SUSTAINABILITY IN CONSTRUCTION

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UNIVERSITAT POLITÈCNICA DE VALÈNCIA

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ÍNDICE DE CONTENIDOS

SUMMARY

In this book, the central theme is sustainability in construction. The best works presented to the International Conference on Sustainable Construction and Demolition are edited as book chapters, which were carefully reviewed and selected on the basis of articles of relevance, clarity and originality and published in this Book of Chapters. The international conference was held in Valencia, Spain on 17-18 November 2021.

PROLOGUE

Sustainability in construction.

This book shows in the form of book chapters the best works presented at the 1st International Conference on Sustainable Construction and Demolition held in Valencia, Spain, from November 17 to 18, 2021, under the thematic area of sustainability in construction.

This conference sought to disseminate the current situation from a perspective of improvement in the construction sector, where technological advances need to be constantly reviewed to manage their evolution efficiently and sustainably.

The conference dealt with Sustainability in Construction, Technology, Energy, Environment, Circular Economy and Life Cycle Analysis, debating in an international forum with innovative contributions that will undoubtedly give positive results in the immediate future.

The Conference has been a platform for contributions with an academic community established in collaboration with the professional world and the business sector to present and discuss new and current work. This has resulted in the Conference being successful.

All the book chapters were subjected to a review process by reviewers of the scientific committees, external reviewers and members depending on the corresponding topic of the article. After a rigorous review process, the chapters were selected based on their originality, relevance and clarity for the purpose of the conference presentation.

A POSSIBLE ROLE FOR BUILDINGS IN THE SEARCH FOR A SUSTAINABLE TRANSPORTATION IN UNIVERSITY CAMPUSES

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ABSTRACT

Higher education institutions are increasingly striving to become fully sustainable organizations The search for sustain ability in university campuses includes zero carbon transportation that implies the use of electric vehicles (EV) and their recharge with electricity from renewable sources. Nevertheless, this requirement is normally considered only for displacements inside the campus; but, for a real sustainable approach, the displacements from and to the campus of the involved EVs should be also taken into account. Therefore, there is a need to supply EVs in the campus with enough clean electricity to recharge them for the consumption generated in these total displacements. Buildings in the campuses usually have parking spaces that could allocate the needed recharge points. Additionally, they can accommodate renewable sources, either PV panels and/or wind generators that could provide the clean electricity needed for the recharges. Therefore, a methodology has been developed to take into account all these aspects: EVs displacements, recharge capabilities, system design and economic viability. Simulation of this methodology for a university campus located in the Valencia area is addressed and detailed planning for application to a specific building of the UPV is outlined.

Keywords: Sustainable transport, electric vehicles, recharge, university campus, buildings, renewable energy.

INTRODUCTION

The need to reduce greenhouse gas emissions (GHG) (IPPC,2009) requires significant actions on the transport sector, given this demand sector is responsible for approximately 28% of the total GHG emissions (Sims, *et al.*, 2014) Electric vehicles (EV) have been considered as the most promising alternative to internal combustion ones, given their null tail pipe emissions and, in consequence, EV acceptance is gaining momentum, both at the public and the political levels (Müller et. al, 2019; Jingwen, 2019). Nevertheless, EV could generate GHG emissions when their batteries recharge is taken into account, so emphasis should be put to assure the use of renewable sources for the electricity required in that recharge process in order to reach the goal of a smart mobility, which is an important requirement for the EVdiffusion in sustainable districts (Chellaswamy et.al, 2017; Miceli, 2017).

Higher education institutions are increasingly striving to become fully sustainable institutions (Miceli, 2017). There is a strong movement for universities to become leaders in driving society towards a more sustainable future, through improving the sustainability of the built environment and their practices and operations, and through their education al, research and wider community engagement missions (Filho et.al, 2019). Given the need to actively address the challenges of climate change, university leaders have a growing interest in reducing their campuses environmental impact. This implies to promote the efficient use of energy and other resources on the university campuses (Almeida et.al, 2018). Sustainability initiatives are vastly described in literature, especially for the operational phase, including some initiative failures (Amaral et.al, 2021). Campuses are normally constituted by a large number of buildings that are responsible for a high energy demand. Therefore, they could become demonstration sites for new technologies and systems to improve energy efficiency and clean generation.

The search for campus sustainability includes looking for sustainable transportation, which should imply that the transportation requirements of campus users do not generate any environmental impact (Pouria, 2019). Therefore, they should be carried out with vehicles that do not emit emissions and that the necessary recharges are carried out with clean electricity sources (WeiRu Chang *et al*.,2009; Mingrui Zhang *et al*.2019; Anastasiadis, 2017). These recharges should be covering the consumption made by the users of the campus, (professors, students, administrators, etc.) not only in their displacement inside the campus but also in their movement between their place of residence and the campus, in both ways: going to the campus and coming back to their residence place. Given that many buildings include parking spaces, the design of new buildings, or the adaptation of existing ones, looking for sustainability must have the possibility of covering the recharging of the vehicles parked in them with enough installed power to guaran tee a full coverage of the above-described consumption.

In this work, a methodology is presented for the design of the recharging system in a building that guarantees the sustainability of the transport of the vehicles that use its parking. The possibility of injection into the building network, or in the main grid, of the electricity surpluses is included, and the economic viability of this approach to sustainable transport on a university campus is analyzed. Simulation of the methodology application to a standard campus and detail planning for the design of the system to install in a building in the Universitat of Valencia are also included in this paper.

METHODOLOGY

Methodology developed for this study follows the flow diagram shown at figure 1. Input data includes the EV input and output fluxes with time resolution and the building characteristics (number of parking places, location, area available for renewable sources, etc.). In order to determine the level of electrical power to install, an average permanence time for the vehicle in the parking should be deduced.

Being the EV input flow Ni (t) and the output one No (t), the number of EVs at a particular time in the parking, Np (t), will be given by:

$$N_p(t) = \int_0^t [N_i(x) - N_0(x)]\,.\,dx \tag{1}$$

By defining a permanence time τp, it is possible to relate vehicle input flux and the number of parked ones.

$$N_p(t) = \int_0^t N_i(x) * e^{-{(t-x)}/{\tau_p}}\,.\,dx \tag{2}$$

Using equations (1) and (2) it is possible to deduce the permanence time with time resolution. Nevertheless, for the determination of the electrical power to install to guarantee a full recharge of the parked vehicles, an average value of the permanence time can be used. This average value can be deduced by using the following discrete approach to the problem. The number of parked EVs at the j instant can be given by:

$$N_p(j) = N_i(j) - N_0(j) + N_p(j-1) \tag{3}$$

and introducing an average permanence time $\overline{\tau}_p$

$$N_p(j) = N_i(j) + N_p(j-1) - \frac{N_p(j-1)}{\overline{\tau}_p} \tag{4}$$

Using (3) and (4) $\overline{\tau}_p$ can be deduced:

$$\overline{\tau}_p = N_p(j-1)/N_0(j) \tag{5}$$

Recharge power demand will be given by:

$$P(j) = {N_p(j) * \overline{D} * \overline{C}}/{\overline{\tau}_p} \tag{6}$$

Where $\overline{D}$ is the average distance traveled and $\overline{C}$ is the average consumption of the parked vehicles. The total power to be installed will be given by:

$$P_{inst} = Max\left(P(j)\right) \tag{7}$$

Evaluation of the building renewable resources will allow determining. by using HOMER code (HOMER, 2021) the microgrid configuration to be implemented. Using this configuration and the available renewable resources, it is possible to deduce which fraction of this power demand could be covered by the microgrid and, additionally, the bidirectional interaction with the grid in order to deduce the electricity balance.

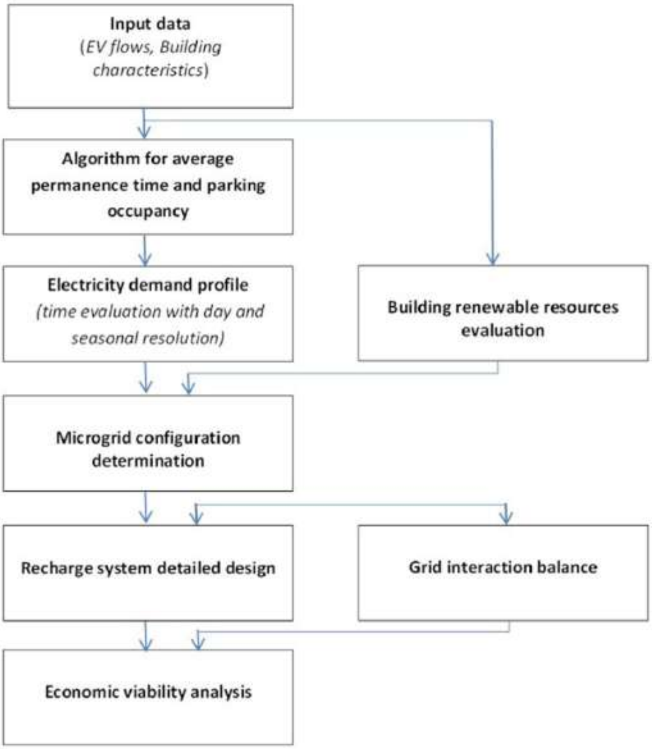

Figure 1. Methodology flow chart

SIMULATION RESULTS

In this section the application of the proposed methodology to a standard campus in the Valencia region is presented. Simulation of the EV Input flux is done by assuming a combination of normal distributions with peak values early in the morning and in the afternoon to take into account the two main shifts of arrival of professors and student to the campus. Output flux is deduced by assuming an average permanence time in the order of 3 hours. Using those fluxes in eq.3 is possible to determine the number of EVs in the parking. Figure 2 details those fluxes, the number of parked vehicles and the permanence time along the day.

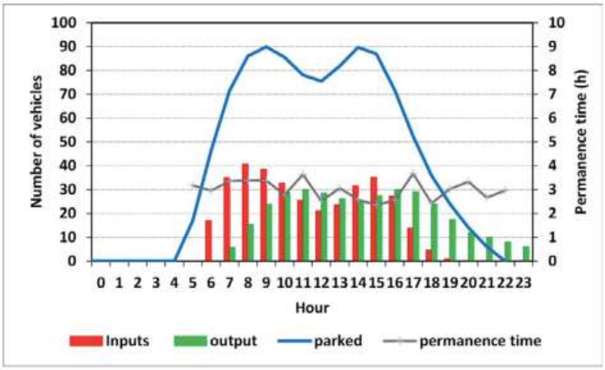

Figure 2: EV fluxes and permanence time

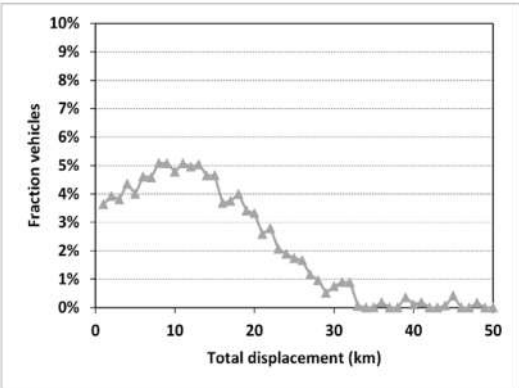

Figure 3: Displacement distribution

Table 1: Parameter values used in the simulation

PARAMETER	VALUE
Building area (m^2)	2300
Number of parking places	100
Average full distance (km)	13,5 ± 2,0

Consumption (kWh/100 km)	20 ± 1,5
Permanence time (h)	3,0 ± 0,4

Remaining input data for the methodology application are detailed at table 1. The building characteristics include capacity of the parking, and surface available for PV panels or wind generators. Simulation of the percentages of EVs for each total displacement is detailed at figure 3 and for the EV consumption that depends in the type of vehicle (Ke, 2017), an average value is assumed.

By using these values for the different variables of the eq.6, it is possible to determine the profile of the power requirements to assure the full recharge of the parked EVs. Obtained results are presented at figure 4. The maximum renewable power to supply the recharge needs of the parked vehicles is in the order of 80 kW with an uncertainty of about 15%.

Given the characteristics of the area, PV has been considered as the renewable source to be used. Radiation is highly dependent on the season, therefore in real application, study should be done with season resolution. In this simulation, the average radiation for the entire year is assumed and with the data from (PVGIS, 2021), it is possible to deduce the annual average PV efficiency and, by a comparison between the required recharge power and the available renewable power, to deduce a power balance for the system. Figure 5 details the PV efficiency and the power balance.

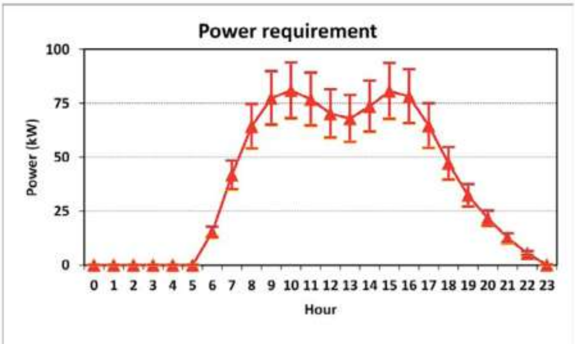

Figure 4: Power requirement for parked EVs recharge

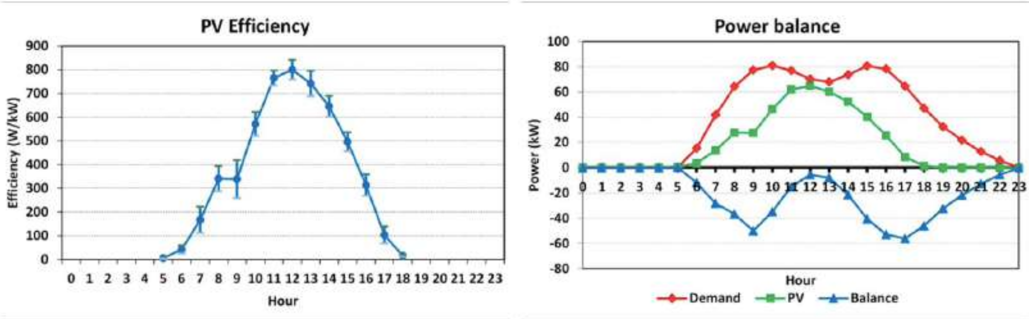

Figure 5: PV efficiency and power balance

An unbalance between demand and supply is deduced due to the lack of renewable energy at times where there is already a high demand for recharge. Therefore, a support from the grid, or from any kind of energy storage included in the system, is needed. Integrating the balance along the day, the required energy from the grid or the storage system can be deduced. To get a sustainable system, two conditions should be met: a) the electricity from the grid, in case this is the supporting system should come from renewable sources (green electricity), and b) there should be an excess of PV generation in order to get a net zero energy balance. This second condition implies an increase in the renewable power to be installed. Figure 6 details the dependence of the electricity balance with the increase factor in the installed power. The conclusion is that at least a factor 2,5 should be applied to the deduced power and, for this case, the PV power to install should be around 200 kW.

Conceptual design was addressed by using HOMER code (HOMER, 2021). According to the considered roof area and the requirement to get a nul energy balance with the grid, different photovoltaic systems in the range 100 to 230 kW, in steps of 5 kWp, were tested. Net zero energy balance for electricity consumption and generation from renewables sources was obtained for 205 kWp. Figure 7 shows an estimation of the contribution from renewable and grid to the demand. There is a clear need for support for the grid, especially during winter time, but the balance is compensated by the renewable surplus during the central daytime up to reach a 100% of renewable contribution for the demand requirement: 330,324 kWh/year and 331,223 kWh/year for demand and renewable generation, respectively. Simulation results provide a cost of electricity (COE) of 0.071 €/kWh for the considered renewable experimental setup which is lower than the reference price of 0.096 €/kWh for electricity supply from the grid. The application of this methodology to an specific building in the UPV (the ETSID building) could be considered using the above mentioned approach, but with a more detailed design; in particular, attention should be given to the variation along the year of the different variables to be taken into account. Actions to be addressed are outlined in table 2.

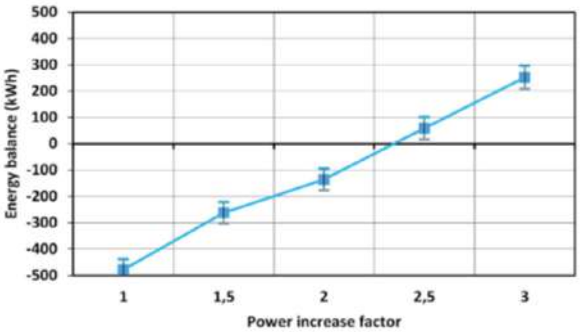

Figure 6: PV power increase needed for net zero

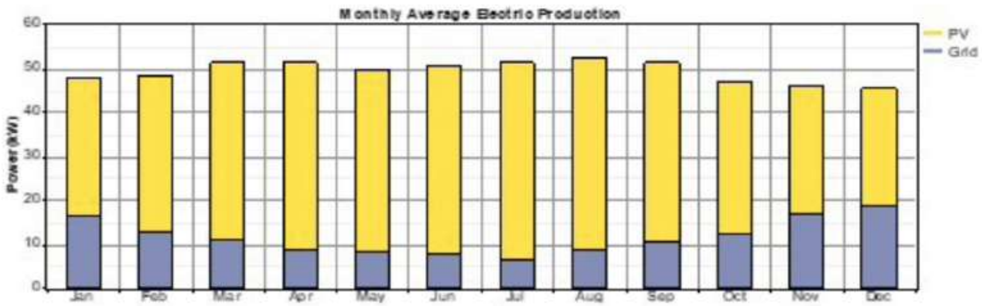

Figure 7: Monthly averaged electric generation

Table 2: Actions in a specific application to an UPV building

Item	Action
EV input and output fluxes	Collect data from central parking services, with 15 minutes time resolution for the different weekdays along the entire year, to deduce the seasonal variations.
Renewable sources	Determine the solar radiation and the wind speeds with time resolution for the different seasons of the year.
Building characteristics	Available space for PV and wind generators in the roof. Connection to the grid and available area for microgrid installation and storage system.
Electricity balance	Installation of metering system for recharge units, connection to the grid and/or storage system and development of the corresponding software.
Economic viability	Detailed analysis of the total cost of the system and revenues from CO_2 emissions and possible charges to the users.

CONCLUSION

Transportation sustainability is an important item to include in the search for university campus sustainability. These campuses are normally constituted by a large number of buildings that are responsible for a high energy demand. Therefore, these buildings could become demonstration sites for new technologies and systems to improve energy efficiency and clean generation, but they can also play a role in the transportation sustainability, by accommodating in their designs the needed recharge systems and the renewable sources to supply them. In this paper, a campus is considered sustainable from the transportation point of view once there are provisions to recharge EVs not only in their displacement inside the campus but also in their movement in both ways between their place of residence and the campus. A methodology to take into account all the requirements for building parking areas to this goal of transport sustainability has been developed and the simulation of its application to the Valencia area, using average values for the entire year, shows that it is possible to recharge the EV needs with the support of the main grid or an storage system, but with a net zero balance by using the surplus of electricity generation in the main hours of the daytime. This implies to increase in a factor 2,5 the nominal power required by the estimated EV recharge demand. Detailed planning for the application of this approach to a specific building in the UPV campus is proposed.

