and environmental benefits, the technology behind this material has become the best choice for all technicians and promoters who wish to meet a variety of objectives, sustainability being first.

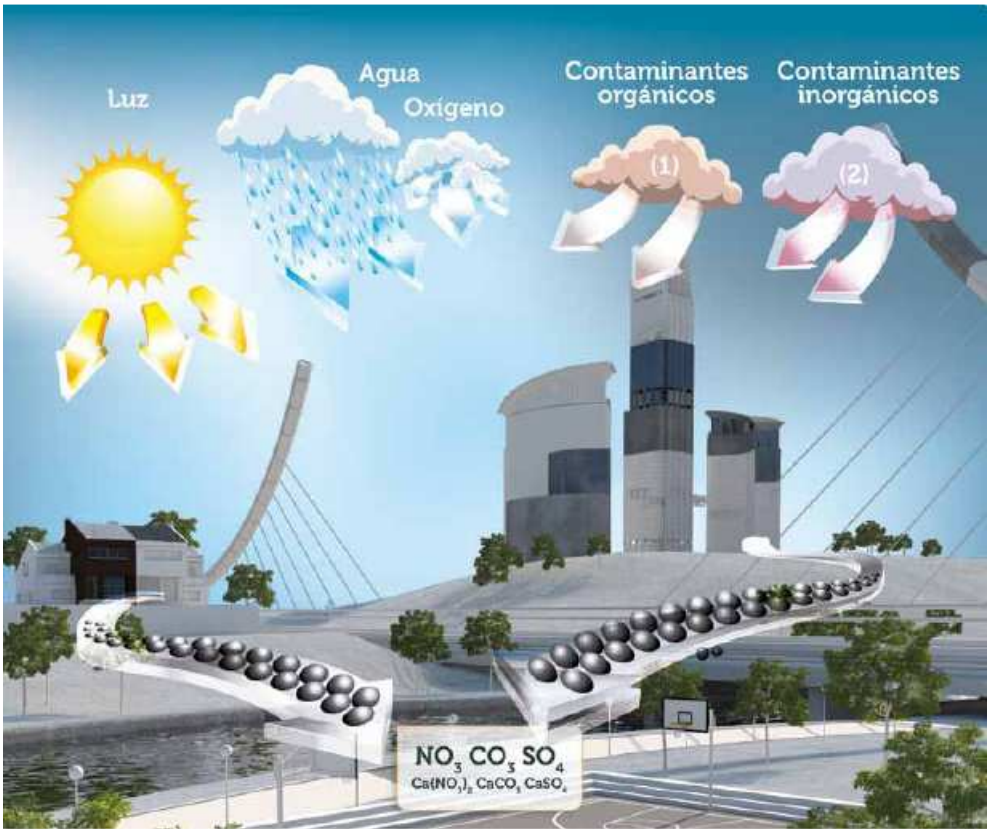

Fig. 6 “Outline the process of photocatalytic oxidation of cements”
Source: FYM-Italcementi Group.

Photocatalysis is similar to photosynthesis natural phenomenon whereby a substance called photocatalyst, through the action of natural light or artificial causes strong oxidation and converts harmful organic and inorganic substances into totally harmless compounds. (fig. 6)
This process is therefore an accelerator of the oxidation mechanisms already existing in nature. It maximizes a faster decomposition of pollutants and prevents their accumulation. In addition, experimental evidence shows that constructive solutions made of photocatalytic cements are able to retain their aesthetic appearance unchanged over time.
The action of photocatalysis is not only the elimination of these organic molecules, but it indirectly also reduces the negative effect of dirt particles represented by common powder (inorganic). The latter, in fact, uses organic molecules to adhere to surfaces; not having these molecules, adhesion is minimal and disposal easier. [4]
The photocatalytic principle is the base of the photoactive cements and binders designed and patented by FYM-Italcementi Group. It is used to for the manufacture of a wide range of materials with cement base (from paintings to mortars and prefabricated elements) with which you can make pavements, plasters and any horizontal or vertical and cladding structure. The photocatalytic materials are not consumed during the reaction, so that their effects are not depleted over time.

Photocatalytic cement can be applied to a variety of materials:

- Concrete floors.
- Concrete cobble.
- Concrete roof plates.
- Driveways and sidewalks of streets and roads.
- Road marking paints.
- Concrete roof tiles.
- Mortar and coatings.
- Cement based paints.
- Panels and precast concrete slabs.
- Noise concrete barriers and safety for roads and highways.

5.- Direct application of photocatalytic technology in a house.

Once we have reviewed the key features and capabilities of the material we are going to see how this technology is applied to real work. Initially, we can see that the application does not differ significantly from the application of any other common material for coating. As mentioned at the beginning, this house is the first case of a private promotion in southern Spain where this photocatalytic material has been used.

In the house that is presented in this paper, it has been used a MorcemSec Active coating by Puma, having incorporated the i-active principle by FYM-Italcementi Group, with decontaminating and self-cleaning properties. In the building lot on which the house was built the necessary conditions for a good photocatalytic self-cleaning effectiveness were met:

- Lots of sunlight.
- Close to the green areas of the banks of the Genil river.
- Prescription of façades with smooth surfaces.
- Relative humidity medium or low.

Fig. 7 “Flatness Control cement mortar base photocatalytic coating” Source: the author.

Before applying the material, it was necessary to obtain a correct flatness of the surface for photocatalytic cement finishing. This material was mortar cement CEM II / BP 32.5 N and clean sand (M-15). The irregularity of the substrate becomes essential as much as the coating material will end plaster 5mm thick. Like all finishing

plasters, its thinness makes it impossible to solve the problems of base material, so that control of the flatness of the surface becomes fundamental to the ultimate success. In this case said flatness was controlled by using rules every two meters. (fig. 7). The application of the final material was performed using a hose and mechanical mixer, for a continuous proper material contribution. His finish was achieved using manual rules and blades 2m relying on the previous work of mortar base. Like other finish materials (plaster or monolayers) the control of cuts cloths are necessary by placing profiles that limited working hours. (fig.8) Volumes, edges and holes of the house marked the cut lines necessary, fleeing in all cases the usual solutions.

Fig. 8 “Appearance of the façades during construction. July 2013.” Source: the author.

Having been almost two years since the end of the works, the appearance of the coating of the house remains excellent. If we compare the following two images (fig.9), it is shown the status of the façade in July 2013 (top) and February 2015 (bottom). Neither exterior defect is detected nor dirt settling on the façade has been deposited. Similarly it can be calculated based on the surface of photocatalytic material applied on the housing (about 465m^2) capacity degradation (oxidation) of the NOX will be about 18 kg/year.

Photocatalysis has been perhaps one of the most innovative and promising solutions in the cement industry in the last twenty years, through active research conducted by the FYM-Italcementi Group.

Fig. 9 “Comparison of coatings. July 2013 (top) and february 2015 (bottom)” Sources: Federico Arcos and the author.

6.- Conclusions

Once we have discussed the key features and capabilities of the material we want to state as the main conclusion that the use of photocatalytic materials must be a commitment to all future interventions. The awareness for technicians is easy as we are used to recognize the calculations and data provided to us by the industry and the research in materials. The next step is to convince private promoters and applicators on the environmental improvements involved in the use of these new materials. Thus, the workability of the material makes it closer to the applicators who find no difference with the traditional products. On the other hand, the environmental benefits that occur on the surroundings and the durability of the material will be an incentive for the promoters to choose its use.

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