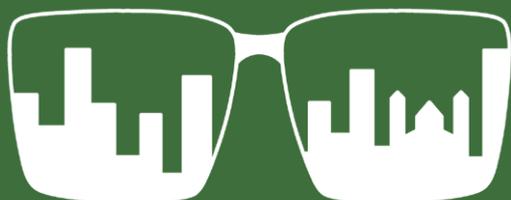


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THE SUSTAINABLE WHITE CITY

Paolo De Marco^a

^a Universitat Politècnica de València, Valencia, Spain

ABSTRACT

The history of architecture and urban planning tells of white cities, whose chromatic characteristic derives from the use of local resources (stone, lime) and which unconsciously responded to principles of environmental sustainability. During the first half of the twentieth century, some European countries undertook economic and social policies aimed at the agricultural development of the territories and a consequent repopulation of the countryside. Especially in the south of Spain, numerous white-colored cities were founded.

Global warming issues call into question the current organization of the city, which must renew itself and create comfortable and compatible living conditions with long-term development. Today the importance of color is reaffirmed in the possibility of re-establishing the contemporary city according to principles of environmental and economic sustainability. In the field of architectural design, one of the central aspects to consider is the amount of energy that buildings need to cool down, and the amount of heat they emit into the atmosphere. Especially in areas with warm climates, the energy consumption of a building is determined by its thermal insulation properties, which mainly depend on the material and color of the external surfaces. The use of white color allows to reduce the heat absorbed by buildings, with lower energy consumption and emissions; furthermore, the amount of heat re-emitted in the atmosphere is reduced, with the possibility of decrease the urban heat island effect.

This simple chromatic principle of architecture can be extended to the urban scale thanks to a wide range of products and technologies, so

that some cities have already undertaken a chromatic conversion.

The contribution tells the idea of a sustainable white city and, starting from examples of built architecture, it defines the possible principles, materials, techniques and technologies available for the design of architecture and the contemporary city.

KEYWORDS

Architecture; design; tradition; innovation; color.

1. TRADITION AND CONTINUITY OF THE WHITE COLOR

The origins of the use of white in architecture and the arts are distant and difficult to trace, related to primordial values and ancient ideals such as the sacred and purity, which give this particular color an almost universal meaning (Zammerini 2014). The history of architecture and urban planning tells of ancient white cities, whose chromatic characteristic derives from the use of local resources (stone, lime), a traditional practice that has above all hygienic reasons but which, almost unconsciously, responds to principles of environmental sustainability. In fact, in the thinking of vernacular architects, the holistic conception of the project is completely synergistic with the methods and materials available. The practice of whitewashing the walls of buildings spread throughout the Mediterranean area mainly during the eighteenth century, thanks to the hygienic properties of lime; at the same time, the white coating protects the masonry, decreases

solar radiation and improves the thermal conditions of the buildings. For these reasons, for centuries white color can be considered one of the characteristics of Mediterranean architecture and cities, which also corresponds to a spatial principle based on the construction of elementary and compact volumes - another principle of economy that also has the effect of reducing the exposed surfaces - the adoption of shaded patios and courtyards, and the creation of a few and measured openings, which allow lighting without heating. But the color white is also strongly linked to classical culture: for many centuries (and until the early 19th) the idea that Greek sculpture and architecture were white, idealized in the monochrome of Parian marble, resisted. In the eighteenth century, the tales of the *Grand Tours* and the passion for antiquities emphasize a mythical ideal of Greek art that Johann Joachim Winckelmann encoded in "noble simplicity and quiet grandeur" in which white enhances the beauty and perfection of forms (Winckelmann 1994, 117). Despite Winckelmann's historical reconstructions then turn out to be erroneous, these aesthetic theories are followed by most of the neoclassicals, influencing the plastic arts and architecture for a long time up to the present day (Collins 1970, 111-116). In the revolution wrought by the Modern Movement, white is the background of a page on which to write a new story: it expresses the cleanliness of the surfaces (to which the absence of ornament and the need for hygiene refer), the purity of forms and principles, the concepts of abstraction and denaturalization of volumes and materials¹. Subsequently, the events of white in some cases are directly linked to the nationalist ideals of the ideologically similar governments of Italy, Spain and Portugal, where a new trend arises that leads to the study and recovery of popular building traditions, to the interest in spontaneous and anonymous architecture. This trend will have its peak, at the height