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DESIGN OF A GEOPOLYMER FOR CONSTRUCTION 3D PRINTING

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ABSTRACT

In this research, the mixture designs are exposed to achieve a geopolymer mortar suitable for 3D printing. Both the fresh appearance and the influence on the strength of dosage variations are evaluated to determine a mixture that meets all the requirements for additive manufacturing.

Keywords: 3DCP, 3D Print, geopolymers, asd.

INTRODUCTION

Building with 3D printing is one of the great upgrade opportunities in the construction industry. Likewise, the combination of this technology with the incorporation of low carbon footprint materials such as geopolymers opens the door to sustainability for the entire industry.

PAPER

INTRODUCTION

For the mix design of a geopolymer suitable for 3D printing, the present study focuses on the properties of fresh state and early age, with the aim of establishing if the proposed dosages satisfy the adequate requirements for 3D printing mortar. The

3D printing of mortar has specific requirements that require a high control of the mixture in the fresh state. The tests carried out to determine a mixture of alkaline activation mortar based on slag and soda as a valid activator for such application are detailed below.

METHODOLOGY

In the tests, standardized aggregate and the same type of slag called "ADANA" with Blaine 5000 will be used. The aim is to determine the optimal concentration of soda in relation to slag and the result of the mechanical properties. A capillary water absorption test is also carried out on mortars following the procedure described in the UNE EN 101518 standard.

Table 1. Capillary absorption

SAMPLE	CAPILLARY ABSORPTION (%)
ADANA	6.18
ADANA	6.9

<u>Mix 1</u>

Once the results of the hardened state of mixture 1 have been obtained, the fresh state is analyzed and the early acquisition of resistance is evaluated.

Table 2. Dosage of Mix 1

MATERIAL	DOSAGE (g)
Slag	450
Diss. NAOH (15%) and water	310
Aggregate DIN	1350

The fresh state results, fundamental for 3D printing, are shown in Table 3. It shows the lack of thixotropic property, fundamental for the necessary layer stacking in 3D printing.

Table 3. Fresh state of mix 1

TEST	RESULT
Fluidity	Very high
Thixotropy	Not thixotropic

The resistance results shown in Table 4

Table 4. Resistance results for mix 1

DAYS	FLEX (MPa)	COMPRESSION (MPa)
1 day	1.17	3.43
2 days	2	8.78

3 days	2.43	14.50
5 days	2.64	20.93
7 days	2.97	24.99
28 days	2.90	34.89
90 days	5.57	42.45

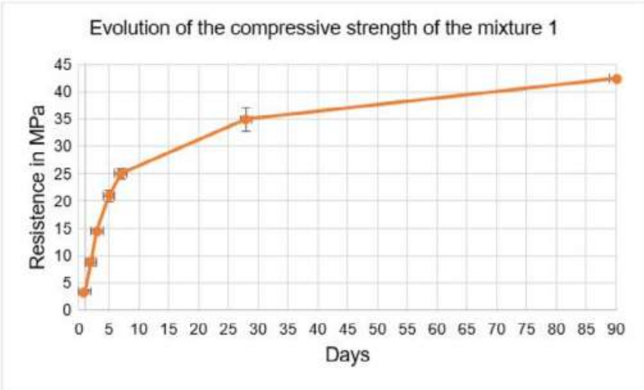

Figure 1. Evolution of the compressive strength 1 of the mixture.

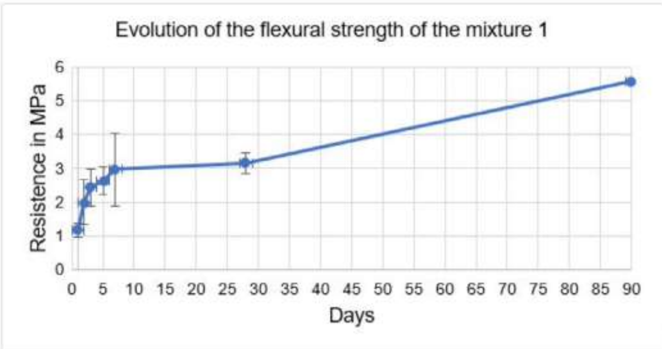

Figure 2. Evolution of the flexural strength of the mixture 1.

The setting time that is shown in Table 5 was determined following the UNE-EN 196-3: 2005 + A1: 2008 standard. The measurements were carried out in a Vicat automatic equipment (Controls Vicamatic, model 63-L0027 / E). This equipment has a metallic needle with a mass of 300 ± 1 g. The equipment performs a total of 26 measurements where the user can program the start time and the time between measurements. In this way, the resistance exerted by the paste immersed in water to the penetration of the metal needle is measured. A 400 g paste was kneaded with the slag for 3 minutes in a Controls Automix kneader (model 65-L0006 / A) according to the UNE EN 196-3 standard.

Table 5. Beginning and end of setting

INITIAL TIME (MIN)	FINAL TIME (MIN)	AT (MIN)
113	238	125

Tests have been carried out to determine the shrinkage of the slag used and of the other 4 slags that were studied. Figure 1 shows the different shrinkage tests carried out on slag samples, including the one used in these tests.

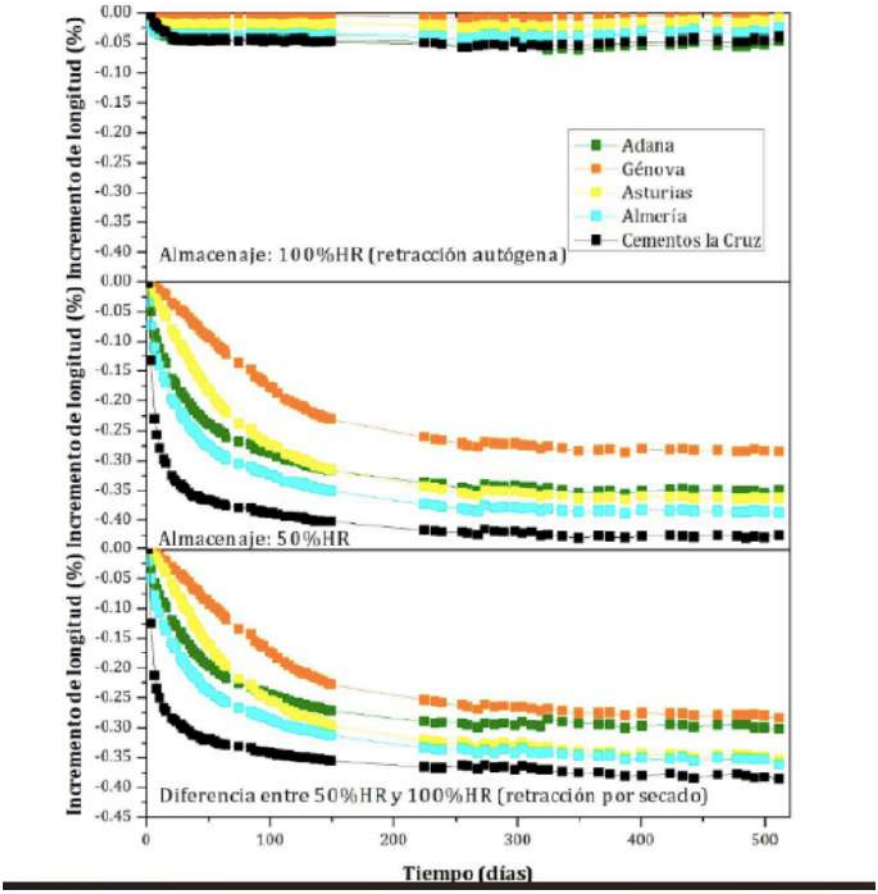

Figure 3. Shrinkage test carried out on different slag samples including ADANA.

Mix 2

Having observed that the fresh state behavior of mixture 1 does not meet the necessary requirements for 3D printing, a second formulation is proposed with the aim of achieving the property of stackability in the sample.

Table 6. Mix 2 dosage

MATERIAL	DOSAGE (G)
Slag	450
Diss. NAOH (15%) and water	250
Aggregate DIN	1350

The fresh state results shown in Table 6 show an improvement in the fresh state behavior in relation to the thixotropic property.

Table 7. Fresh state of mix 2

TEST	RESULT
Fluidity	Good
Thixotropy	Slightly thixotropic

The resistance results shown in Table 7 show an improvement in the resistance of the sample compared to Mix 1.

Table 8. Results of resistance of the mixture 2

DAYS	FLEX (MPa)	COMPRESSION (MPa)
1 day	1.93	7.03
2 days		17.53
3 days	3.17	20.32
5 days		31.3
7 days	4.03	35.19
28 days		46.15

CONCLUSION

It is concluded that the increase in the content of the solution of water with soda directly intervenes in the properties of fresh state and resistance.

An increase of dissolution can improve the properties of fresh state to adapt them to 3D printing, however it produces a direct impact on the reduction of mechanical resistance.

On the other hand, the reduction of water dissolution with activator content improves the mechanical properties modifying the workability of the mixture in a fresh state.

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CURRENT SITUATION AND FUTURE OUTLOOK FOR CONSTRUCTION WASTE IN NEW BUILDINGS

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ABSTRACT

Since construction is one of the oldest trades in the world, so is the waste produced in this industry. However, it was over time that some of these elements started to become a social problem specifically when they began to generate a negative environmental impact. In this article, we review some strategies focused on mitigating environmental damage such as waste regulation, optimization of construction processes, and waste reuse (for construction and non-construction purposes). We will see some examples and difficulties in such strategies to capture a perspective on construction waste in new buildings.

Keywords: Deconstruction, heritage materials, circular economy, heritage conservation, materials life

INTRODUCTION

In its beginnings, the art of building was an activity with little pollution and relatively controlled waste. This is because the materials used, such as stone, did not require complex manufacturing processes and returned to the ground almost identically (Reixach, *et al*., 2000).

However, as society evolved, new materials, construction processes, and building systems were also developed. Therefore, at present, the final disposal of various construction and demolition wastes can generate negative environmental impacts such as soil degradation and erosion, destruction of vegetation, and/or loss of environmental services (Mejía, *et al*., 2015).

Similarly, these wastes have been increasing due to population growth, the pursuit of economic development as well as their mismanagement (Reixach, *et al*., 2000; Pinzón and Cortes, 2019). This leads to the existence of few disposals are as, high management costs, and disposal in places that are not conditioned for this purpose, which occurs particularly in larger cities (Mejía, *et al*., 2015).

The recycling of construction materials indeed occurred long before the concern for the environment began, such as when the Carolingians, the Arabs, the Romanesque, and the Renaissance took advantage of the Roman ruins that existed everywhere to carry out their works (Reixach, *et al*., 2000). Similarly, in some periods the incorporation of substances leftover from other industries (straw, bones, skins) into the construction sector has also been observed (Reixach, *et al*., 2000). This strategy has also worked in the opposite direction when construction waste is used in non-construction processes such as soil bioremediation (Mejía, *et al*., 2015).

However, it has been in recent periods that such strategies, as well as waste management strategies and optimization of construction processes, have been used for environmental purposes, although there are still certain difficulties in their implementation (Reixach, *et al*., 2000; Pinzón and Cortes, 2019; Suárez, *et al*., 2019).

This shows a global trend towards the reduction of the negative impacts of construction waste on the environment, although there is still a need for greater linkage and environmental sensitivity among the different actors involved in the construction process. The circular design of new buildings according to the guidelines recently adopted in the European Union introduce a new vision in the way of building and involves all stakeholders, also opening new horizons in the field of heritage conservation.

Construction waste management

Currently, construction waste can be classified as polluting and non-polluting. In the first instance, the degree of contamination of waste will depend on the:

Use of non-endemic materials

- Complexity of the elaboration of the construction material

- Heterogeneity of elements in the construction system.

We will see that if homogeneous construction systems (with few elements) and endemic materials are used in construction, with a simple or null elaboration process, then we will consider that the waste is non-polluting. An example of this can be found in the ruins of Tulum (see figure 1) located in the state of Quintana Roo, Mexico. It can be seen in the image that the constructions are made of stone joined by mortars (binders with water). The residues from similar works do not hurt the environment.

Figure 1. Ruins of Tulum, Mexico. Author: Jorge Arturo Gutiérrez (2021)

On the other hand, when the construction system is heterogeneous (with several construction elements), non-endemic materials are used and with a complex elaboration process, then the waste is considered polluting.

Today, we note that construction waste from vernacular architecture generates minimal or no impact on the environment, while for polluting waste there are various strategies to mitigate the negative impact they generate on the environment. These solutions can be classified as follows:

- Regulation of waste management (either by legal norms or by management plans).

- Waste reduction through the optimization of construction processes.

- Reuse of waste for construction purposes

- Reuse of waste for non-constructive purposes.

In the first case, mention is made of local standards in different countries (such as NOM-161-SEMARNAT-2011 in Mexico), as well as some international standards such as ISO-14001 applicable to companies in the construction sector and referring to the minimization of impacts on the environment and compliance with current environmental legislation.

In the same vein, some authors have made efforts to diagnose the management of construction waste, as in the case of Serraglio and Acevedo, in 2020, who made a spatial analysis of the deposits in Presidente Bernardes, Brazil. Or, as in the case of Suarez *et al*. in 2019, who analyze management instruments in the city of Villavicencio in Colombia.

However, and despite the above, in some places, there is still no clear perception about the responsibility that should be assumed regarding the management of construction and demolition waste to reduce the impact that this type of material causes on the natural environment (Reixach, *et al*., 2000; Pinzón and Cortes, 2019; Suárez, *et al*., 2019). The above brings as a consequence that there is little linkage between what the State establishes and what society executes, as mentioned by Pinzón in 2019 about his study in Guamo, Republic of Colombia.

Other reasons why this set of strategies are not widely disseminated are related, as Tam (2007) mentions, to low financial incentives, increased overhead, low disposal costs, and the growth of a competitive market.

Other authors instead, propose to reduce the volume of waste, through the improvement of construction processes (Halliday, 2008). To this end, Bravo *et al*. (2019) propose quantifying such waste which also impacts the economic category. In turn, these authors identify that the most influential waste generation in their case study in Chile is found in the finishing phase (being the predominant waste of this item the partitions at 84%) which exceeds by 3.56 times that of rough work (where concrete predominates as waste material in the item with 91%).

Regarding the reuse of elements, there are initiatives to identify the potential reuse of waste. Such is the case of Chica and Beltrán (2018), who in the city of Medellín defined it for excavation and masonry waste in a soil-cement slab made up of 95% of such materials; or the case of Santos (2012) who uses marble waste as filler for the production of concrete and as a base for the manufacture of bricks (Santos, ét. al., 2012).

The use of waste for the manufacture of others has also been seen in the proposal of Valdés, who uses recycled aggregates from the manufacture of concrete for new materials (Valdés ét. al., 2011). And although they mention a 13% lower resistance compared to blocks without recycled materials, it is a good alternative to mitigate environmental damage.

There is also a recommendation to use granulated foundry slag as a substitute for part of the cement in concrete (Ceccato, *et al*., 2009). In addition, waste from other industries, such as sludge from the paper industry, has already been used to produce prefabricated panels for construction (Quinchia, *et al*., 2007). Similarly, various construction systems have emerged that facilitate the assembly/disassembly of their elements to avoid demolition waste and facilitate their reuse elsewhere. As an example, we cite masonry without mortar joints, designed to facilitate their placement from one site to another (Gutiérrez 2012 and 2015).

On the other hand, some authors have found potential uses for waste in industries other than construction. For example, Mejía suggests that construction and demolition wastes have a high potential to be used in the bioremediation of land degraded by mining, due to their mineral content (calcium, magnesium, iron, manganese, copper, zinc, and nickel) in addition to the fact that they can provide benefits to plants due to their sodium, silicon and copper content (Mejía, *et al*., 2015). From the above, we perceive that despite the alarming levels of pollution, there is a global trend to mitigate the negative impacts of construction and demolition waste on the environment. These trends range from initiatives, projects, construction proposals, and detailed analysis in the management and construction process. However, there is still work to be done to coordinate efforts among the actors involved in construction, as well as to promote sensitivity and awareness of the impact caused by these wastes to find more and better alternatives.

The circular construction design: an innovative strategy for sustainable construction

Sustainable development is the challenge of the new millennium to meet the needs of the present and guarantee future generations the same opportunities for growth as in the present. Sustainability implies the recognition of a set of inviolable values of human action revolving around environmental protection, economic growth, and social equity, the so-called three pillars of sustainability, necessary to provide prosperity, means, and concrete opportunities for progress to all peoples of the earth [Borowy, 2014].

More than thirty years after its implementation on a global scale since the publication in 1997 of the Bruntland Report of the World Commission on Environment and

Development, sustainable development remains an unfinished business that has too often been reduced to sterile sectoral policies aimed at environmental protection in the face of the growing needs of the productive sector. In reality, sustainability requires a holistic vision that is capable of capturing the interrelationships between economic development, protection of the natural environment and social justice, and the involvement of all components of society (governments, institutions, associations) and every citizen. To implement this ambitious program requires a radical change of the current economic and social paradigms based on the linear economy scheme of take-produce-use-throw away and adopt new circular economy models capable of self-regenerating as natural cycles and proceeding to infinity with finite resources [Ellen Macarthur Foundation, 2010].

In the circular economy, waste generation is minimized and the value of products and their materials is maintained as long as possible through an exchange, repair, reuse, and recycling. As in the natural cycles of the ecosystem, the extraction and disposal phases are eliminated thanks to the circularity of the use of objects which, if they are no longer repairable or reusable, become secondary raw materials for the production of new objects. Recognizing the value of the objects around us is the basic premise of the circularity of the economy. This capacity for discernment allows us to transform a waste that is nothing more than a material that has lost its function or whose function is no longer useful in the changing needs of contemporary society into a new material that can satisfy new needs.

The fuzzy boundary between material and waste depends on the elements of knowledge of who judges the value of the object that can become waste in the absence of its use or material in the hypothesis of reuse or recycling. The methodological approach to knowledge of the objects around us required by the circular economy has profound similarities with the approach of conservation science that acquires a range of information with different scales of detail and different disciplinary skills to assess the uniqueness of material heritage. In both cases, the deeper the knowledge of the asset, the greater the possibility of extending its life and regenerating its value. The construction sector is one of the main sectors in the economic and social development of nations, with a huge impact on the environment. On a global scale, it consumes on average more than half of the natural raw materials extracted annually, generates more than one-third of the total amount of waste, and contributes around 10% to the annual emission of greenhouse gases [Kaza *et al*, 2018]. In February 2020, as part of the European Green Pact actions, the European Commission drafted a document outlining guidelines for circular design to reduce construction and demolition waste, optimizing the use of materials, and reducing the environmental impact of the construction sector [European Commission, 2020].

The priority objectives of circular design are durability, adaptability, and waste reduction, and recovery. Durability extends the life cycle of buildings through the use of building systems and materials that can be easily maintained, repaired, and replaced. Adaptability requires the development of a new design culture capable of anticipating changes in needs, planning adaptations and transformations of spaces for better use and reuse of the building and each of its components. The reduction and valorization of waste promote design, construction, and deconstruction processes capable of preserving the value of materials at the end of a building's useful life and allowing their reuse with minimum energy consumption and minimum waste production according to the practice of up-cycling. The building, like all man-made objects, should be conceived as an organic whole of functional parts, which can be broken down into the individual materials of which they are made, which individually contribute to determining the sustainability of the whole building.

In circular design, materials must be easy to assemble to enable a rapid construction process and, at the same time, they must be easy to disassemble so that they can be easily deconstructed at the end of the building's useful life. Unlike demolition, deconstruction does not produce waste, but rather architectural components that can be reused in new construction. BIM (Building Information Modeling) is the strategic tool to support the sustainability of the design, execution, and management of circular construction [Green Building Council Italy, 2020]. BIM design conveys all the information flow necessary to elaborate a kind of passport of the construction, its components and materials according to a functional hierarchical breakdown to the de-construction and reuse processes in the value chain. The passport reports as generalities the initial performance characteristics and updates them throughout the life cycle by making "visas" indicating transformations and variations of functions and performances. Tracking the origin and technical characteristics of each building material gives an identity to each building component that at the end of its life becomes a repository of materials opening urban mining scenarios that safeguard natural resources and reduce the amount of demolition debris [BAMB,2020].

Integration between heritage conservation and sustainable construction

Sustainable development also calls for reflection in the field of heritage conservation. According to the current scientific approach to restoration, the historical and artistic value of the construction must be preserved by conserving the materials of which it is made according to the criteria of minimal intervention, compatibility, reversibility, and recognizability [Torsello, 2018]. The knowledge of materials and construction techniques is functional only to maintain the epiphany of the image of the building, whose value remains rigidly anchored according to the criterion of hic et Nunc to the place and time of construction [Bernardo, 2018]. However, the widespread degradation of heritage, in many cases reduced to the state of collapsed buildings or ruins, together with the awareness of the scarcity of resources give the materials of which the construction is composed an intrinsic value that goes beyond keeping the construction alive. Circular design makes it possible to reformulate the connections between construction and the life of materials, which neither begins nor ends with their use in specific buildings or places.

The reuse of heritage materials allows the loss of construction to be transformed into a potential gain, overcoming the timeline and confinement of place in a continuous history of use, deconstruction, and reuse. Construction that is no longer salvageable becomes an urban quarry of materials that have even greater value than newly produced materials as part of tangible heritage. The circularity of materials reduces the amount of demolition debris and encourages economies of scale based on the recycling and valorization of architectural heritage materials. An innovative example of recycling of built heritage materials is the spin-off Opalis (an anagram of the word spolia) of the Belgian company Rotor DC, which has created a digital inventory of materials recovered from dilapidated Modern Movement buildings [Rotor DC, 2012]. Recycling architectural heritage materials can also stimulate the creative design of new sustainable buildings. The Resource Rows residential complex, designed by architect Anders Lendager in the city of Copenhagen, is one of the most striking examples. The façade of the complex was built by reusing masonry panels from the deconstruction of the city's Carlsberg brewery industrial complex (Fig.2).

Another example of reuse of heritage materials that deserves special mention is the C. K. Choi, Asian Research Institute on the campus of the University of British Columbia in Vancouver, Canada. The building was constructed in 1996 to a design by Matsuzaki Wright Architects and is known for being one of the first green buildings in Canada to receive several awards for resource efficiency and energy conservation. The building consists of five identical blocks with curved roofs reminiscent of Asian architectural forms and large glazed surfaces that provide natural light to the interior spaces (Fig. 3).

In a recent article, Susan M. Ross highlighted one of the lesser-known sustainability aspects of the C.K. Choi building design [Ross, 2020]. The building's load-bearing structure of solid brick and wood masonry was constructed entirely of recycled materials. Bricks from demolition sites in the city of Vancouver were used for the masonry. The wood structural elements were salvaged from the deconstruction of the adjacent 1941 Armory building owned by the university, which once housed students during military service (Fig. 4). The technical characteristics and state of preservation of the wooden truss structure of the Armory were evaluated before the deconstruction of the building. The results obtained in the preliminary investigation conditioned the design of the C.K. Choi Building, which salvaged most of the timber structural elements with a pioneering experiment in up-cycling of heritage materials (Fig.5). The reuse of the wooden beams from the Armory in the construction of the Asian Research Institute also has the value of redress of the grievance suffered by the Japanese Canadian students who lost their student status with Japan's entry into World War II.

Figure 2. Patchwork facade of the Resource Rows residential complex (built with masonry panels obtained from the deconstruction of the Carlsberg Brewery, Copenhagen, Denmark). Photo by Mikkel Strange.
Source. https://www.theguardian.com/cities/2020/jan/13/the-case-for-never-demolishing-another-building (2021)

Figure 3. C. K. Choi Building, Asian Research Institute on the Campus of the University of British Columbia in Vancouver, Canada.
Author: Liliana Colmenero F. (2021)

Figure 4. C. K. Choi Building, Asian Research Institute on the Campus of the University of British Columbia in Vancouver, Canada.
Author: Liliana Colmenero F. (2021)

Figure 5. Wooden beams of the former University of British Columbia Armoury
Source: Ross, (2020).

Figure 6. Interior of the C.K. Choi Building showing the use of wood components from the former Armory for structural purposes
Source: Ross, (2020).

CONCLUSION

It can be observed that throughout history there has always been construction waste; however, it has been more recent that such waste is having negative impacts on the environment due to the heterogeneity of the elements in a construction system, the use of non-endemic materials and complex manufacturing. Currently, environmental solutions have been sought that we can classify as waste reduction (either through normative regulations or through the optimization of materials) and the reuse of the elements (either for constructive or non-constructive purposes).

In perspective, and despite the alarming levels of pollution, there is a tendency for society to become aware of the importance of the proper management of construction waste and to coordinate its efforts to make the best possible use of it. However, it is still necessary that there is a link between the different actors involved in the construction process and that they in turn are endowed with sensitivity, knowledge and coordination capacity for the proper treatment of construction waste. The circular design of buildings introduces a new vision of construction that is reduced to a set of functional components and parts, easily assembled and disassembled. The digitization of information supported by BIM makes it possible to create a passport for the building and the individual materials that compose it, in which all the performance characteristics and transformations undergone during the entire life cycle are recorded.

The digital identity of materials together with innovative deconstruction practices make it possible to extend the life of materials beyond the useful life of the building, which at the end of its life becomes a source of materials for new construction. The cyclic regeneration of the material maintains its initial value with minimal energy requirement and minimal waste generation according to the good practice of up-cycling. The extension of the useful life of materials in circular design allows the integration of the needs of architectural heritage conservation and sustainable construction. The architectural heritage in ruins can become a source of materials for the creative design of new sustainable buildings according to a new transversal ethic of conservation and sustainability based on the mitigation of resource consumption and the reduction of the amount of demolition waste.

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EDILIZIA ECOSOSTENIBILE: L'USO INTELLIGENTE DI PANNELLI DECORATIVI CON MATERIALI RICICLABILI

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ABSTRACT

Al giorno d'oggi il settore edile deve affrontare un'importante sfida: saper gestire l'intero patrimonio edilizio presente nel mondo; negli ultimi anni, infatti, non si è stati in grado di rispettare i requisiti minimi per avere un ambiente ecosostenibile e funzionale, avvalendosi, inoltre, del continuo sviluppo della tecnologia e dell'innovazione. Ormai da qualche decennio l'uso di alcuni materiali ha contribuito all'incremento dell'inquinamento, al tempo stesso le analisi condotte in modo innovativo dei materiali PIÙ COMUNI, la produzione di nuovi, il riuso attraverso il riciclo (in alcuni casi parziale in altri totale), hanno aperto prospettive che coniugano ecologia, tecnologia e sicurezza.

Keywords: Sustainable Construction; Decorative panels; Building Recycling; Innovation; Green building.

INTRODUCTION

L'idea fondante è quella di offrire un contributo di studio all'analisi di alcuni materiali utilizzati per la produzione di pannelli decorativi, suscettibili di riutilizzo, una volta concluso il loro ciclo di vita; tutto ciò nasce dalla constatazione di un ripetuto impiego di materie prime non sfruttate adeguatamente e di un utilizzo controproducente di risorse non rinnovabili, nocive per l'ambiente e per l'ecosistema. Lo scopo dei pannelli di finitura è di personalizzare l'aspetto dell'involucro edilizio ottenendo effetti estetici creativi, difficili da proporre con il tradizionale intonaco. I prodotti ed i materiali da rivestimento devono sì garantire un buon impatto visivo, ma devono anche rispettare requisiti minimi indispensabili nei confronti degli agenti atmosferici (raggi solari, pioggia, umidità, gelo, calore) fino alle intemperie, della corrosione, del fuoco, garantendo longevità fisica e meccanica, con limitate operazioni di manutenzione e pulizia, e semplificazione degli eventuali interventi di riparazione; a tutte queste caratteristiche oggi necessariamente si affianca quella della sostenibilità, che si esplica anche attraverso l'uso di materiali riciclati, riciclabili epossibilmente leggeri. Un rivestimento di facciata avrà un notevole impatto architettonico, carattereizzando fortemente l'edificio, ma soprattutto un grande impatto ambientale. E' possibile scegliere diverse soluzioni di rivestimenti di origine vegetale (legno, sughero, BAMBÙ), minerale naturale (pietra), artificiale (ceramica, vetro, alluminio), sintetica (plastica), a cui dobbiamo aggiungere materiali innovativi come polimeri naturali, Etfe e materiali biomimetici.

Per esplicitare in forma comparativa,le prestazioni principali dei materiali qui analizzati è stata predisposta un tabella comprendente: origine (naturale, artificiale e riciclato); durabilità (secondo la EN 350); peso proprio (unità di misura); messa in opera (facile, media e difficile); certificazione (FSC, EPD, C2C, LEED, CE, BREEAM, ecc.); classe di utilizzo (secondo la EN 335); resistenza al fuoco (D.M. 26/06/1984, EN 13501-1 da A a F); riciclabilità a fine vita(%) e costo (m^2).

Rivestimenti decorativi per esterni

<u>Legno</u>

La grande lavorabilità e le ottime caratteristiche meccaniche e fisiche del legno portano questo materiale ad essere adatto come elemento costruttivo naturale, tradizionale ed universale, attribuendo però la dovuta importanza alla scelta dei trattamenti, che varia anche a seconda del tipo di legno utilizzato. L'azienda Parklex ha ideato un rivestimento di fibre di legno naturale, la cui superficie, impregnata di resine termoindurenti, viene pressata ad alta pressione e temperatura, dando così forma ad un pannello. Il colore deriva dal tipo di legno utilizzato per cui la scelta del progettista risulta derivante dalla tonalità del colore che preferisce (bambù, ciliegio, eucalipto, faggio, acero, noce, rovere, ecc...).

Il pannello della Parklex configura un'efficiente soluzione bioclimatica: isolamento termico, drenaggio dell'umidità e, in base alla posa, anche ventilazione adeguata all'edificio, riducendo inoltre la dissipazione del calore nei mesi più freddi e l'assorbimento del calore nei mesi più caldi, il tutto a vantaggio di un netto miglioramento del comfort a vocazione passiva (Fig. 1).

Figure 1. Strati del Parklex La Alhambra Information Points, Granada, Spagna Vanke Exhibition Center in Bayuquan.

Sughero

Il sughero, materiale che era già in utilizzo nell'antichità, oggi viene preferito nell'ambito di un'edilizia bio-compostabile, anche nella realizzazione di pannelli decorativi. Il primo impiego con forti valenze architettoniche del sughero in faccia a vista risale all'anno 2000, in occasione dell'Expo di Hannover, Alvaro Siza Vieira e Eduardo Souto de Moura progettarono il padiglione del Portogallo interamente rivestito di sughero espanso; negli anni è stato in continuo aumento il ricorso a questi pannelli poiché in grado di rispettare i requisiti minimi per avere un ambiente ecosostenibile sfruttando tutti i vantaggi intrinseci del materiale.

L'Amorim Cork Insulation è un'azienda portoghese che produce pannelli in sughero espanso definiti "CORKPAN MD FACCIATA"; risultato del processo termico di espansione, che permette di agglomerare i granuli tramite la fusione della suberina e delle altre sostanze cerose contenute nel sughero, che fungono da collante naturale. Il processo di espansione, completamente naturale, non altera in alcun modo le caratteristiche del sughero, ma le amplifica, determinando l'aumento del volume del singolo granulo e il miglioramento del suo potere coibente di circa il 30%. La struttura del pannello di sughero si presenta permeabile al vapore, ma insensibile ad acqua e umidità, queste caratteristiche gli conferiscono una stabilità dimensionale ed una discreta longevità nonostante le condizioni atmosferiche. La facciata dell'edificio, durante la sua vita, potrà assumere tonalità differenti, in funzione del microclima del luogo in cui viene installato il pannello, infatti sarà possibile notare differenze di tonalità anche tra le facciate dell'edificio, a causa della diversa esposizione alla luce solare; in generale, si è notato che il pannello di sughero, soggetto all'azione delle intemperie, tende ad assumere una tonalità più scura, mentre, soggetto alla luce intensa del sole ed in climi più asciutti, assumerà tonalità più chiare.

In Sicilia, in provincia di Ragusa, è stata, ad esempio, progettata e realizzata, "Villa Nemini Teneri", costruita sulla base di un progetto firmato dall'architetto Giovanni Benedetti in collaborazione con lo studio Errante Architetture e lo studio Darch2 dell'architetto Danilo Demaio, in un'oasi biosostenibile a misura d'uomo e di ambiente, dove vivere ad impatto zero (Fig. 2). Questa villa siciliana si presenta con l'intera superficie esterna rivestita di pannelli di sughero "CORKPAN MD FACCIATA", montati uno accanto all'altro. In questo modo l'edificio appare come un'unica costruzione, continua, termoisolante e fonoassorbente.

Altro esempio di struttura rivestita in sughero è il "Centro di Formazione di Ginnastica di Guimaraes", Portogallo, realizzato da Pitagorasgroup. Da questo edificio, ideato nel rispetto dell'ambiente e ad alta efficienza energetica, traspare un chiaro equilibrio tra tecnologia e architettura. Tutte e quattro le facciate sono composte da pannelli in sughero scuro, provviste di aperture con vetro a specchio dalla forma quadrata o rettangolare; i pannelli, collocati in un gioco di pieni e vuoti, conferiscono alla facciata una non linearità e una discontinuità in grado di accentuare un equilibrio dinamico tra la struttura ed il contesto ambientale circostante, rendendo il tutto fortemente caratterizzato e quasi "reciprocamente" sostenibile (Fig. 3).

Figure 2. Villa Nemini Teneri, Ragusa, Sicilia

Figure 3. Centro di Formazione di Ginnastica di Guimaraes, Portogallo

Bambù

Il bambù è utilizzato in bioedilizia, anche al di fuori del territorio asiatico, per la sua capacità traspirante,. In Italia esistono edifici che si sono avvalsi di questo esotico materiale, come ad esempio a Milano, nel Business District della Certosa; infatti l'edificio destinato agli uffici, commissionato dallo STAM Europe a Goring & Straja, presenta canne di bambù posizionate verticalmente lungo la facciata. Il bambù, come materiale cardine di questa architettura, trova le sue fondamenta nel forte significato simbolico che lo contraddistingue sia nella tradizione culturale cinese che in quella giapponese; inoltre, per le sue peculiari caratteristiche intrinseche, non necessita di alcun tipo di modifica o di lavorazione prima di essere usato come materiale edilizio (Fig. 4).

Proprio dalla tradizione giapponese e ispirandosi alla struttura del bambù, ha preso vita, nell'architettura contemporanea, una particolare soluzione al problema dell'isolamento dal calore esterno, definita successivamente con il termine "Bioskin", pelle biologica. Ottimizzata e resa efficiente dallo studio Nikken Sekkei per la nuova sede della Sony City Osaki a Tokyo, riceve il premio al World Architecture Festival 2012 nella categoria "Production, Energy and Recycling". All'edificio di quasi 30 piani nel cuore della città di Tokyo è stata applicata nel rivestimento esterno una vera e propria rete di piccoli tubi di ceramica porosi, che mediante un apposito sistema di raccolta posto sul tetto dell'edificio, permettono all'acqua piovana di fungere da isolante termico naturale; infatti il calore irradiato dal sole sulle pareti dell'edificio porta questa "barriera d'acqua" ad evaporare consentendo una riduzione della temperatura interna dell'edificio fino a 2° C, abbattendo, inoltre, il consumo energetico dovuto all'utilizzo dei sistemi di condizionamento dell'aria e, di conseguenza, le emissioni di CO_2.

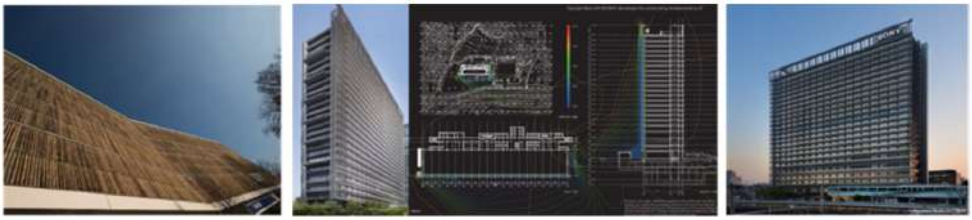

Figure 4. Lo STAM Europe a Milano presenta canne di bambù su tutta la facciata La Bioskin ispirata al bambù nel Sony City Osaki a Tokyo.

Pietra

La pietra esiste come tale in natura; è il materiale privilegiato per la realizzazione di opere in armonia con l'ecosistema, soddisfa i requisiti richiesti dalla bio-architettura, essendo atossica, perché salvo poche eccezioni, non rilascia vapori, gas, esalazioni, fumi o polveri sottili nell'ambiente e non favorisce lo sviluppo e il rilascio di muffe e microorganismi, batteri, funghi; non è infiammabile e rientra nella classe A1 di reazione al fuoco dei materiali edili (UNI EN 13501-1) poiché in caso di incendio non propaga né alimenta fiamme e non emette sostanze nocive e/o dannose.

La pietra è riciclabile (all'infinito) e in caso di smaltimento per demolizioni e/o disassemblaggi può essere recuperata e recuperata; tuttavia le estrazioni dei minerali, legate ad una grande varietà geologica, risultano attività con impatti molto elevati sulla salute degli abitanti e dell'ambiente. Tutti i siti estrattivi che sfruttano un giacimento di sostanza minerale, seguono la legge ai sensi del Regio Decreto 1443/1927, così da regolamentare le attività antropiche, come la frequenza e la dimensione fisica dei prelievi, che possono rischiare di alterare lo stato delle componenti ambientali e le caratteristiche del territorio circostante, (cfr. Legge n. 431 del 4 agosto 1985, nota come Legge Galasso). La pietra naturale è impiegata in diversi settori dell'edilizia, distinguendosi come elemento che rispecchia perfettamente il concetto di durabilità nel tempo, tuttavia, allo stesso tempo, può presentare significative limitazioni, due su tutte il proprio peso e lo smaltimento; ed è proprio per ovviare a questi due difetti che trovano spazio gli studi e le analisi di alcune aziende in cerca di innovazione.