of its diffusion, in the famous Bernard Rudofsky's *Architecture Without Architects* exhibition at the MoMA in New York and in the homonymous book published in 1964. In Spain, during the first half of the twentieth century, as part of a program for the repopulation of rural areas (initiative common to many nations), the color white asserted itself as a particular character in the architecture of newly founded cities. In this context, white experiences a great diffusion as a common feature of the various colonizations, predominant in these neopopular architectures, which certainly refer to the elements of traditional architecture of southern Spain, but which starting from these introduce interesting linguistic innovations, so much so that it can be considered a pioneering experience on the theme of the rural house and on urban planning (Centellas Soler 2009). Among the many works of interest, those by José Luis Fernández del Amo and Alejandro De la Sota stand out. The projects of the *pueblos* extend the chromatic principle of white to the entire new settlement and, thanks to the sensitivity of their designers, they become bearers of the architectural concerns of the time, certainly extendable to the rest of European culture but, by their nature, referable to the specificity of contexts. This architecture built with reduced economic resources, with essential and humble tools (both design and technical-construction), rediscovers the true *spirit of necessity* that guides the *highest* forms of the art of building. A pioneering and experimental experience, capable of influencing the development of architectural and urban research from the twentieth century up to contemporaneity. So, the history of the white color in architecture is clearly linked to the history of construction materials, techniques and technologies that, as they evolve, contribute to the creation of forms, styles, movements and trends. The events of white architecture - and not only of it - cannot

¹ On the issues of color in modern architecture, a relevant contribution is that of Cramer Ned, "It was never white, anyway", in *Architecture* n. 88, 88-91. On the same theme, an analysis of the context of modernity is provided by Juan Serra Lluch, "Il mito del colore bianco nel Movimento Moderno", in *Disegnare: Idee Immagini* n. 41, 66-77.

be separated from the cultural evolution in the succession of the epochs, from the specificity of the places, from the psychological meaning, as they cannot be understood without considering the technological progress of the architecture. Today, new materials and innovative techniques allow to think about further applications of the color white in architecture - combining spatial research and sustainable thinking - potentially extendable, thanks to a wide variety of solutions, to the entire city.

2. SUSTAINABILITY OF COLOR

2.1. Physical factors

Global warming issues call into question the current organization of the city, which must renew itself and create comfortable and compatible living conditions with long-term development. Today the importance of color is reaffirmed in the possibility of re-establishing the contemporary city according to principles of environmental and economic sustainability (De Marco, Margagliotta 2018). In the field of architectural design, one of the central aspects to consider is the amount of energy that buildings need to cool down, and the amount of heat they emit into the atmosphere. Especially in areas with warm climates, the energy consumption of a building is determined by its thermal insulation properties, which also depend on the material and color of the external surfaces. The use of white color allows to reduce the heat absorbed by buildings, with lower energy consumption and emissions; furthermore, the amount of heat re-emitted in the atmosphere is reduced, with the possibility of decrease the *urban heat island* effect. In fact, regardless of the material and construction technique chosen for each architecture, the use of white offers some advantages for the sustainability of buildings. It can be said, in fact, that white is the greenest color in architecture, both for the exterior and the interior of the building (Lechner 2015, 120).