L'azienda Remax "Petra Light" e la Marconi, ad esempio, producono un innovativo pannello costituito da una lastra di pietra naturale di soli 5 mm che, accoppiata ad un supporto leggero e composito, permette di ottenere un peso fino ad un terzo di quello che avrebbe un tradizionale pannello in pietra massiccia del medesimo spessore complessivo del pannello; è realizzabile con varie tipologie di marmo, granito, travertino, onice e pietra in genere, senza compromettere qualità estetica e durabilità.

Altro materiale innovativo è il "D-Layer", una "pellicola" in pietra poco più spessa di 2 millimetri che, per il sistema di produzione, risulta adattabile a qualsiasi superficie. Viene fornito in rotoli come carta da parati e applicato su pannelli con apposite colle e finiture protettive superficiali, e può essere utilizzato anche per esterni. E' composto da un film di "polvere di pietra" applicato su un supporto di fibre naturali fissato con resine acriliche, la materia prima è dunque il materiale di scarto della lavorazione dell'arenaria, che normalmente verrebbe buttato (Fig. 5).

Figure 5. Stratificazione del pannello Petra Light; pellicola in pietra D-Layer.

<u>Bioplastica</u>

La Bioplastica è un materiale composto, interamente o in parte, da biomassa organica, invece che dalle tradizionali molecole derivanti dal petrolio; tra le materie prime rinnovabili più utilizzate per la produzione di bioplastica troviamo l'amido e la cellulosa, ricavati dal mais e dalla canna da zucchero, comunque, esistono molte altre opzioni tra le quali scegliere, per esempio, nel 2013 Elif Bilgin, vinse un premio per aver creato bioplastica dalla buccia della banana; come esistono altre risorse rinnovabili, quali la buccia del mango o delle patate utilizzate in Europa per sviluppare nuove tipologie di packaging nel settore alimentare. I polimeri plastici "bio" possono anche essere impiegati in applicazioni di livello ingegneristico, come negli involucri degli accessori elettrici ed elettronici, o per la produzione di pannelli decorativi in edilizia.

In edilizia un team di professori e studenti del ITKE, del Dipartimento di Strutture e Costruzioni della Facoltà di Architettura dell'Università di Stoccarda, supportato dal EFRE (European Fund for Regional Development), nell'ambito del Research Project Bioplastic Facade, hanno sviluppato un prototipo di pannelli decorativi per facciata totalmente riciclabili, realizzati proprio con un materiale in bioplastica, che contiene più del 90% di composti riciclabili (Fig. 6).

I granuli di bioplastica sono estrusi in lastre, mediante il procedimento della termoformatura; le lastre possono essere ulteriormente elaborate in base alle singole esigenze per ottenere superfici e strutture anche di notevole complessità, in questo caso vengono rivestiti con pannelli tetraedrici la struttura reticolare sottostante; la forma complessa è realizzata collegando tra loro i tetraedri con anelli di rinforzo e travicelli. Un'ulteriore caratteristica di questo materiale è che a fine vita può essere riutilizzato o smaltito tramite compostaggio.

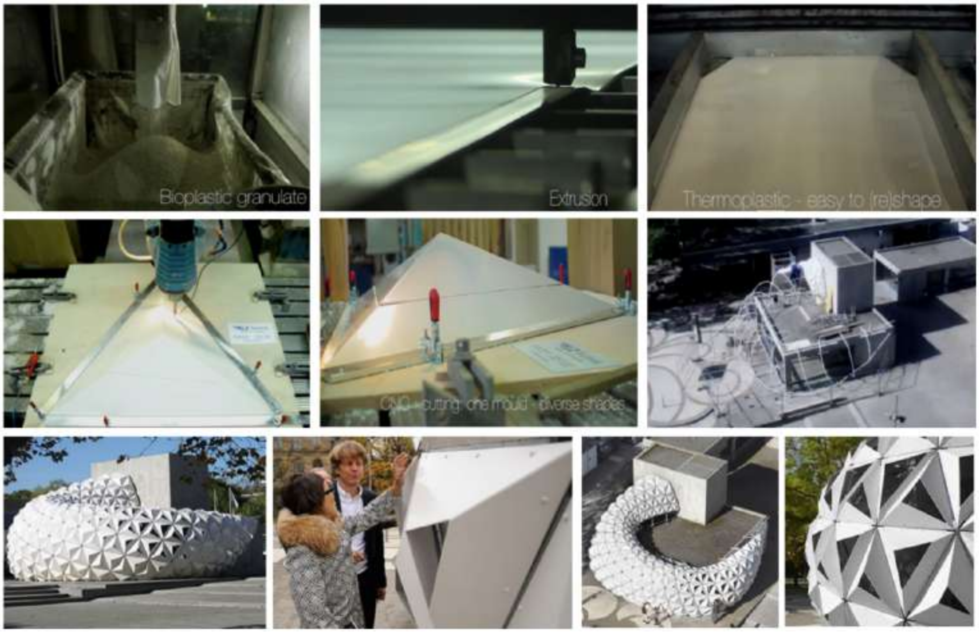

Figure 6. Durable and Recyclable Bioplastics Facade Mock-Up, Stuttgart 2013

Etfe (Etilene – Tetrafluoroetilene)

L'etilene tetrafluoroetilene (ETFE) si presenta come un polimero (un aggregato esteso di entità molecolari di dimensioni inferiori) scoperto negli anni 40 un po' per caso; le sue molecole si ottengono da una reazione radicalica tra fluoro e etilene, il più semplice tra i composti organici contenenti un doppio legame. Il processo di sintesi è a base d'acqua, non richiede l'utilizzo di solventi chimici, né di derivati del petrolio ed è in accordo persino con le regole sancite dal Trattato di Montreal, questo vuol dire che non rientra tra i materiali che danneggiano lo strato di ozono atmosferico. Quando il suo ciclo di utilizzo è terminato la membrana viene fusa e riutilizzata ottenendo così una percentuale di riciclaggio del 100%. L'etilene tetrafluoroetilene ha molte caratteristiche che permettono il suo utilizzo in edilizia, per esempio, il legame tra carbonio e fluoro è un legame chimico molto energetico, questo vuol dire che risulta poco reattivo e quindi molto stabile, questa proprietà gli permette di conservarsi inalterato anche per 30 anni. Un'altra dote fondamentale è la quasi trasparenza nei confronti dei raggi solari perché non interagiscono con i legami che tengono unito il polimero e passano quindi quasi indisturbati. E' considerato un ottimo isolante termico perciò, in genere, si osserva un importante abbassamento dei costi energetici dovuti al mantenimento delle strutture quando l'ETFE viene adoperato; la presenza del fluoro nella struttura del polimero fornisce un aiuto nei confronti degli incendi, infatti se il materiale viene a contato con fiamme vive non le fa propagare, anzi tende a spegnere l'incendio in autonomia. L' ETFE è già presente sul mercato ed utilizzato in molte strutture in tutto il mondo.

Uno degli edifici più famosi che è stato costruito impiegando tale polimero è l'Allianz Arena, stadio della città di Monaco di Baviera, in Germania,dove per la facciata sono stati usati dei cuscini di ETFE che si possono riempire d'aria, in quantità variabile, in base alle necessità climatiche; sfruttando delle pompe, per migliorare l'isolamento termico (Fig. 9). Un altro esempio sono le due facciate dinamiche e a risparmio energetico dell'edificio Media-Tic, situato nel cuore del Distretto 22@ a Barcellona e progettato dall'architetto spagnolo Enric Ruiz-Geli; una facciata si presenta con un singolo livello di pannelli imbottiti, con all'interno una miscela di azoto per filtrare i raggi solari; l'altro prospetto è caratterizzato da uno sviluppo tridimensionale di pannelli prismatici ugualmente imbottiti e ancorati su una rete in acciaio che riveste la struttura. Grazie a dei sensori e ad una tecnologia digitale le tre camere d'aria all'interno di ogni cuscinetto di ETFE funzionano come un diaframma che tramite dei sensori calcola il calore e l'angolatura solare per regolare la schermatura e l'isolamento termico (Fig. 7).

Figure 7. Allianz Arena, Monaco di Baviera, in Germania; Media-Tic, Distretto 22@, Barcellona, Arch. Enric Ruiz-Geli.

<u>Materiale Biomimetico</u>

La biomimetica, la potremmo definire come un'applicazione delle nuove tecnologie allo studio della biologia al fine di produrre materiali e strutture ispirati agli organismi e agli ecosistemi. Non una semplice copia, quindi, né tantomeno un'impostazione estetica, di design, ma un vero e proprio modo nuovo di intendere l'architettura e l'edilizia, senza prescindere dalla salvaguardia dell'ambiente e del clima da un lato e dalla sostenibilità energetica dall'altro. Nell'edilizia sono state fatte alcune sperimentazioni: Chao Chen, studente del Master in Product Design al Royal College of Arts di Londra, racconta di aver avuto una specie di fulminazione osservando come reagivano le pigne di Hyde Park sotto la pioggia. Infatti, una volta che le gocce d'acqua entrano in contatto con la superficie delle pigne, queste allungano il guscio esterno per proteggere i pinoli. Su questa osservazione, Chen ha ideato un materiale laminato, che potrebbe essere utilizzato per le facciate, come elemento sia decorativo che funzionale, che reagisce a contatto con l'acqua e modifica la sua forma naturalmente, senza il bisogno di alcun sistema elettronico o meccanico. Le fibre si espandono a contatto con l'acqua distendendosi e, in questo modo, si forma una superficie che allungandosi o incurvandosi si apre e si chiude a seconda dell'intensità della pioggia, tuttavia è ancora in fase di sperimentazione poiché è necessario infatti verificare prima la resistenza del materiale ai venti o il numero di volte in cui può rimanere a contatto con l'acqua (Fig. 8).

L'architetto Menges Achim di Stoccarda, con il contributo dei colleghi Steffen Reichert e Oliver David Krieg, è riuscito a mettere a punto due strutture metereosensitive, Hygroskin e Hygroscope, semplicemente sfruttando le proprietà naturali del legno attraverso la biomimetica. Attraverso l'igroscopicità (la capacità degli oggetti di assorbire o cedere umidità dall'ambiente circostante a seconda della necessità dell'oggetto stesso) nel caso di Hygroskin, in mostra permanente presso il Frac Centre di Orleans, che attraverso questa caratteristica permette di autoregolare i livelli di umidità interna senza alcun tipo di aiuto tecnologico o umano. L'involucro è stato realizzato sovrapponendo ad una struttura in acciaio una serie di pannelli lignei in abete rosso, tagliati da una stampante 3D laser, nella cui parte centrale sono stati collocati dei sottilissimi fogli triangolari in legno, che vanno a formare delle aperture, cuore pulsante della biomimetica del padiglione.

Il secondo progetto è stato soprannominato Hygroscope e si trova in mostra permanente al Centre Pompidou di Parigi, dove sono state create due copie identiche rispettivamente inserite all'interno di due teche in vetro: una al cui interno sono riprodotte con esattezza le condizioni climatiche di Parigi; mentre nella seconda è riprodotto lo stesso microclima del museo in base all'umidità emanata dal numero di visitatori (Fig. 9).

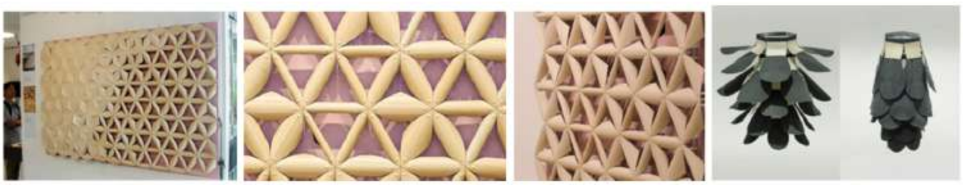

Figure 8. Materiale laminato biomimetico, Chao Chen.

Figure 9. Hygroskin, Frac Centre di Orleans, Francia Hygroscope, Centre Pompidou di Parigi, Francia.

Tabela comparativa

		Legno	Sughero	Bambù	Pietra Alleggerita	Bioplastica	Etfe	Biomimetico
Origine	Naturale	x	x	x	x	x		x
	Artificiale						x	
	Riciclato	x	x	x	x	x	x	x
Durabilità (Legno EN 350 da 1 a 5)	1		x	x			x	
	2				x			
	3	x						
	4							
	5							
Peso proprio	Kg/m3	750	150/180	500/800	-	-	1700	-
Messa in opera	Facile	x	x	x	x			
	Media						x	x
	Difficile					x		
Certificazione		FSC PEFC EPD	FSC CE EPD	FSC EPD C2C LEED CE BREEAM	CE LEED ETAG004	-	CE LEED DGMB BREEAM	-
Classe di utilizzo (EN 335)	1							
	2							
	3	x	x		x		x	
	4	x	x	x	x		x	
	5							

Resistenza al fuoco (D.M. 26.06.1984 da 0 a 5), (EN 13501-1 da A a F)	0 – A1 – A2				A1		A1	
	1 B		1	1			B S1 d0	
	2 – C		2					
	3 – D	3						
	4 – E	4						
	5 – F							
Riciclabilità a fine vita	%	100%	100%	100%	100%	100%	100%	100%
Costo	m^2	Secondo tipologia di legno	100€	30 40€	-	-	10- 100€	-

CONCLUSION

In definitiva negli ultimi anni, così come emerge da quanto studiato, molti sono gli interventi eseguiti su edifici nuovi o recuperati, utilizzando queste nuove tecnologie che sempe più catturano non solo l'interesse dei tecnici ma anche dell'utente; gli interventi nei settori dell' ecosostenibilità si sono sempre più perfezionati a tal punto da trovare una giusta collocazione nel panorama edilizio internazionale. Volano di questi studi risultano essere anche i provedimenti legislativi, che i vari stati hanno varato, negli ultimi anni, a tutela dell'ambiente, profondamente colpito dallo sconsiderato smaltimento dei rifiuti edili.

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PROPOSAL OF AN INTERNATIONAL CHARTER FOR THE VALORISATION AND SUSTAINABLE DEVELOPMENT OF SMALL TOWNS IN INLAND AREAS: THE "SALERNO CHARTER"

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ABSTRACT

The depopulation of small towns in inland areas, caused by the social, economic and cultural dynamics of contemporary society, is leading to the impoverishment of the tangible and intangible assets of these settlements, as well as a demographic imbalance in which cities are becoming increasingly crowded, and small municipalities are becoming abandoned. Therefore, it is necessary to propose strategies and guidelines in order to promote their sustainable devel opment so that their unexpressed potential can be exploited. There are many aspects to be taken into account in a systemic framework of territorial development, with it being necessary, in this context, to provide or implement essential services and infrastructures in order to avoid discomfort, especially to the new generations, while also introducing any all-innovative tools and systems to facilitate decentralised living and working.

The aim of the "Salerno Charter" is, therefore, to outline the strategic guidelines to mitigate the depopulation of entire fragile geographical areas and to avoid the risk of the impoverishment of the building, landscape and cultural heritage; to reduce the exodus of the inhabitants of many small municipalities towards the cities, or to contrast the fleeing of the current guardians of the territory, so as to preserve the heritage of ancient knowledge and traditions by keeping the identity and memory alive.

The built, landscape, and cultural heritage in small towns is a resource that belongs to everyone and is an expression of the diversity of societies through history. The "Salerno Charter" aims to define the principles, goals, methods and tools to valorise the authentic features of the civilisation that characterises the identity of settlements in inland areas, supporting the permanence of inhabitants as the main actors in the preservation of knowledge and in actions of sustainable growth and development.

Keywords: : Small towns, International charter, valorisation, landscape heritage, cultural heritage.

INTRODUCTION

The issue of small towns depopulation in inland areas has attracted the interest of scholars and researchers in recent decades, who have proposed strategies to stem a phenomenon that is affecting not only many European Countries but also marginal geographical areas all over the world.

At the same time, the landscape, environmental and cultural importance of these territories has been noted: they are complementary places to the city, green lungs where the air is healthy, there is a richness of artistic, architectural and archaeological heritage, and ancient knowledge and traditions (handed down through generations) are kept alive, treasures of memory and identity (Fiore *et al*., 2019).

However, the decline of small settlements is gradually taking on significant proportions, with repercussions in the social, economic and cultural spheres: there is an increasingly intense demographic centralisation in medium-sized cities and metropolises, which, according to the most reliable projections (Department of Economic and Social Affairs, Population Division, United Nations, 2019), is destined to increase over the next thirty years, leading to widespread land degradation and the consequent gradual disappearance of the signs that characterise small-scale landscapes. As reported in the United Nations World Urbanization Prospects 2018: "Globally, more people live in urban areas than in rural areas, with 55 per cent of the world's population residing in urban areas in 2018. In 1950, 30 per cent of the world's population was urban, and by 2050, 68 per cent of the world's population is projected to be urban".

These data are certainly significant and show, on the basis of statistical analyses, the constant de-marginalisation of inland areas and small towns. The issue is extremely complex and has different dynamics. There are many causes, including the contingent economic crisis, the geographical isolation typical of marginal areas, the lack of work that forces young people to move away to find employment, the shortage of efficient infrastructures and services (education, health, transport), the scarcity of places for leisure and sport, and changes in lifestyles and consumption that tend to be standardised and conditioned by big commercial brands (D'Andria *et al*. 2020).

The risk is that small towns may become places of oblivion, where the features of a centuries-old civilisation are lost, linked not only to artefacts but also to traces and elements of intangible culture. Small towns are a valuable heritage of cultural identity that must be safeguarded, as the International Charter of Krakow (2000) clearly underlines: “Each community, through its collective memory and awareness of its past, is responsible for identifying and managing its heritage. The individual elements of this heritage carry many values, which may change over time. From this process of change, each community develops a conscience and an awareness of the need to protect the values of its common heritage”. In most of the investigated areas, many significant elements characterising the places are still preserved, such as the ancient system of settlements, the historical structure of cultivations, the organisation of rural routes, the original relationship between built-up areas and territory, but also religious traditions, recipes referring to products partly forgotten, knowledge in the field of traditional building, tailoring and crafts in general.

Although the phenomenon in question is ongoing and increasing, in recent years, there has been greater attention and interest in tackling these issues, not only because of the risk of “desertification” of entire geographical areas but also because of the opportunities that the resources available there may offer, as well as for a more balanced and sustainable demographic distribution within the framework of territorial systems. There are a number of relevant studies investigating the relationship between small towns and their territorial areas, analysing social, institutional and economic aspects on a broader scale. Among these, there is Small and medium sized towns in their functional territorial context (Servillo *et al*., 2014) which examines the role of small towns in connection with neighbouring cities, outlining their development potential as part of specific governance dynamics.

The ESPON ESCAPE (European Shrinking Rural Areas: Challenges, Actions and Perspectives for Territorial Governance) project investigates the causes and consequences of the depopulation of inland areas, providing indications about valid strategies and actions that have as a starting point the peculiarities of each small reality (Copus *et al*., 2020).

H2020 ROBUST (Rural-Urban Outlooks: Unlocking Synergies) addresses rural contexts and municipalities in more detail, identifying, supporting and strengthening policies aimed at enhancing mutually beneficial linkages between urban, peri-urban and rural areas. It, therefore, highlights the importance of rebuilding the city-countryside interdependence, given that “the city can be the right ally for the villages, creating links and developing new entrepreneurship with them” (Berizzi *et al*. 2019).

The attention for small towns has also increased due to the greater common sensitivity to cultural heritage, landscape values, history and environmental quality, all factors that can be used to encourage investment, tourism, and land consumption.

Therefore, the regeneration of villages in inland areas is a vast field on which a new idea of conservation and revitalisation can be based, producing added value, growth and rebirth in contexts undergoing depopulation.

To this end, the definition of guidelines is of crucial importance, with it being necessary to: contemplate safeguard and development, i.e. the protection of tangible and intangible assets together with economic growth; envisage factors leading to the welcome of those who settle (or re-settle) permanently and aspire to a higher level of services and quality of life; define actions aimed at safeguarding the settlements' historical structure and economic and social development in line with the progress and models of contemporary society.

The "Salerno Charter" was drawn up in the wake of an International Conference entitled Small Towns from problem to resource. Sustainable Strategies for the valorisation of building, landscape and cultural heritage in inland areas held at the University of Salerno on 19-20 September 2019, whose scientific results were collected in a volume (open access e-book) published by Franco Angeli Editore.

Starting from the considerations on the topics discussed during the Conference, thanks to the researchers of the Department of Civil Engineering at the University of Salerno (www.unisa.it) and with the collaboration of the universities of Valencia (www.upv.es) and Tirana (www.upt.al) represented by the authors, a series of reflections and in-depth studies were carried out, which constituted the basis for the development of common awareness, i.e. the need to propose a method aimed at guiding experts in the safeguarding and valorisation of small towns in inland areas by using specific guidelines.

In this perspective, the "Salerno Charter" sets itself as a reference for the revitalisation of the built environment, the strengthening of infrastructures, the reorganisation of the territory and, at the same time, the sustainable recovery of identities and cultural assets and, more generally, of resources. The aim is to revive the inland areas so that in the complex panorama of today's society, the small towns in the vast area can represent not a problem but rather a resource; in other words, they can play a role in relaunching the territory.

It is true, as already mentioned that these 'small' settlements lack services and infrastructures, that work is scarce (especially for young people), and that opportunities for meetings and exchanges are very limited. However, they are 'human-scale' places, where the air is healthy, the discomforts of anthropic concentration are reduced, where ancient knowledge and traditions (protected and handed down from generation to generation) characterise the identity and represent a treasure of knowledge and memory for a lifestyle in harmony with the rhythms and cycles of nature.

Along with these considerations, it is also worth mentioning that in small towns there is a concentration of handicrafts, excellent agri-food production, as well as unique natural resources such as woods, hills, waterways and crops that characterise the places. These are all factors that can develop unexplored ‘economies’ with a high added value, able to produce wealth, safeguard the territory and ensure sustainable economic development.

It is necessary to take into account the dynamics of the global economy, the technological revolutions underway, the use of increasingly autonomous machines that tend to replace man at work, and the demand for more and more advanced services: in short, it is necessary to take into account the dynamics and speed of the changes that characterise our time and the influence that these dynamics may have on the transformation of settlements, in the consciousness that innovation, as in the past, will certainly lead in the future to an evolution of our models of living and repositioning of man in the territory. It will also be necessary to be prepared in order to manage changes quickly, to understand their developments and to avoid or, at least, reduce the probability of the risks that may arise (Fiore *et al*. 2019).

For this reason, it is essential to know small settlements in detail, “intimately and profoundly”, as Angelo Sofo (2010) states, it is necessary to “place ourselves in a situation of listening, trying to perceive the invisible behind the visible in order to come into contact with the essence of that small fragment of the Earth on which we are called to act”. Regaining possession of marginal areas means setting up a knowledge culture that can reveal their history, fragility and potential, even before planning actions and interventions.

The loss of ability to recognise the marks of the place can lead to the uprooting of the individual, the severing of the relationship between man and the environment, with the consequent affirmation of the logic of a demagogic economic power that upsets, destroys and erases the traces of time, in the name of a feared progress.

Looking at the territory’s settlements in these terms means considering them as products that speak of people and to the people who live and transform them in constant interaction with the environment. According to this meaning, the expression ‘place’, even if used to indicate a materially delimited portion of space, in reality, goes beyond the mere spatiality and material extension, having its own and well-defined character that involves a wider sphere, the cultural, social, ethical. There are elements of experience that are inserted in the sphere of traditions, craftsmanship, subsistence economy, social relations, etc. that strongly connote the built environment and reveal its meaning; grasping the signs of the place's meaning signifies "giving aesthetic value to social facts" (Mukarovsky, 1971). Therefore, it is important to emphasise the most negligible, even apparently insignificant details, and the seemingly marginal details that sometimes turn out to be revealing. Even if the spatial elements are carefully sifted with analytical criteria, it is important not to forget the "small discernments", as Winkelmann said, i.e., identifying all the clues that can be traced back to the identity framework of the places.

The initiatives aimed at recovering and valorising small towns, therefore, require an integrated approach with an analysis of factors relating not only to the more technical aspects but also to those models of re-inhabitation in which space and time have values linked to identity, memory and traditions; the place is so because it is "inhabited, humanised, recognised, periodically refounded by the people who are part of it or feel part of it [...] the places are social and cultural constructions, the result of a continuous production by the inhabitants" (Teti, 2017).

The "Salerno Charter", therefore, intends to outline strategic guidelines to contrast the migration of inhabitants from small towns and to encourage communities and territories to become increasingly aware of the value of the ancient knowledge, traditions, culture and memory heritage. The intention is to define the principles, goals, methods and tools for valorising the authentic features that characterise the identity of small settlements, promoting the permanence of the last guardians, who are the main actors in the maintenance of the cultural heritage and, at the same time, of the growth and development actions, but also the possibility for the new generations to find employment opportunities, social improvement and quality of life.

International Charter for the Valorisation and Sustainable Development of Small Towns in Inland Areas Preamble

Considering the different international documents on the protection, conservation, regeneration, valorisation and management of land and settlements;

Concerned about the depopulation and abandonment of small towns in inland areas due to various social, economic and cultural dynamics of contemporary society;

It is necessary to implement actions in order to rebalance human settlements in the territory, with a view to a better organisation and interaction between cities and small municipalities, for a more balanced consumption of land and resources.

Considering that the heritage of tangible and intangible assets of these places represents a resource, belonging to all individuals and societies, and runs the risk of being impoverished. the parties hereby agree as follows:

Art.1 - The object of this guideline Charter are small settlements located in inland areas, i.e. in peripheral and fragile areas characterised by progressive depopulation and at risk of degradation and abandonment, with consequent effects on the territory (countryside-landscape relationship) and cultural heritage (material and immaterial).

Art. 2 - A systemic vision and the implementation of coordinated actions are basic factors for achieving the goals of economic, social and cultural growth of the settlements under consideration.

Art. 3 - The heritage of cultural and natural assets must be safeguarded and valorised so that it can represent an income for the protection and development.

Art. 4- The relationship between man-building-environment has to be strengthened and rebalanced through actions aiming at the redevelopment of built-up areas, the revitalisation of the countryside, the promotion of landscape culture, the protection of the environment, the reduction of land consumption.

Art. 5- It is essential to safeguard and promote the resources available: protected natural areas, regional and national parks, historical town centres and historical-artistic assets, archaeological sites, villages and castles, museums and small libraries, churches, religious presidia and shrines, protoindustrial artefacts, rural/vernacular architecture, the agricultural landscape, historical paths and pilgrimage routes, geosites, watercourses, sheep tracks and ancient roads, as well as any other significant testimony to the memory and identity of places and collective culture.

Art. 6- Demo-ethno-anthropological assets, as well as ancient knowledge and trades handed down from generation to generation, should be detected, surveyed and valorised in order to preserve the intergenerational identity and the sense of belonging to the place.

Art. 7 - Through the construction of services, infrastructures and new transport networks, with public and/or private investment, it will be possible to satisfy needs that consolidate the permanence of the inhabitants. Residence in small towns is an essential requirement for keeping alive local knowledge, traditions and know-how, as well as safeguarding the environment and preventing hydrogeological risks.

Art. 8 - An organisation associated and/or in consortium form can guarantee the sustainability and efficiency of services. The different forms of association envisaged by national regulations, through inter-municipal aggregation processes, with the aim of reorganising and distributing services and equipment in a balanced manner, are extremely important.

Art. 9 - The use of flexible and digital distance working is one of the tools useful to reduce costly and polluting commuting to the cities and to maintain a continuous daily presence in small municipalities able to support local economies as well as social and community life.

Art. 10 - Forms of cultural, religious and experiential tourism are essential for the growth of inland areas. They can be suitably developed in such a way as to reconcile economic and social development with the need to safeguard the authenticity and protection of the territory's resources.

Art. 11 - Food and wine tourism can be developed through an organic action promoting the supply chains and brands of typical products. The demand for hotel accommodation can be met through the creation of 'Albergo Diffusi', agritourism and bad and breakfasts, preferably using disused buildings (old mills, cottages, farms, abandoned buildings or sections of historical centres, etc.).

Art. 12 - Greater media attention to the positive aspects of these territories is desirable in order to highlight the potential of new sustainable models of economic development, centred on the green economy production paradigm, on the values of social/community cohesion and health benefits (air, water, soil quality). The promotion (communication) can be carried out both through traditional information media (television, radio, newspapers) and through new tools such as social networks, but also using innovative knowledge systems like cultural heritage information system, GIS, augmented reality technology, etc.

Art. 13 - A reversal of the urbanisation trend may lead to a gradual decongestion/ depollution of cities and metropolises, also in line with the goals proposed in the

European climate programmes. Healthier living conditions, a diet based on zero-km products, greater contact with nature and with open spaces can promote the relocation and rebalancing of territorial human activity.

Art. 14 - Appropriate measures in favour of youth employment and the creation of new enterprises and cooperatives, also by means of a significant reduction in bureaucracy and tax exemptions, are desirable in order to avoid the departure of the new generations from their native places and to prevent the consequent ageing of the population.

Art.15 - The recovery and revitalisation of historical centres are desirable (with attention not only to prestigious buildings but also to all the artefacts and pertinence with testimonial-historical and choral value). In any case, an improvement in the comfort and quality of housing should be envisaged (upgrading, energy efficiency, domotics, etc.) in order to make buildings as responsive as possible to users' expectations.

Art. 16 - The traditional local handicrafts, the cultivation of autochthonous plant species, the production and transformation of typical products are of great interest. Schools of arts and crafts should be encouraged, involving local artisans, who are holders of manual skills and practices handed down from generation to generation.

Art. 17 - The most advanced technologies will be able to improve agricultural work, the care of forests, the balanced production of products, and encourage young and/or female entrepreneurs. In this way, it will be possible to guarantee a higher quality of production, environmental protection and control of the territory's needs.

Art. 18 - The bottom-up processes for citizen participation in urban governance and management are necessary for the active collaboration of residents in planning and transformation choices.

Art.19 - The awareness of the cultural, environmental and identity issues highlighted in this document should be encouraged by all means and strongly addressed to young people, starting from primary school education. In this context, education should be promoted in the rediscovery of environmental values, the beauty of natural assets and art, and the knowledge of community spirit and traditions.

Art. 20 - It is believed that all the actions outlined above can help achieve harmonious, balanced, efficient and sustainable territorial development. The goal to be pursued can be summarised as a gradual and effective contrast of the current phenomena that see the inland areas marginalised and characterised by: loss of population, reduction of collective services, the decline in employment and land use, hydrogeological instability, environmental degradation, impoverishment of the historical-artistic heritage, loss of ancient knowledge and local traditions.

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EVALUACIÓN DE LA ALTURA DE DEFECTOS INTERNOS DE SOLDADURA MEDIANTE TÉCNICAS RADIOGRÁFICAS. APLICACIÓN AL CONTROL DE ESTRUCTURAS METÁLICAS

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ABSTRACT

The present paper proposes a working method for determining the height of defects in the welds of metal constructions using radiographic techniques. First, the problems associated with the detection of defects in metal welding are briefly exposed, as well as some of the techniques commonly used. Next, the fundamentals and procedure of the proposed method are described. All this is accompanied by a practical case as an example and experimental validation, to finish with the conclusions and the advantages derived from the application of the method to the control and execution on site of welded joints.

Keywords: Radiological inspection, defects metal welding, construction, welded structures.

INTRODUCTION

Durante la ejecución de las uniones soldadas realizadas sobre estructuras metálicas se recurre habitualmente a la inspección visual, mediante la cual es factible controlar eficazmente gran parte del proceso. Adicionalmente, también se precisan otras técnicas de inspección capaces de determinar y evaluar posibles defectos internos presentes en una soldadura. Dichos defectos, SEGÚN la normativa vigente, pueden ser determinantes para la aceptación o rechazo de las soldaduras efectuadas. De ahí la importancia de la fiabilidad en los métodos de detección que, también deben ser viables técnica y económicamente para facilitar y extender su utilización.

SUMMARY

En esta ponencia se presenta un método que permite estimar la altura de los defectos en uniones soldadas a partir de técnicas radiográficas. En primer lugar, se expone brevemente la problemática asociada a la detección de defectos en la soldadura de metales, así como algunas de las técnicas utilizadas habitualmente para ello. A continuación, se describen los fundamentos y la operativa del método propuesto. Todo ello, se acompañada de un caso práctico a modo de ejemplo y validación experimental, para finalizar con las conclusiones y las ventajas derivadas de la aplicación del método al control y ejecución en obra de uniones soldadas.

Inspección por ultrasonidos

Esta técnica se basa en la transmisión de ondas sónicas a través de un medio físico homogéneo, como podrían ser las soldaduras presentes en una estructura metálica. Las ondas son generadas por un transductor de material piezoeléctrico que, al recibir impulsos eléctricos, vibra a una frecuencia entre 0.5 y 25 MHz. Al poner en contacto el transductor con el elemento a inspeccionar, la vibración se propaga a través del mismo a una determinada velocidad (5930 m/s en el caso del acero y ondas longitudinales). Cuando las ondas sónicas se encuentran con un medio no homogéneo o una discontinuidad, son reflejadas y captadas de nuevo por el transductor, lo que se visualiza en forma de picos sobre la representación gráfica mostrada en la pantalla o el dispositivo de registro del equipo de medida (Figura 1). Cada pico indica la presencia de una discontinuidad (defecto).

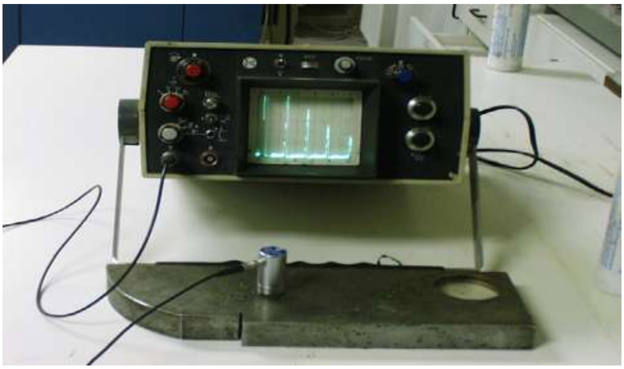

Figura 1.- Picos correspondientes a sucesivas reflexiones captadas por el equipo de inspección por ultrasonidos, que indican la existencia de posibles defectos en la pieza en contacto con el transductor.

Esta técnica puede aplicarse a cualquier tipo de material excepto a los porosos, susceptibles de generar múltiples reflexiones que serían interpretadas como un falso positivo en la detección de defectos. Además, para la correcta interpretación de las reflexiones captadas por el equipo se precisa de una formación específica y una notable experiencia (Yadav, Yadav, and Dubey 2021) (Yadav *et al*. 2021).

Inspección radiográfica

El fundamento de la inspección radiográfica se puede explicar con la ayuda de la Figura 2. En ella se muestra la representación esquemática de un equipo de Rayos X (RX) y pueden apreciarse sus componentes principales. El cátodo es un filamento de Wolframio unido a un circuito por el que se hace pasar una corriente eléctrica de entre 1 y 10 mA que provoca la incandescencia del filamento, formándose una nube de electrones que son proyectados hacia el ánodo a elevada velocidad debido a la diferencia de potencial generada por un transformador de hasta 1000 kV.

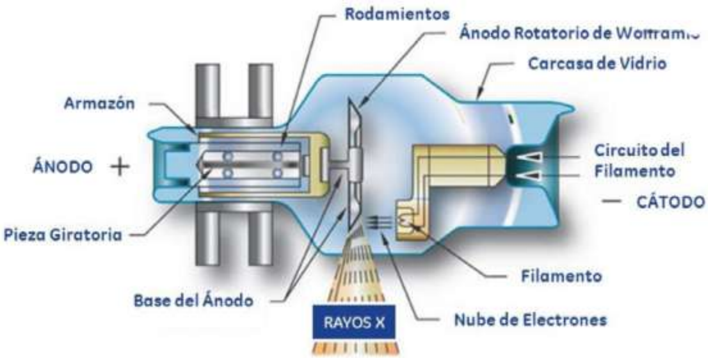

Figura 2.- Esquema de un generador de Rayos X.

Aproximadamente, el 98% de la energía de los electrones que inciden sobre el ánodo se transforma en calor; mientras que el 2% de la energía restante origina un flujo de fotones de corta longitud de onda que son colimados dando lugar al haz de RX. Cuanto menor es la longitud de onda de la radiación más penetrante será esta. Es decir, la capacidad de penetración de los RX está determinada por el potencial generado en el transformador de la unidad (Figura 3). Por otra parte, la penetración de la radiación también dependerá de la capacidad de atenuación, que aumenta con la densidad y el número atómico del material. Por ejemplo, los siguientes materiales se han enumerado según orden creciente de su capacidad de atenuación: madera, plástico, aluminio, hierro, cobre, latón, bronce, plata, plomo y mercurio.

Figura 3.- Equipo de RX refrigerado por aire.

.La longitud de onda (λ) de los fotones emitidos desde el cátodo viene dada por la Expresión 1, donde Å = 10-10 metros.

$$\lambda = \frac{12400}{V} \overset{0}{A} \qquad \text{(Expresión 1)}$$

Las técnicas de inspección radiográfica tienen la ventaja, respecto a la inspección por ultrasonidos, de que sus resultados son fácilmente interpretables: en una radiografía se aprecia a simple vista la forma de la irregularidad o el defecto detectado. Por contra, tiene las limitaciones propias de una imagen bidimensional; en la cual, por ejemplo, no puede apreciarse la dimensión vertical (altura) del defecto detectado en una unión soldada. No obstante, la estimación de la magnitud del defecto en tres dimensiones (estimación de la altura del defecto) puede realizarse mediante el análisis que se presenta más adelante (Trytek 2002) y que forma parte del método propuesto.

Además de la inspección radiográfica convencional, para casos de mayor responsabilidad pueden utilizarse otras técnicas de radiación. Por ejemplo, las que emplean fuentes isotópicas como los rayos Gamma (Gammagrafía industrial).

DESCRIPCIÓN DEL MÉTODO

Lo expuesto hasta ahora justifica la conveniencia de disponer de un método fiable, que proporcione resultados fácilmente interpretables y que permita una caracterización tridimensional de los defectos detectados. Todo ello se puede conseguir complementando la inspección radiográfica convencional con una técnica capaz de proporcionar una estimación de la altura de los defectos. En esto consiste básicamente el método que se presenta a continuación, acompañado de los elementos esenciales para el mismo, como película radiográfica, indicadores de calidad y densitómetro.