The physical properties of the color white make it particularly efficient from an energy point of view and therefore sustainable. If we are to consider temperatures, the most sensitive surfaces to the absorption of sunlight are the ceilings. The greater reflection of light rays causes, for example, that white ceilings heat half of black ones. This characteristic is quantifiable through solar reflection, also known as albedo, that is, a parameter that measures the capacity of a surface to reflect solar radiation. An albedo equal to 0 (zero) indicates a surface that does not reflect sunlight and, therefore, absorbs it in its entirety, with a consequent increase in temperature; conversely, an albedo value of 1 (one) indicates that sunlight is fully reflected. Table 1 indicates the albedo values for some surfaces commonly used in construction, of which it is observed that the white color has an albedo that varies from 0.5 to 0.9 (50% - 90% solar reflection), depending on the roughness surface and cleanliness. The so-called cool roofs are precisely the roofs that remain cool, or rather less warm, than traditional roofs. Especially in hot climates, paying attention to these aspects of construction can significantly reduce building overheating, resulting in lower costs to cool it down. At the same time, the widespread use of cool roofs can affect the urban scale for the reduction of the already mentioned *heat island* effect. Even on vertical surfaces, the white color reduces heat, two-thirds less compared to a black wall. If applied in buildings arranged in narrow streets, the white color increases the diffusion of natural light on the lower floors. In general, opaque white surfaces can be considered more sustainable than glazed ones, even if they are protected with sunscreens or shading elements. These briefly enumerated principles could be applied to the project of architectures more suitable to the climate and, ultimately, more sustainable; In any case, to more accurately quantify the reduction in temperatures, it is necessary to evaluate not only the color of the material, but also its thermal transmittance properties.

Building surface	% Albedo
White paint	50-90
Highly reflective roof	60-70
Colored paint	10-40
Brick and stone	10-40
Concrete	10-40
Red/brown tile roof	10-40
Grass	20-30
Trees	10-20
Corrugated roof	10-20
Tar and gravel roof	5-20
Asphalt paving	5-20

Table 1. Albedo of typical building surfaces (Lechner 2015)

2.2. Space and perception

According to some studies on human response to the color of its environment, white should not be chosen as the color of a space where people stay for a long time, such as offices or classrooms (Birren 1978; Mahnke 1996). This observation is not based on aesthetic but ergonomic reasons: the use of white - which has the highest light reflection factor of all other colors - associated with high levels of illumination (natural or artificial) and glossy and reflective finishes, it can produce glare and, consequently, a decrease in environmental comfort, causing visual, mental and emotional fatigue. In fact, to adapt to very bright environments, the eye muscles continuously act to reduce the opening of the pupil, with the consequent rapid tiredness. If the chromatic component confers a particular dimension in the architecture, this is even more true if the color is white (Cage 1993). In fact, white has the ability to minimize solar radiation (with the clear advantages previously described), improve the perception of shapes,

expand spaces, enhance the play of light and shadow; in contemporary architecture, the use of white can refer to ideologies and specific spatial and linguistic investigations. According to design choices, today more than ever materials are projects in themselves (Deplazes 2013); in addition to building the architecture, the material qualify the space with its perceptual qualities (opacity-transparency, smoothness-porosity, temperature), so that even color must be considered an architectural material. The higher performance demands in contemporary buildings determine a constant drive to implement product quality and improve traditional techniques. These requests also lead to the adoption of materials that have been tested in other scientific fields and then, in some cases, conduce to the definition of exclusive materials for a special work, which can then be extended for a wider production. But the sustainability of architecture does not only concern the energy performance of a building or a set of these. A profoundly sustainable thought must also consider the influence of the project on the landscape (urban and otherwise), its correspondence to the cultural context and the relationship with the construction and living traditions. White architecture, in this sense, refers to universal values capable of adapting to the different conditions of the places.

3. APPLICATIONS FOR ARCHITECTURE AND THE CITY

This simple chromatic principle very present in the architecture of individual buildings may be extended to the urban scale thanks to a wide range of products and technologies, so much so that some cities have already undertaken a chromatic reconversion, intervening on the space and on the existing buildings, as a first step towards a profound change in the paradigms of building and urban design. Below some realizations are analyzed, chosen to represent the principles of white in architecture and which, thanks

to the qualities they emanate, allow the specification of the range of products available for the sustainability of white, by relating their uses and the possibilities they offer to the different design purposes of architectures. It is then made up of a catalog of solutions, materials, techniques and technologies available for the architectural project and the contemporary city.