Película radiográfica

Una película radiográfica clásica está compuesta por un chasis hermético en cuyo interior hay una fina placa de plástico transparente recubierta en toda su superficie por una emulsión de bromuro de plata. Esta placa, a su vez, se sitúa entre dos láminas de plomo de una décima de espesor que evitan la radiación difusa incidente sobre la película y mejoran la calidad de la radiografía (Figura 4). La película radiográfica debe situarse lo más próximo posible a la pieza a irradiar, evitando con ello la aparición de imágenes difusas. Cuando se inspecciona una unión soldada, la película se sitúa en la cara opuesta de la pieza a la zona de la soldadura y unida a dicha superficie. En la cara donde se ha efectuado la soldadura se colocan los denominados indicadores de calidad o ICI.

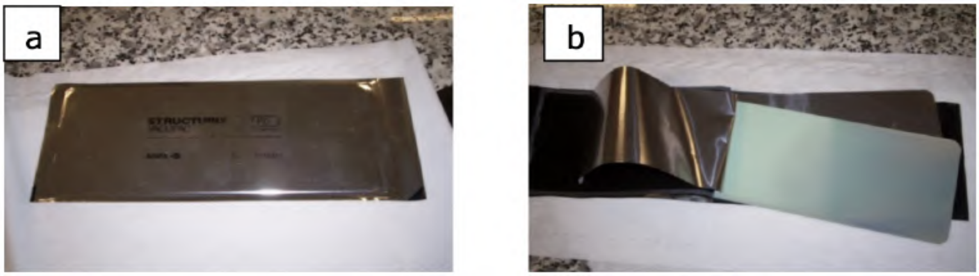

Figura 4.- (a) Chasis de película de RX. (b) Componentes interiores de la película radiográfica.

Indicadores de calidad en uniones soldadas

Los indicadores de calidad están constituidos por tres juegos de hilos, cada uno con siete hilos (Figura 5); y existen indicadores de este tipo para distintos materiales, como acero, cobre y aluminio (Figura 6). En ellos, el sentido creciente de la numeración indica una disminución del diámetro de los hilos: en el primer juego la numeración va de 1 a 7, que corresponde a diámetros de hilo entre 3.2 mm y 0.8 mm); de 6 al 12 en el segundo (diámetros de 1 mm a 0.25 mm); y de 10 a 16 en el tercero (diámetros de 0.4 mm a 0.1 mm. Como puede apreciarse, hay dos hilos del mismo diámetro en cada uno de los juegos que van consecutivos.

Figura 5.- Esquema de un indicador de calidad, e indicador de calidad colocado sobre una unión soldada.

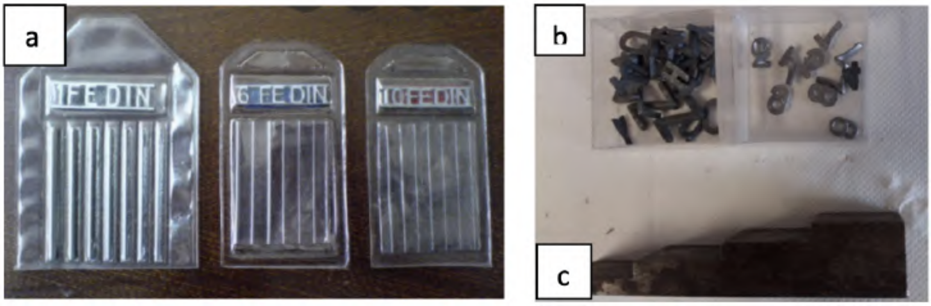

Figura 6.- (a) Juego de índices de calidad. (b) Letras y números de plomo. (c) Índices de calidad de escalerilla.

Al irradiar la muestra, la radiación la atraviesa e incide sobre la película radiográfica; donde la radiación difusa es eliminada por las láminas de plomo y la radiación nítida incide sobre la placa de plástico impregnada de la emulsión de bromuro de plata. Esta radiación (ionizante) ioniza la emulsión liberando el bromo del compuesto inicial que se visualizará en color negro al revelar la radiografía. Si la película ha estado muy poco tiempo sometida a la radiación y la ionización del bromuro de plata ha sido insuficiente, la película revelada será transparente y, por tanto, inservible; en este caso, la densidad radiográfica es de 0.5 o menor. Si la película ha estado mucho tiempo irradiada, al revelarla, toda la plata se habrá ennegrecido y tampoco podrá percibirse nada; en este caso, la densidad radiográfica es de 4 o mayor. En resumen, la densidad radiográfica deberá estar comprendida entre 0.5 y 4.

Densidad radiográfica y densitómetros

La densidad radiográfica está asociada al grado de ennegrecimiento observado en la placa revelada tras ser irradiada, y se puede cuantificar mediante la Expresión 2.

$$\log \frac{L_0}{L_{final}} \quad \text{(Expresión 2)}$$

L0 = Luminosidad inicial
Lfinal = Luminosidad final

Los densitómetros, como el mostrado en la Figura 7, permiten determinar la densidad radiográfica. Para ello, deben ser calibrados con la ayuda de una fuente luminosa de gran intensidad y, posteriormente, las medidas se realizarán colocando la zona prevista en el aparato para la entrada de luz sobre la radiografía.

Figura 7.- (a) Vista anterior del densitómetro para su calibración o puesta a cero. (b) Vista posterior del densitómetro, donde se aprecia la zona de entrada de la luz en el apoyo superior izquierdo.

Caso práctico: verificación de una soldadura mediante el método propuesto

El ejemplo y la validación experimental del método se ha basado en la verificación radiográfica de uniones soldadas (Figura 8) realizadas sobre chapas de fundición nodular de 6 mm de espesor, con varilla de aporte ER 316L, a tres pasadas, mediante procedimiento TIG y con preparación de bordes en bisel a 30º (Alcón *et al*. 2021) (Hangai *et al*. 2021) (Cárcel-Carrasco *et al*. 2019)(Cembrero *et al*. 2017)(Pascual *et al*. 2008).

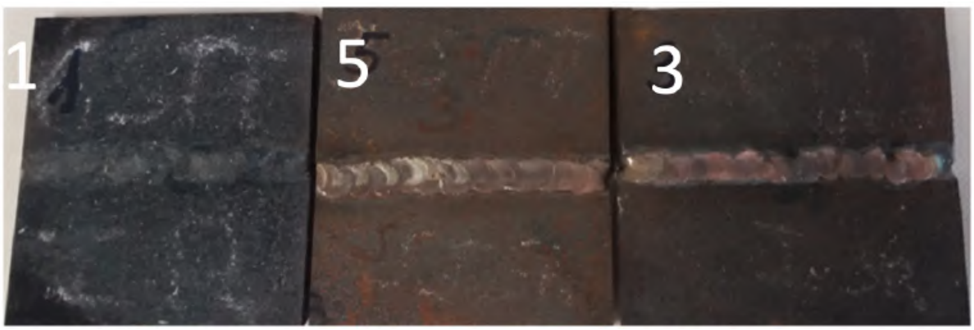

Figura 8.- Uniones soldadas sobre chapas de fundición nodular.

La preparación de las muestras a irradiar, descrita en el apartado anterior, se ilustra en la Figura 9, donde se aprecian la utilización de la película radiográfica y de los ICI (Manterola Armisén and Martínez Cutillas 2016).

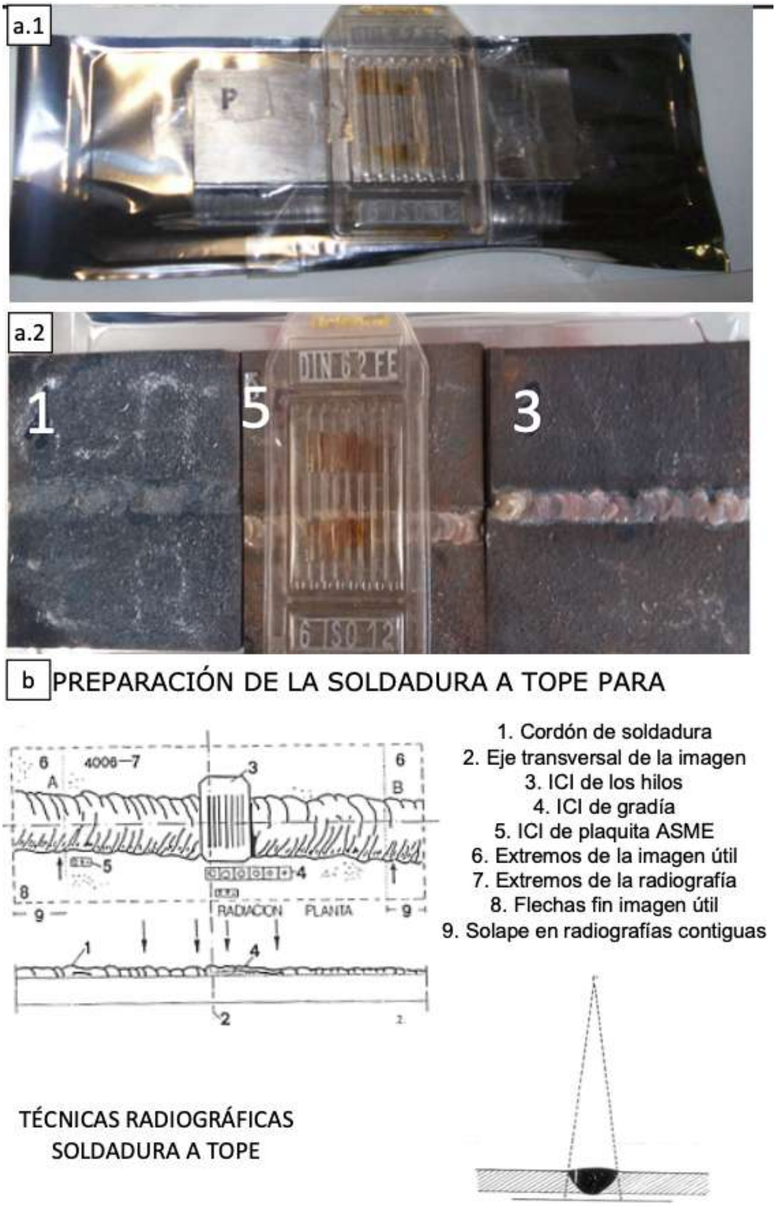

Figura 9.- Fotografías (a) y representación esquemática (b) de la preparación de una pieza a radiografiar con indicador de calidad de hilos (ICI) e identificador con letra o número de plomo, para la verificación por RX en soldadura a tope.

Para determinar los parámetros necesarios en la irradiación de la muestra y obtener la imagen radiográfica en condiciones óptimas, se utiliza la gráfica de exposiciones suministrada por el fabricante (Figura 10). En el recuadro vertical interior que aparece en la figura se indica el tipo de película, la intensidad en mA, la distancia de irradiación y la densidad radiográfica que se obtendrá.

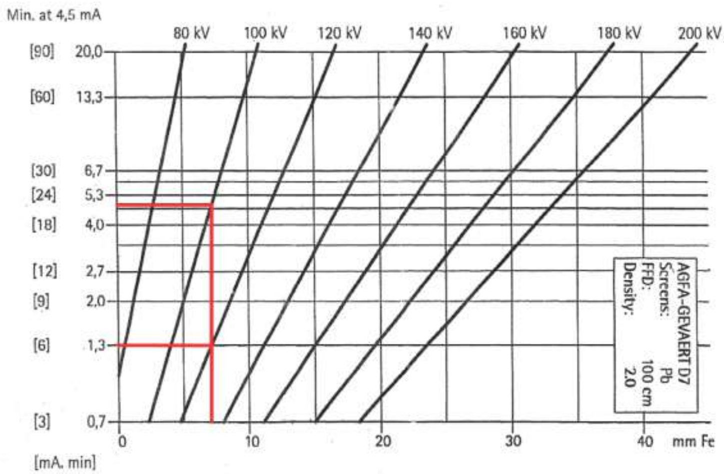

Figura 10.- Gráfica de exposiciones del equipo de RX, donde se indican el tiempo (minutos) y el potencial de exposición (kV) para un espesor de la muestra (mm) y unas referencias determinadas (recuadro).

Aunque las piezas a irradiar tienen 6 mm de espesor, se considera una dimensión de 7 mm en la unión soldada. Desde ese punto (7 mm) se traza una perpendicular por el eje de abscisas hasta intersectar con una de las líneas inclinadas que representa el potencial de irradiación en kV. En este caso, podría ser la de 100 kV o la de 120 kV. Si se seleccionan 120 kV, la exposición en mA.min/m2 será de (Torres et al. 2011) y el tiempo de exposición será de 1.3 minutos, para una distancia de 1 metro y una intensidad de filamento de 4.5 mA; obteniéndose con estos parámetros una densidad de 2.

La exposición radiográfica viene, que definida por la Expresión 3, es una medida de la cantidad de radiación recibida por la muestra inspeccionada.

$$Ex = \frac{i \cdot t}{d^2} = \frac{A \cdot \min}{m^2}$$ **(Expresión 3)**

Figura 11.- Radiografía obtenida en el examen radiográfico realizado sobre las muestras de la Figura 8.

En la Figura 11 se muestra el resultado obtenido tras revelar la película radiográfica, donde pueden observarse variaciones de tono en la densidad radiográfica, que se deben a las variaciones locales de espesor en distintas zonas de las muestras.

La puesta a cero del densitómetro (Figura 12) se ha realizado como se explicó en el apartado 3.3, y con ella se obtiene L0, o condición inicial para luminosidad (Cely *et al*. 2018)(Fernández Torres *et al*. 2011).

Figura 12.- Puesta a cero o calibración del densitómetro.

A continuación, se obtiene la lectura de la densidad radiográfica en la zona de la radiografía correspondiente a la soldadura (Figura 13).

Figura 13.- Lectura de la densidad radiográfica en la unión soldada.

Como puede observarse, la radiografía está correctamente realizada ya que la densidad radiográfica de la unión soldada coincide con la densidad para la que se ha irradiado según las características de la gráfica de exposiciones (Figura 10), de donde se ha obtenido el valor de los parámetros a utilizar.

Para determinar la altura de los defectos que se aprecian en la Figura 11 (las zonas más oscuras en el cordón de soldadura) se utiliza la gráfica de la Figura 14, donde se indica el valor de la densidad radiográfica (en ordenadas) en función del logaritmo decimal de la densidad relativa (en abscisas) y donde las líneas inclinadas corresponden al tipo de película radiográfica empleada (X, Y o Z).

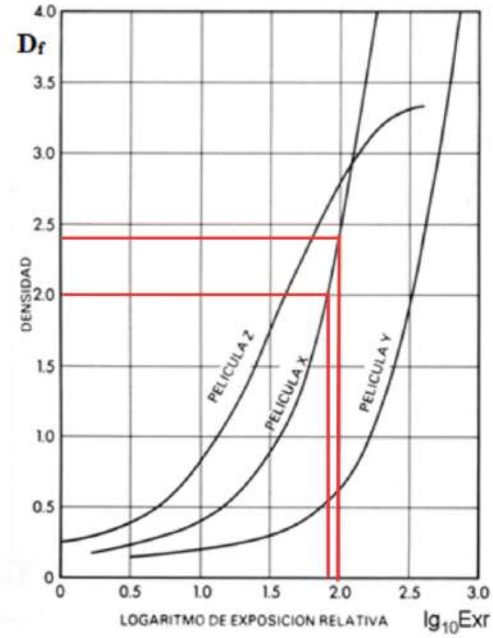

Figura 14.- Gráfica de densidad radiográfica.

La Figura 15 muestra la lectura correspondiente a uno de los defectos que se aprecian en la Figura 11.

Figura 15.- Lectura de la densidad radiográfica en uno de los defectos de la unión soldada.

En función de la exposición y de las densidades, aplicando la Expresión 4, se podrá obtener la altura del defecto.

$$log\frac{Ex_2}{Ex_1} = f(D_2) - f(D_1) \qquad \textbf{(Expresión 4)}$$

En este caso, para una exposición de 6 mA.min)/m^2 a 120 kV y con un tiempo de irradiación de 1.3 minutos, según la gráfica de exposiciones (Figura 10) le corresponde una densidad radiográfica de 2. En la gráfica de la Figura 14 se traza una horizontal desde este punto (densidad 2) hasta la línea inclinada que corresponde a la película utilizada (D7Pb) y desde la intersección con ésta, una vertical que proporcionará el valor de la función de densidad (1.87).

Pero, la lectura del densitómetro en el defecto es de 2.44 (Figura 15). Por tanto, según la gráfica de la Figura 14, a esta densidad de 2.44 le corresponderá una función de densidad de 2.

Considerando todo lo anterior, para obtener el valor del espesor en la zona inspeccionada (defecto) se tiene que responder a la siguiente pregunta: ¿Qué exposición (Ex1) se debería aplicar en la zona inspeccionada para que la densidad sea 2, sabiendo que para la exposición de 6 mA.min/m2 (Ex2)se ha obtenido una densidad de 2.44?

Sustituyendo estos datos en la Expresión 4 se obtendrá:

$$log\frac{6\,mA.min/m^2}{Ex_1} = f(2{,}44) - f(2) = 2 - 1{,}87 = 0{,}23$$

De donde se puede obtener el valor de Ex1:

$$\frac{6\,mA\,.min/m^2}{Ex_1} = 10^{0,23}$$

$$Ex_1 = \frac{6\,mA.min/m^2}{10^{0,23}} = 3{,}53\,mA.min/m^2$$

Ahora, en la gráfica de exposiciones (Figura 16) se traza una horizontal por el valor de 3.53 mA. min/m2 hasta intersectar con la línea de 120 kV, el potencial utilizado, y, desde el punto de intersección, se traza la vertical hasta el eje de abscisas, donde se obtiene el valor del espesor correspondiente (aproximadamente 5.3 mm).

Por lo tanto, la altura estimada del defecto será de 1.7 mm: la diferencia entre el espesor considerado inicialmente en la zona de la unión soldada (7 mm) y el espesor real, o consistente con los datos obtenidos en la inspección radiográfica (5.3 mm).

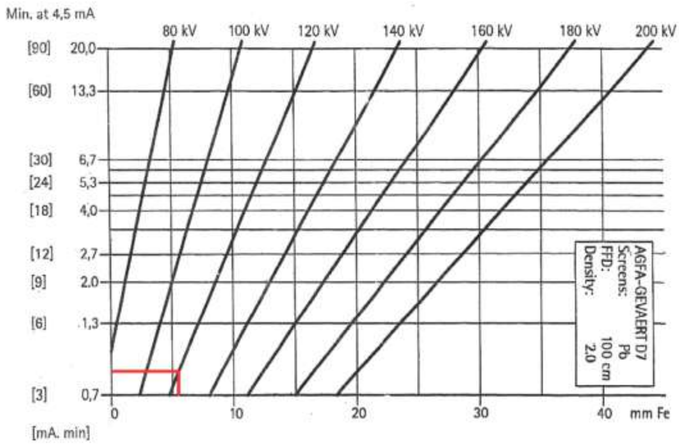

Figura 16.- Valor en la gráfica del espesor para la densidad 2.44.

CONCLUSION

Tal y como se ha demostrado para el caso de uniones soldadas, el método propuesto permite realizar un dimensionado tridimensional aproximado de las discontinuidades (defectos) mediante la técnica de inspección radiográfica. El método es fiable y fácil de llevar a la práctica; los resultados, que son numéricos y muy simples, no conllevan problemas de interpretación; y no se precisa de un equipamiento adicional al necesario para efectuar una inspección radiográfica convencional.

Por todo ello, se concluye que este método es de interés para la caracterización de defectos de soldadura en general y, particularmente, para las uniones soldadas presentes en la estructura metálica de cualquier tipo de construcción civil. Ya sea para determinar el grado de cumplimiento de la normativa de seguridad que les aplica y/o para valorar el riesgo asociado a su estado y nivel de defectos durante las operaciones de construcción, revisión, mantenimiento, demolición o desescombro.

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ECO RESTYLING VIRTUOSO E VIRTUALE DELL'ESISTENTE

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ABSTRACT

Il controllo della forma nelle strutture architettoniche è una caratteristica naturale della pratica dell'ingegneria e della progettazione architettonica. La conoscenza necessaria per il suo sviluppo si basa su due fondamenti: il primo, l'approfondita conoscenza dell'esistente, fa sì che le prestazioni e la funzione dell'edificio siano intimamente connessi alla forma degli spazi costruiti; il secondo dà un'idea relativamente nuova, considerando il sistema di cal colo impiegato per controllare i dispositivi in modo autonomo, attraverso i principi igroscopici. Quando combinati, ciascun tipo di conoscenza può essere utilizzata per approfondire l'architettura e l'ingegneria sia a livello teorico che a livello metodologico. Il controllo della forma è di grande interesse all'interno dell'architettura perché è l'ingrediente primario necessario per produrre involucri edilizi che cambiano forma. Le strutture architettoniche reattive richiedono una rivalutazione delle nozioni esistenti di creazione dello spazio, in pratica, questi sistemi richiedono una rivalutazione delle metodologie costruttive e progettuali sia in ambito ingegneristico che architettonico. In questo articolo viene approfondita.

Keywords: Eco restyling; Hygroscopic actuation; Responsive architecture; Wooden structures; Lightweight marble structures.

INTRODUCTION

In questo articolo viene presentata una ricerca sui sistemi architettonici in biopietra, che alleggeriscono il rivestimento esterno dell'edificio, e in elementi lignei naturali reattivi; tanto la biopietra quanto gli elementi lignei, in modo autonomo si adattano ai cambiamenti ambientali, sfruttando le diverse proprietà che tali materiali manifestano a livello chimico, elettrico e fisico-meccanico. Oltre alla pietra utilizzata per rivestimenti esterni e interni, le nuove tecniche e il progresso in campo edile hanno permesso la progettazione e produzione di prodotti in marmo alleggerito, che forniscono all'edificio soluzioni sia tecniche che estetiche. Combinato con l'alluminio, lo strato sottile della pietra supera i limiti del peso e può essere utilizzato in diversi formati in base alle applicazioni.

La ricerca presentata segue una strategia integrativa, che può essere considerata no-tech, che si basa sui principi biologici piuttosto che meccanici. In natura alcuni vegetali impiegano diversi sistemi per rispondere ai cambiamenti ambientali. Un modo particolarmente interessante passa attraverso la risposta igroscopica, in quanto vi sono piante che forniscono, per il loro funzionamento a livello metabolico, un modello interessante per avere un movimento autonomo e reattività passiva. Il documento presenta un'idea di eco restyling esterno di un edificio esistente, attraverso l'utilizzo di pannelli in pietra alleggerita ad alto contenuto tecnologico e in lamelle di legno che seguono il principio igroscopico.

Elementi naturali di eco restyling

Riuso della pietra in architettura

L'uso dei materiali lapidei nelle costruzioni è ed è stato per lungo tempo prerogativa esclusiva di opere di particolare rilievo e importanza, realizzate per durare nel tempo come, ad esempio, chiese o edifici pubblici. Esiste un legame indissolubile e preciso tra zona di appartenenza dell'edificio e materiale lapideo impiegato. Il materiale lapideo prevalentemente disponibile in loco, infatti, ha influenzato in maniera determinante tipologie costruttive e linguaggi formali in più di una fase storica. Ciò deriva dal fatto che la distribuzione dei materiali litoidi superficiali non è omogenea e le zone della superficie sono caratterizzate da composizioni differenziate del suolo con presenza di specie lapidee specifiche. Lo sviluppo dell'impiego dei materiali lapidei come paramenti non strutturali è stato accompagnato dall'evoluzione delle tecniche di lavorazione in strato sottile, anche in abbinamento a materiali di supporto di natura diversa.

Un esempio è la lavorazione del marmo: negli ultimi anni l'evoluzione industriale ha portato a nuove tecniche di produzione e il marmo alleggerito è una di queste. Composto da una lastra di marmo di sottile spessore (fino a 3 mm), unita ad un supporto strutturale in alluminio dalla forma alveolare situato tra due lamine di alluminio rinforzato, oppure tra uno strato di resina strutturale e uno in fibra di vetro, impregnata con resina epossidica. Ci sono molteplici aziende in Italia che producono pannelli in marmo alleggerito, utilizzato non solo per i rivestimenti decorativi da esterni, ma anche per interni o arredi, come la NC Marmi, la Remax e la Sacerdote Carrara. (Fig. 1)

Figure 1. Stratificazione del pannello Petra Light della Remax; Pannello di marmo alleggerito NC Marmi.

Reattività naturale in architettura

In natura ci sono vari esempi di movimenti dinamici e sensibili alla variazione del clima. Particolare interesse è la capacità igroscopica il cambiamento o l'adattamento che può essere osservato in una varietà di piante che conferisce un potenziale sostenibile nelle applicazioni in architettura. Il movimento della pianta guidato dall'umidità può essere classificato in due modalità: quello attivo di pressione del turgore cellulare e quello passivo innescato dall'allungamento differenziato del materiale. Se il movimento di pressione cellulare attivo è collegato al metabolismo delle piante, l'alternativa passiva è il risultato del comportamento igroscopico del materiale e della sua composizione anisotropa, in risposta ai cambiamenti ambientali. Per esempio nelle conifere, una volta che il cono delle pigne diventa maturo, le squame si seccano e si aprono per rilasciare i semi; successivamente, al fine vita del cono, la pigna, non essendo più direttamente collegata all'albero, cade. Da quando il movimento è innescato grazie a variazioni climatiche, la struttura molecolare del materiale è completamente reversibile per un gran numero di cicli di apertura e chiusura.

La deformazione geometrica delle sottili scaglie è ottenuta attraverso due diversi strati di fibre; lo strato esterno è costituito da cellule parallele, lunghe e densamente ammassate con pareti spesse, mentre lo strato interno del seme possiede fibre di sclerenchima, differenziate con fibrille di cellulosa nella parte superiore e parte inferiore rispetto all'asse longitudinale. Attraverso questo rigonfiamento e il restringimento, il materiale esegue la deformazione passiva autonoma. Il comportamento igroscopico del materiale è particolarmente interessante in architettura, poiché non richiede alcun tipo di azione esterna, né meccanica né elettrica. L'igroscopia descrive la capacità di un materiale di assorbire e di rilasciare umidità nell'atmosfera per mantenere costantemente un relativo equilibrio con l'ambiente circostante. Gli innovativi metodi di calcolo computerizzati e le nuove macchine di fabbricazione hanno permesso la progettazione e la produzione, in edilizia, degli elementi di materiale reattivo sintetico e biomimetico che andranno a comporre i pannelli di finitura. Attraverso la comprensione dei principi microstrutturali che facilitano il comportamento igroscopico nella pigna, le continue ricerche hanno permesso di trasmettere questo principio su scale industriale. L'utilizzo del fusto può essere considerato il più efficace, per la produzione delle scaglie legnose, composte da materiale simile e comportamento isotropo. Sebbene il tessuto vascolare del fusto non presenta la microstruttura necessaria per ottenere il movimento possiede proprietà igroscopiche che creano cambiamenti dimensionali nel materiale, con possibili restringimenti e rigonfiamenti ciclici. I movimenti sono importanti caratteristiche funzionali della pigna, poiché dipendono dal livello di umidità relativa dell'ambiente circostante.

Il diverso livello di umidità dell'ambiente può facilmente indurre, nello strato interposto tra esterno e interno, un movimento differenziale nelle scalie della pigna. Se il campione è abbastanza sottile, il materiale risponde dissipando lo stress attraverso una deformazione elastica del forma complessiva, cioè un arricciamento del materiale, questo comportamento è altamente reversibile oltre ad essere riproducibile. Sono stati condotti vari studi su questa complessa procedura, per esplorare, analizzare, manipolare e calibrare i vari parametri che influenzano il comportamento del legno in determinati contesti atmosferici.

Per traslare il comportamento di queste lamelle a dei componenti di maggiori dimensioni, come i pannelli che tratteremo, è stato necessario testare una vasta gamma di specie legnose, quali faggio e acero europeo. Oltre all'igroscopia, il materiale ideale dovrebbe poter resistere a cicli ripetuti, di pioggia e soleggiamento, risultando anche sufficientemente economico. In tal senso sono risultati significativi parametri come: direzionalità omogenea delle venature, fragilità, densità, disponibilità commerciale e resistenza ai funghi. La ricerca ha verificato che, nonostante il legno di faggio abbia un comportamento maggiormente igroscopico rispetto all'acero europeo, quest'ultimo dimostra nel complesso migliori prestazioni, grazie a una serie di altri parametri, come per esempio il modulo di elasticità inferiore (Faggio 14.000 N/mm2 e Acero europeo 9.400 N/mm2), una resistenza alla decomposizione marginalmente maggiore e maggiore omogeneità delle fibre.

Il comportamento igroscopico del legno è direttamente correlato alla struttura cellulare e all'angolo delle microfibre rispetto alla direzione assiale delle cellule, pertanto, l'allungamento igroscopico appare perpendicolare alla direzione della fibra. I campioni di materiale più spessi richiedono più tempo per bilanciare il loro livello di umidità con l'ambiente esterno e quindi avrà una resistenza alle forze deformanti intrinseche più lunga, mentre avviene il viceversa per i campioni più sottili.

Le varie prove in laboratorio sulle diverse tipologie di legno e sulle diverse forme date, mostrano che il ritiro e la dilatazione delle fibre del legno avvengono in risposta diretta all'umidità relativa circostante, calcolata in funzione dell'umidità assoluta e della temperatura dell'aria. Durante il processo di fabbricazione vengono effettuati controlli sulle condizioni ambientali, che consentono il raggiungimento di uno specifico stato di curvatura e un determinato livello di umidità. Oltre al monitorare il comportamento delle lamelle, viene controllata la disposizione geometrica delle lamelle stesse e degli ancoraggi, poiché anch'essa influenza il movimento dell'intero sistema; infatti i vari meccanismi di apertura con forme geometriche differenti dimostrano comportamenti molto diversi in termini di distribuzione topologica, grado di apertura, direzionalità e coerenza di comportamento.

Due progetti, presi in esempio, si basano sull'utilizzo di materiali con attuazione igroscopica passiva e autonoma, suggerendo un approccio architettonico basato sulle capacità comportamentali intrinseche che possono rispondere ai cambiamenti climatici esterni. Il primo prototipo "HygroScope" è configurato per aprire le lamelle all'aumentare dei livelli di umidità relativa, mentre il secondo prototipo "HygroSkin" segue la risposta inversa, chiudendosi in condizioni di elevata umidità relativa. Entrambi i prototipi offrono una direzione concreta verso un processo di progettazione integrata, in cui il pensiero progettuale implica lo sviluppo di sistemi e reattivi. (Fig. 2)

Figure 2. Hygroskin, Frac Centre, Orleans, Francia – Hygroscope, Centre Pompidou, Parigi, Francia.

Tra esistente e innovazione

La tecnologia sensoriale raccoglie, archivia e cataloga una moltitudine di informazioni su utenti, ambienti e processi a scala globale. Questa informazione non presenta solo la moltitudine e la variazione insita in un sistema complesso ma forma anche la base per approfondire la comprensione della relazione reciproca che esiste tra parametri, vincoli, input e influenze di uscita. Questa comprensione rende imperativo lo sviluppo dell'architettura come sistema piuttosto che come un isolato oggetto o spazio.

La ricerca presentata dimostra due principali innovazioni nei paradigmi del design, delle quali verrà presentata di seguito un'applicazione.

Il primo paradigma innovativo, riferito ad una reinterpretazione della pietra, considera il design rigenerativo del materiale, accoppiato ad un supporto leggero e composito, che permette di ottenere un pannello decorativo di forma complessa ma leggero, senza compromettere qualità estetica e durabilità.

Il secondo paradigma, riferito ad un'applicazione innovativa del materiale legno, illustra il funzionamento, l'applicazione e la resa formale sull'edificio oggetto di studio, presentando le potenzialità funzionali ed estetiche del sistema, il quale, anziché sfruttare un complesso ed energivoro sistema elettromeccanico, sfrutta la variazione di comportamento al variare dell'umidità e della temperatura.

Eco restyling dell'esistente

L'edificio scelto è collocato nella zona di San Michele, una frazione collinare della V circoscrizione del comune di Messina, distante circa 3 km dal centro cittadino ,nella vallata del torrente omonimo, affluente del torrente Giostra. Considerando il patrimonio edilizio residenziale, situato nella zona in esame, possiamo notarne la grande diversificazione, infatti lo stesso ricomprende i rioni risalenti alla ricostruzione post-terremoto come "Casette Ritiro", i quartieri di edilizia popolare realizzati nel secondo dopoguerra e fino agli anni 1950-60 lungo la vallata del Giostra, le aree di espansione (per lo più edilizia agevolata e convenzionata), che negli ultimi trent'anni hanno saturato i quartieri San Licandro e Annunziata, ma anche complessi edilizi di maggior pregio lungo il Viale della Libertà e la Nuova Panoramica dello Stretto e i villaggi sia costieri che interni, caratterizzati da una edilizia "minuta", ormai inglobati dalle realizzazioni più recenti. (Fig. 3)

Per realizzare l'eco restyling è stata eseguita una elaborazione planimetrica, nella quale sono stati individuati ed evidenziati: lo stato odierno degli edifici originari del piano dello IACP (Istituto Autonomo Case Popolari) in relazione alle modifiche che hanno subito nel tempo e quelli demoliti o sostituiti con altri edifici; successivamente è stato condotto un controllo sull'infittimento edilizio, che non ha tenuto in considerazione la presenza di vincoli e parametri urbanistici, come per esempio, le distanze tra i fabbricati.

Figure 3. San Michele, V circoscrizione del comune di Messina, Sicilia, Italia

Nel progetto di eco restyling viene proposta una caratterizzazione formale dell'edificio attraverso l'utilizzo di pannelli in marmo alleggerito e pannelli ad alto contenuto tecnologico in lamelle di legno che seguono il principio igroscopico.

I pannelli in marmo alleggerito sono composti da due strati esterni sottili e resistenti ai quali si frappone un'anima (spesso indicata col termine core) a bassa densità. Il risultato è un composito a basso peso con un utilizzo efficiente dei materiali. Il comportamento strutturale è riconducibile a quello delle travi a doppia T. Le superfici esterne forniscono rigidezza a flessione e sopportano gli sforzi indotti dai momenti flettenti lavorando una in compressione l'altra in tensione, come le flange della trave. L'anima garantisce una buona rigidezza a taglio del pannello e mantiene le superfici esterne alla corretta distanza così da garantire il momento d'inerzia costante della sezione complessiva. I vari strati solitamente sono tenuti insieme da colle. I pannelli in marmo alleggerito vanno a ricoprire un'intera parete dell'edificio: la sottostruttura è una intelaiatura reticolare curvilinea, viene rivestita con i pannelli tetraedrici in marmo alleggerito, fino a dare la forma particolare di guscio, realizzata collegando tra loro i tetraedri con anelli di rinforzo e travicelli. (Fig. 4)

Mentre la parete rivestita in materiale biomimetico è formata da un telaio classico (montanti e traversi), dove vengono fissate le lamelle in legno, la cui forma può variare in base alle esigenze estetica: in questo caso hanno una forma a foglia, scelta in funzione della posizione del pannello. (Fig. 4)

Essendo di materiale igroscopico, il pannello stabilisce un equilibrio con l'ambiente circostante assorbendo o cedendo vapore acqueo. Il legno può contenere acqua in quantità variabili a seconda delle condizioni atmosferiche in cui si trova, in quanto l'assorbe e rilascia per raggiungere l'equilibrio igroscopico con l'ambiente. Quando il legno si ritrova circondato da aria umida, si ha da una parte una continua evaporazione di molecole d'acqua dal legno nell'aria che lo circonda e dall'altra una continua condensazione di molecole acquee dell'aria nel legno. L'equilibrio igroscopico è di tipo dinamico, viene spezzato e progressivamente ricreato quando variano le condizioni igrometriche dell'aria, questo processo permetterà alle lamelle in legno di aprirsi e chiudersi.

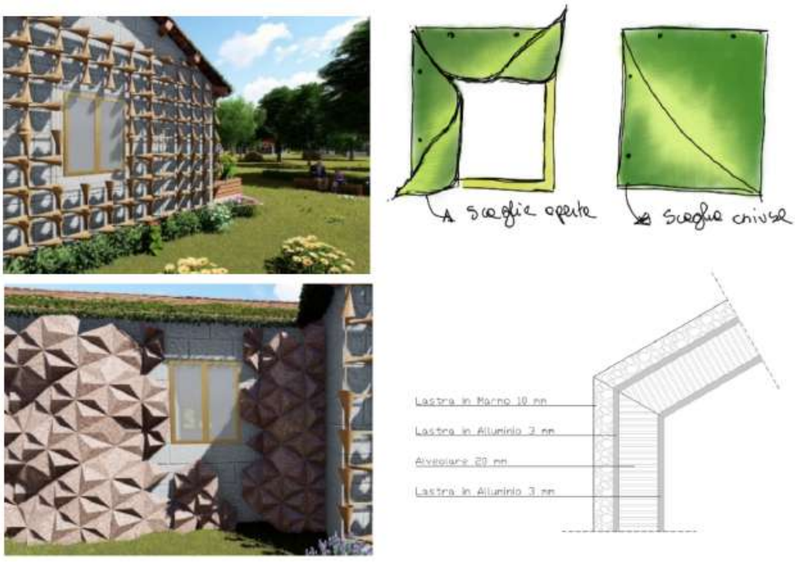

Figure 4. Eco restyling quartiere San Michele, V circoscrizione del comune di Messina, Sicilia, Italia

CONCLUSION

Sebbene la ricerca su questi materiali e l'applicazione ipotizzata rispondono ad un criterio di dimensioni ridotte del componente ligneo, è plausibile ipotizzare che attraverso meccanismi di produzione industriale si potranno incorporare proprietà prestazionali aggiuntive e superare le limitazioni delle dimensioni del pannello.

Il lavoro presentato illustra come questa interdipendenza tra il sistema e il suo ambiente possa essere sfruttata al meglio quando serve ad un analogo scopo, come nel caso del rapporto tra legno e condizioni atmosferiche, otra marmo e peso proprio. Qui, il sistema materiale è stato fortemente caratterizzato a livello morfologico, per lascare il segno di una nuova estetica e di una nuova tecnologia in un ambiente costruito fortemente degradato.