3.1. Conversion of existing places

For the intervention on existing buildings (especially for refurbishment and renovation of buildings with shape constraints) an important contribution to the use of white in architecture comes from water-repellent and self-cleaning paints, which can also have insulating properties. A particular case is that of the liquid ceramic insulation that Elisa Valero Ramos has used for the construction of her own studio on a small plot in the center of Granada (Fig. 1). The availability of only 3.60 meters of depth, has led to reduce the thickness of the wall towards the street through the use of this special insulation, put into work as a simple painting. Composed of spherical microgranules of special ceramic, the liquid insulation uniformly covers any surface, forming a continuous, flexible and crack-free layer, which in a thickness of less than 1 mm provides insulation equivalent to 10 centimeters of polystyrene. From the point of view of the project, the use of white inserts the building into the chromatic and material continuity of its surroundings and, in other respects, adequately insulates it. As for the sustainable conversion of horizontal surfaces, flat or sloping roofs, the aforementioned cool roof technology includes a wide range of high solar reflectance paints that can reduce the surface temperature up to 30 °C. With regard to circulation spaces, however, the market offers a range of high-performance water-

based sealants, directly applicable to existing surfaces (including asphalt) as a normal waterproofing product. The white color and the high reflectivity - although they reduce their effectiveness if not cleaned - allow to significantly reduce the surface temperature and consequently that of the environment, also increasing the night visibility of the streets without producing glare².



Figure 1. Elisa Valero Ramos studio in Calle Belén, Granada.

² In 2019, the city of Los Angeles began testing this particular technology on 15 stretches of road.

3.2. Design of new spaces

For the external horizontal surfaces (car parks, secondary roads, paths and pedestrian areas or green ways), there are interesting applications of white draining concrete, as in the case of Italcementi i.lab center in Bergamo, designed by Richard Meier (Fig. 2). The building - also entirely white thanks to the use of a special photocatalytic concrete - is part of a large natural park, accessible by walkways, ramps and outdoor spaces made of white draining concrete. This technology, thanks to the special mix-design, allows to safeguard the aquifers and, thanks to a high albedo, reach significantly lower temperatures than asphaltic floors, with the possibility of reducing the heat island effect typical of metropolitan areas. Regarding the building envelope, plaster still represents the most widespread technique for white architecture, due to its low costs and ease of application, especially for small-scale interventions (Reichel, Hochberg, Köpke 2007). However, to achieve the performance required for current architecture, the plasters acquire increasingly high insulating and breathable properties, obtaining interesting characteristics of durability and sustainability. One of the most interesting technologies applied to renderings is photocatalytic, which today is also being used in other finishing materials for architecture (such as the previously mentioned white concrete). In fact, the photocatalytic plaster is particularly white and shiny due to the presence of titanium dioxide (TiO_2); This chemical compound makes the plaster active, decomposing the microorganisms present in the air: with a process similar to the chlorophyll photosynthesis, air and light oxidize polluting substances and fine particles, forming harmless residues. These compounds are washed away by the rain, thus obtaining anti-pollutant, antibacterial and self-cleaning properties. With a greater durability, the photocatalytic

plaster also allows to prolong its chromatic characteristics and consequently the physical effectiveness of its whiteness. The use of ceramics in architecture dates back to an ancient tradition, particularly widespread in countries and cultures with Arab influence. In its contemporary use, the ceramic material is renewed, so that some elements - today available in large sizes and reduced thicknesses - can be designed according to specific needs. Some producers also manufacture ceramic pieces with photocatalytic characteristics (also in this case with the use of titanium dioxide) that endow the surfaces with antibacterial, anti-pollution, anti-odor and self-cleaning properties. Among the examples of contemporary applications, always in the context of white architecture, the rental housing building in Gójar designed by Elisa Valero stands out (Fig. 3), which on the exterior, both on the facades and on the roof, is clad with alveolar ceramic: stoneware pieces traversed inside by alveoli that improve insulation; Research for sustainability has also led to the use of an enamel that is characterized by its capacity to capture CO_2 .



Figure 2. Italcementi i.lab in Bergamo, by Richard Meier.



Figure 3. Housing building in Gójar, by Elisa Valero.

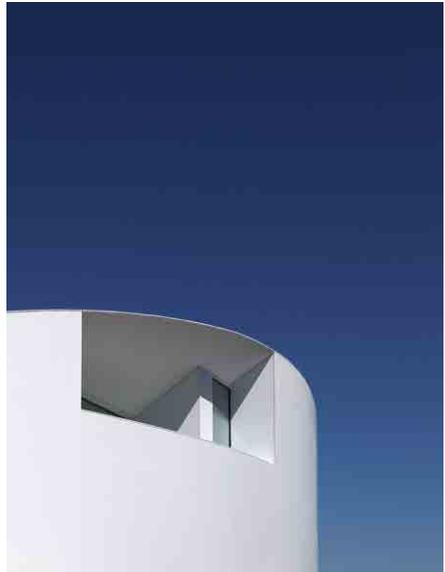


Figure 4. Balint house in Valencia, by Fran Silvestre.



Figure 5. EDP Headquarters in Lisbon, by Aires Mateus.

To remain in the context of Mediterranean architecture, the *Balint house* project by Fran Silvestre Arquitectos studio in Valencia is also interesting (Fig. 4). The white cladding of the unusual curvilinear geometry is made with *solid surface* - a technology widely used for the construction of countertops and sanitary accessories, due to its hygienic properties and the absence of joints. The elliptical and shiny house appears as a monolithic sculptural piece, endowed with a continuous ventilated façade, which also covers the curved roof in continuity. Among the contemporary applications of white concrete coatings, the technology of glass fiber reinforced panels (*Glassfiber Reinforced Concrete - GRC*) is widespread. Present in the architectural field for decades, recent research has improved the characteristics of GRC - greater mechanical resistance and extreme lightness - and has acquired the possibility of prefabricating elements with different shapes and sizes. These technical characteristics, together with the aesthetic qualities, have made GRC panels widely used in white architecture, especially in large-scale projects with complex geometry. The architects Aires Mateus Associados, who often render their small houses white, also used GRC technology in the project of the new headquarters of the electric company EDP in Lisbon, on the banks of the Tagus (Fig. 5): the large building consists of two tall glass blocks whose steel structure is clad with special GRC elements. Oriented to the southwest, these white ribbons run along the facades and cover the square between the blocks, setting the rhythm of the entire composition and solving, with a single expressive gesture, the entire project. The GRC elements act as sunscreens and protect spaces from excessive radiation, varying their size according to the internals, while the diagonal orientation generates a transparency effect that changes in relation to the position of the observer. White, often conceived as an opaque, full and static material, thanks to GRC panels, can express dynamic shapes and combine in an innovative way with transparency and light.

In the historical context of Berlin's Museum Island, David Chipperfield has recently completed a long series of interventions with the James Simon Galerie (Fig. 6). While exposed concrete is widely used in the interiors of the building, the exterior parts are characterized by architectural elements deduced by the neighboring constructions of Schinkel and Stüler, made of *Engineered stone*, a composite material made of stone fragments (in this case limestone and sandstone) joined by a resin. This technology - used above all for the construction of kitchen and bathroom countertops - makes it possible to use the residues from stone treatment and produce elements of large sizes and limited thickness. Finally, some less common materials in contemporary construction are mentioned, which are nevertheless the object of interesting research: fabrics, membranes and translucent polycarbonates, which come to architecture through technological transfer (as in the case of polytetrafluoroethylene, commercially known as *Teflon*) and they come to define new poetics that no longer root the building to the earth (and to history) but are projected towards new concepts of duration and dissolving forms. An example is the *experimental house* at Meme Meadows Center, built by Kengo Kuma, which uses a layer of transparent membranes to provide thermal insulation suitable for the harsh winters of northern Japan (Fig. 7). If the large sloping roof, as well as the larch wood structure, is derived from the traditional constructions of the region (the *chise*, home of the Ainu population), the construction is completed with the use of technologically advanced materials. The outer membrane is a polyester cloth painted with fluorocarbon (colorless substance with high hydrophobic properties), the inner thermal insulation is made of polyester fiber obtained from recycled polyethylene (PET) bottles, while the removable inner membrane is made of polyester cloth. fiberglass. Therefore, the use of transparent plastic materials defines a semi-opaque white volume, capable of being passed through by light.

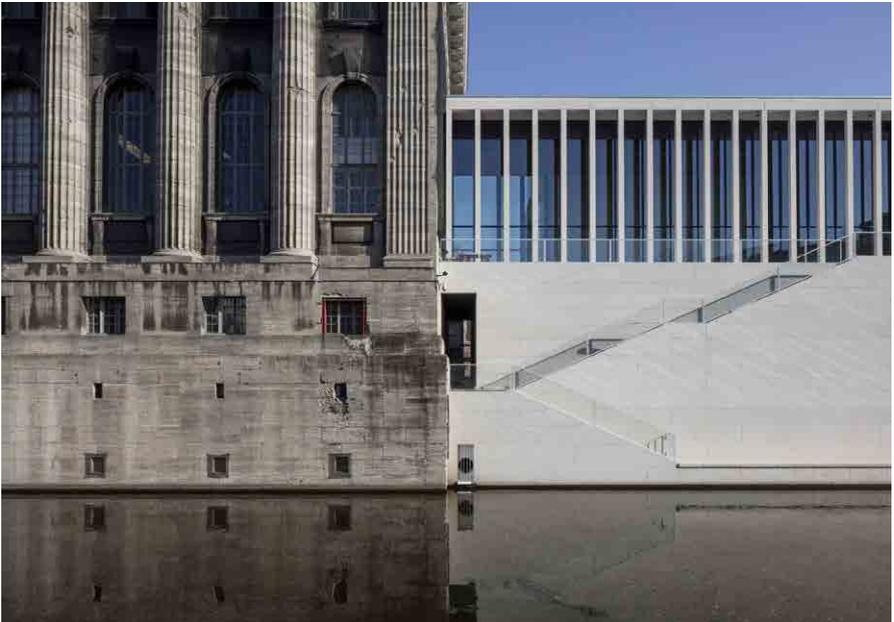


Figure 6. James Simon Galerie in Berlin, by David Chipperfield.



Figure 7. Meme Meadows experimental house, by Kengo Kuma.

CONCLUSION

Today, also due to the recent vicissitudes linked to the pandemic unfortunately still underway, culture, economy and society have returned to discuss the city, its population density, its morphological characteristics and the quality of life of its inhabitants: in other words, we have returned to talk about the sustainability of urban living. The proposal for the displacement of the population from the city for the rediscovery of life in the countryside, supported by some internationally renowned designers, nevertheless appears as an initiative which, if not controlled, could have disastrous effects on the territory. It is useful, however, to return to reflect on the city, first of all on how to intervene on the existing, to make it more responsive to the future vision of living; secondly, on the design of new buildings, public and private spaces. It is from this perspective that color can be rediscovered as an elementary principle of sustainability, as the constructive wisdom of traditional Mediterranean architecture reminds us. Nevertheless, the sustainability of white does not only concern the surface (or the *skin*) of the city, but implicitly includes principles of essentiality and economy for the living space which, consequently, influence people's lifestyles. The sustainable principle of white would thus represent an initiative of rapid feasibility and immediate results, albeit aware that probably, a sustainable model for the city of the future must address much more complex problems. Extending these principles to the urban scale, then, does not mean wrapping the metropolis with a veil of homogeneous, indifferent candor; on the contrary, as demonstrated by the different architectural solutions mentioned above, there are different ways in which white can be used, in the most suitable forms also in relation to particular contexts. From this point of view, white in architecture is not a simple color but

instead represents a spatial principle, with technical and technological implications. "Sustainable design has also become a new marketing strategy both among designers and developers" - claims Juhani Pallasmaa (2010, 34) - describing the trend that favors the proliferation of projects that superficially tackle the issue of sustainability, for example, by adorning condominiums with vegetation but without actually intervening on the quality of the living space. A risk, that of *decorativism*, which in some cases also affects white architecture since, unfortunately, the current sustainability assessment system does not promote environmental policies and truly ecological thoughts. In any case, the search for sustainability must be approached from a holistic point of view, which cannot ignore formal qualities: "aesthetics is the mother of ethics", argues the poet and Nobel Joseph Brodsky, for which sustainability in architecture it will find, together with its own aesthetic, its ethical principles.

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