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Brochure: Sistema per pannelli in marmo alleggerito- Metal clip system for lightened marble panel

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SOSTENIBILIDAD EN LA CONSTRUCCIÓN: CASO DE INSTALACIÓN FOTOVOLTAICA EN INFRAESTRUCTURA AUXILIAR DE UNA PLANTA DE RESIDUOS NO PELIGROSOS

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ABSTRACT

Los sistemas de gestión de la calidad y medioambiente permiten la mejora continua de los procesos en industrias y en empresas de construcción. Partiendo de la ISO 14001 de medioambiente y la búsqueda de objetivos de mejora, se estudia la viabilidad de una instalación fotovoltaica para abastecer una de las infraestructuras auxiliares de la planta de Residuos No Peligrosos (RNP). Se establecen los factores clave que permiten implantarla mejorando todos los aspectos sostenibles de la instalación.

Keywords: ISO 14001, infraestructura auxiliar, instalación fotovoltaica, sistema de gestión, sostenibilidad.

INTRODUCTION

En la actualidad existen numerosos criterios y herramientas de evaluación de la sostenibilidad en infraestructuras y edificación que abarcan MÚLTIPLES enfoques como son la evaluación del proyecto y diseño, de la construcción, del comportamiento social, de la demanda energética, de los productos y materiales para la construcción, etc. (Gómez, 2019). Además, es importante ampliar este marco de trabajo desde el enfoque de la gestión durante la vida útil, detectando las mejoras posibles en el proceso de utilización de las infraestructuras y los edificios.

La cultura de mejora continua que los sistemas de gestión proporcionan a las empresas, así como la aparición de incentivos en España han impulsado la búsqueda de nuevos objetivos para elevar el desempeño ambiental de las empresas a través de las energías renovables.

Según Martí Casadesús (2009) "se puede definir la estandarización o normalización de forma genérica como la actividad encaminada a poner orden en aplicaciones repetitivas que se desarrollan en el ámbito de la industria, la tecnología, la ciencia y la economía". Este artículo trata de mostrar como la aplicación de los sistemas de gestión puede mejorar el ASPECTO ECONÓMICO Y AMBIENTAL en el funcionamiento y mantenimiento de infraestructuras auxiliares en un caso concreto.

Sistemas de Gestión

Existen multitud de normas o estándares entre los que destacan los dirigidos a sistematizar la gestión en beneficio de las organizaciones. Las normas de sistemas de gestión, en inglés Management Systems Standards (MMS) son una herramienta realizada por comités técnicos internacionales especializados y en colaboración con agentes expertos en las áreas de actuación, cuyo objetivo es proporcionar un marco común para la mejora de la gestión de las organizaciones que las implantan.

Los documentos creados por ISO son estándares de uso para cualquier organización independientemente de su tamaño. Los sistemas de gestión están redactados con una aplicación y finalidad (ISO 9001 para calidad, ISO 14001 para medioambiente, etc.) y se pueden utilizar en diferentes sectores como la administración, las industrias y servicios, aunque existen los que se han redactado para sectores específicos (ISO 29001 para industrias petrolíferas, petroquímicas y de gas natural).

Figura 1. Áreas de los Sistemas de Gestión.
Fuente: Elaboración Propia a partir (https://www.iso.org/the-iso-survey.html, 2021)

La norma ISO 14001 permite a las organizaciones tener un marco de referencia para proteger el medio ambiente. Utiliza el enfoque basado en el riesgo con un sistema de actuación Planificar-Hacer-Verificar-Actuar (PHVA) para lograr la mejora del desempeño ambiental, el cumplimiento de los requisitos legales y el logro de los objetivos ambientales.

Los sistemas de gestión de calidad, medioambiente y prevención destacan por su amplia implantación en las organizaciones (Bernardo 2009) y han demostrado su utilidad en las organizaciones en las empresas y administraciones.

SAV dispone desde hace más de 10 años las certificaciones ISO 9001, 14001 y 45001 que suponen una mejora permanente y aseguran una gestión de la calidad total en sus productos y servicios. La experiencia adquirida en la redacción y consecución de objetivos medioambientales, así como la necesidad de establecer nuevos objetivos año a año, plantea un reto cada vez más difícil de conseguir. Sin embargo, la irrupción de las energías renovables proporciona un nuevo marco de actuación como el caso que se presenta a continuación.

Estudio económico de instalación fotovoltaica para suministros de operación de infraestructuras auxiliares

S.A. Sociedad de Agricultores de la Vega (SAV) lleva a cabo la construcción y explotación de la planta de RNP situada en el término municipal de Dos Aguas, en la que se disponen de diferentes infraestructuras auxiliares.

Figura 2. Planta de eliminación de RNP y edificio de control.
Fuente: SAV, 2021

El edificio del personal de control requiere diversos suministros de operación las 24 horas del día como son: red de internet, teléfono, agua potable, electricidad. Debido a la falta de puntos de conexión a la red eléctrica en las inmediaciones el suministro eléctrico en la explotación de necesita el alquiler de grupos electrógenos. Tanto la construcción, como la explotación y el mantenimiento de la planta está condicionado por su ubicación, sin los suministros de operación "normales" y situada a más de 50 km. de la mayoría de las sedes de las empresas subcontratistas.

Inicialmente, para obtener el suministro eléctrico del edificio de control, se estudiaron varias posibilidades:

- Alquiler de grupos electrógenos a largo plazo
- Alquiler de grupos electrógenos con opción a compra
- Compra de grupos electrógenos y precios cerrados de mantenimiento a largo plazo

Sin embargo, con la aparición de la Resolución de 10 de mayo de 2021, de la Presidencia del Instituto Valenciano de Competitividad Empresarial (IVACE), por la que se convocan ayudas destinadas al fomento de instalaciones de autoconsumo de energía eléctrica, con cargo al presupuesto del ejercicio de 2021.(DOGV nº 9084 de 14/05/2021), se plantea la puesta en marcha de una instalación fotovoltaica en el edificio de control. Se realiza un estudio económico de la instalación fotovoltaica previo a la redacción del proyecto y solicitud de ayudas, que se estiman en un 25%, en comparación con los grupos electrógenos cuyos resultados se resumen a continuación.

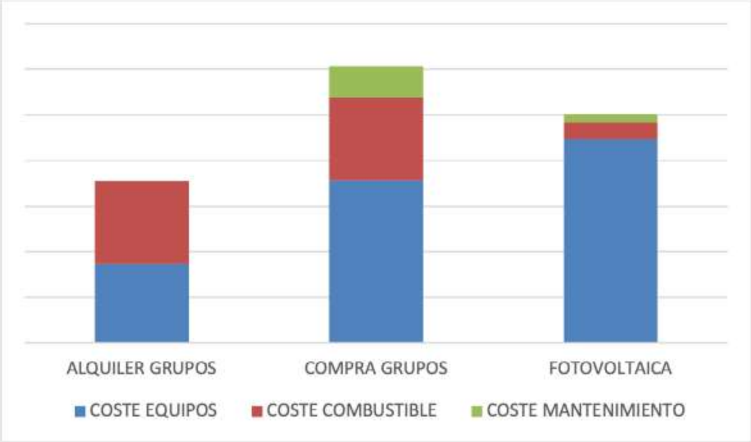

Gráfico 1. Estudio económico suministro electrico a un año.
Fuente: SAV, 2021.

Como se observa en el gráfico 1, el alquiler de grupos frente a la compra de estos tiene un coste menor y que sin embargo el coste de combustible es menor en la compra de grupos, debido principalmente a que los alquilados son usados y los comprados son nuevos y su rendimiento es mayor. Sin embargo, el coste en mantenimiento, en los equipos propios no es 0. Por otro lado, se observa que el coste de la instalación fotovoltaica es más del doble que el alquiler de grupos y algo más elevado que la compra de estos, y destaca el bajo coste de combustible (asociado a un grupo de emergencia que debe llevar la instalación) y el bajo coste de mantenimiento.

Es por tanto a primera vista más rentable el alquiler de grupos, ¿pero ¿cuál es su coste medioambiental? ¿y si se prolonga el uso de la edificación en el tiempo? En el caso de estudio, el edificio de control se va a utilizar hasta la colmatación de la planta e incluso, aun colmatándose, se todos los equipos se pueden reutilizar en una nueva ubicación, sean los grupos o sea la instalación fotovoltaica. Se realiza un cálculo aproximado de los costes teniendo en cuenta una vida útil mínima de tres años, que posiblemente aumente en el futuro.

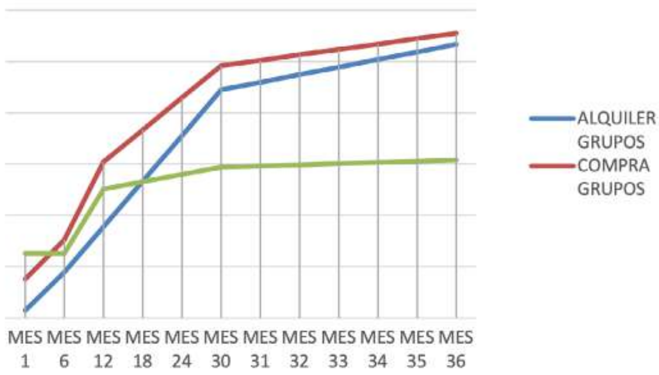

Gráfico 2. Estudio económico a 3 años.
Fuente: SAV, 2021.

Teniendo en cuenta la estimación de vida útil de la edificación por un mínimo de tres años, el estudio económico resultante demuestra que el coste a 3 años de la instalación fotovoltaica es menor que el resto, quedando el alquiler y la compra de grupos casi igualados en costes muy por encima de la fotovoltaica. En el gráfico 2 se observa además como en el mes 18, la instalación fotovoltaica empieza a ser rentable frente al alquiler.

Estudio ambiental de instalación fotovoltaica para suministros de operación de infraestructuras auxiliares

Una de las principales amenazas según el análisis DAFO de la planta, es el excesivo consumo de combustible. El sistema de gestión medioambiental requiere la redacción de unos objetivos de mejora para las amenazas por lo que además de los beneficios económicos de la instalación fotovoltaica, se pretende estudiar sus beneficios ambientales, consiguiendo así cumplir otro de los aspectos de la sostenibilidad.

Para ello, utilizamos la metodología que se encuentra en las directrices de ISO 14001, que consiste en establecer los objetivos enfocados a los procesos de mayor riesgo. Los tres pasos principales se aprecian en la siguiente figura.

Figura 3. Procedimiento para el studio de mejora ambiental.
Fuente: ISO 14001, 2021

Definición del objetivo

El objetivo se debe redactar de forma que defina de manera inequívoca cuál es su objetivo ambiental y que de su interpretación se puedan establecer las metas para conseguirlo. En la figura 1 se muestra un ejemplo de la web creada para la gestión y desarrollo de los sistemas.

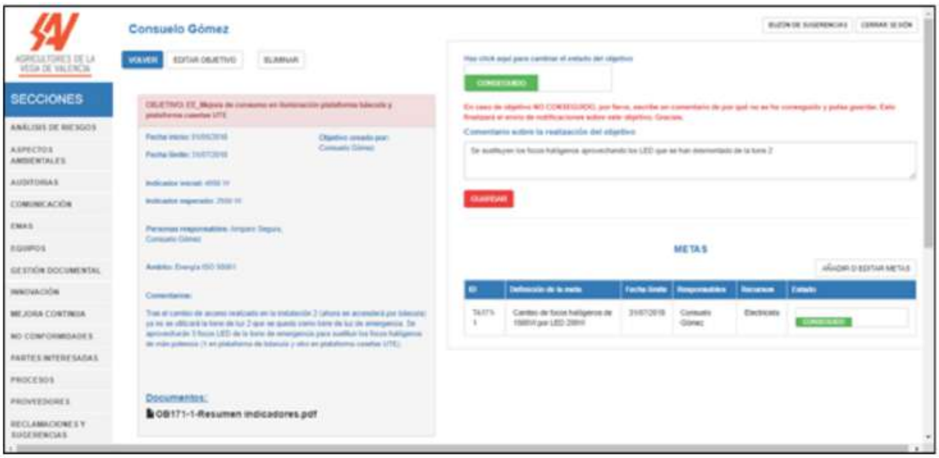

Figura 4. Vista de la aplicación destinada al seguimiento del Sistema Integrado de Gestión (SIG).
Fuente: SAV, 2021

En el caso de estudio, el título de objetivo y la descripción son:

Acción planteada *(OB280) Reducción de un 3% de consumo gasoil en edificio de control y pesaje (báscula) –Planta de eliminación de RNP Instalación 2. En la Instalación 2 se utilizan dos grupos electrógenos de alquiler (uno de emergencia) para el suministro de electricidad en el edificio de control y pesaje, que comprende la báscula,* *el sistema de control, la iluminación exterior y los equipos de las estancias de operadores y de dirección. Estos grupos se colocan inicialmente según la potencia indicada por el instalador. El objetivo es ajustar la potencia de los grupos y cambiarlos por unos nuevos de menor consumo para reducir un 3% el consumo de gasoil.*

Establecer indicadores

Los indicadores se definen con la colaboración del personal de la planta y los técnicos que conocen los procesos y controlan los datos de donde se extraerán los indicadores. Serán fácilmente medibles y se debe establecer el indicador base o inicial (datos reales) para planificar el indicador esperado (dato teórico según el objetivo redactado).

En el caso de estudio, los indicadores son:

- ***Indicador inicial**: 1,93 l/h consumo de combustible en litros/hora en el año 2020*
- ***Indicador esperado**: 1,87 l/h consumo de combustible en litros/hora en el año 2021 (3% menos que el indicador inicial)*

El indicador inicial es un dato real. Para el cálculo de este caso concreto se han extraído los litros de combustible de los documentos de descarga de combustible en el depósito de 500 litros del edificio de control durante el año 2020. Las horas totales registradas en los grupos electrógenos se obtienen de los partes diarios del personal y de los partes de revisión de las empresas de alquiler. Se establece un factor de emisión para cada litro de combustible (gasoil) que consumen los grupos electrógenos, según Ecología. Net (2018) se ha establecido una media de 2,61 kg CO2 por cada litro de combustible.

Establecer metas y control

Se establecen una o varias metas que permitan conseguir el objetivo global, de forma que se controlen todos los pasos a seguir para la consecución favorable del objetivo de reducción de 3% de consumo de combustible en el edificio de control. Las metas deberán definirse como acciones concretas dentro del objetivo y se establecerán los plazos y recursos necesarios para su realización y control.

En el caso de estudio, las metas y su resultado son:

Meta 1: Monitorización de la potencia eléctrica consumida en el edificio de control

- *RECURSOS: Electricista.*
- *PLAZO: fecha límite 31/10/2020.*
- *RESULTADO: CONSEGUIDO. Se coloca un aparato de medida de potencias consumidas en el cuadro general de distribución y se obtienen los datos en excel.*

Meta 2: Análisis de datos obtenidos

- *RECURSOS: Empresas de alquiler y venta de grupos electrógenos.*
- *PLAZO: fecha límite 30/11/2020.*
- *RESULTADO: CONSEGUIDO. Se envían los datos a empresas de alquiler y venta de grupos electrógenos y se solicita un estudio de mejora de consumos.*

Meta 3: Cambio de grupos electrógenos por otros de menor consumo

- RECURSOS: Cambio de grupos por parte de la empresa de alquiler o venta.
- PLAZO: fecha límite 31/12/2020.
- RESULTADO: CONSEGUIDO. Se colocan grupos de menor potencia (pasan a ser en lugar de 45 kvas, grupos de 35 kvas) y con menor consumo teórico a la hora. Se colocan de alquiler para poder realizar el cambio en la fecha prevista.

Meta 4: Control semestral del indicador esperado

- RECURSOS: Albaranes, documentos de descarga, partes de revisión y partes diarios.
- PLAZO: fecha límite 07/07/2021.
- RESULTADO: CONSEGUIDO. El resultado conseguido es mejor incluso que el esperado como se observa en la tabla siguiente.

INDICADORES L/H	Indicador Inicial (año 2020)	Indicasdor esperado 1er semestre 2021	Indicador obtenido 1er semestre 2021
Reducción de consumo gasoil L/H	2,31	2,24	1,93

Tabla 1. Indicadores del objetivo medioambiental.
Fuente: SAV, 2021.

Meta 5: Control final del indicador esperado

- *RECURSOS: Albaranes, documentos de descarga, partes de revisión y partes diarios.*

- *PLAZO: fecha límite 15/01/2022.*
- *RESULTADO: NO CONSEGUIDO. Durante el segundo semestre, esta meta ya no será válida, debido a que, durante el proceso de estudio económico de la mejor opción para suministro eléctrico, se decide apostar por las energías renovables y se ha instalado planta fotovoltaica para autoconsumo que se pone en marcha a partir del 01/07/2021.*

Definición de un nuevo objetivo

En el caso de estudio, el título del nuevo objetivo y la descripción son:

Acción planteada (OB281) Reducción del 70 % del consumo gasoil en edificio de control y pesaje (báscula) – *Planta de eliminación de RNP Instalación 2. En la Instalación 2 se utilizan dos grupos electrógenos de alquiler (uno de emergencia) para el suministro de electricidad en el edificio de control y pesaje, que comprende la báscula, el sistema de control, la iluminación exterior y los equipos de las estancias de operadores y de dirección. Estos grupos se sustituirán por una instalación fotovoltaica que constará de 40 placas solares, 3 baterías y un grupo de emergencia para carga de baterías durante la noche.*

CONCLUSION

Las empresas que tienen una cultura arraigada en sistemas de gestión valoran positivamente la irrupción en el mercado de las energías renovables y, aunque la inversión es alta en comparación con los equipos tradicionales, hay que analizar cada caso de forma individual ya que se pueden establecer objetivos de mejora muy ambiciosos.

En este caso el factor clave y determinante para la instalación de la planta fotovoltaica es la VIDA ÚTIL restante de la planta de Residuos No Peligrosos (suficiente para poder amortizar la inversión) así como su UBICACIÓN que determina la imposibilidad de conexión a la red eléctrica. Otros factores positivos en este caso es la FACILIDAD DE MONTAJE Y DESMONTAJE de la instalación con la posibilidad de ser trasladada a otra ubicación, así como la mejora sustancial en la emisión de CO_2 y ruidos al entorno natural.

El Sistema de Gestión Medioambiental ISO 14001 impulsa la SOSTENIBILIDAD gracias a la consecución de unos objetivos medibles y una planificación ordenada de los mismos, contribuyendo de forma sustancial a la implantación de energías renovables en gran variedad de usos e infraestructuras. Las energías renovables suponen para la empresa un AHORRO ECONÓMICO Y AMBIENTAL, pero, además, una mejora para la SOCIEDAD.

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LA TUTELA DEI VALORI MATERIALI E IMMATERIALI NEL RETROFIT DELL'ARCHITETTURA INDUSTRIALE DI VALENCIA (PARTE 1)

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ABSTRACT

In questo lavoro vengono presentate le principali caratteristiche costruttive dell'architettura industriale valenciana sulla cui base si propone una catalogazione. La catalogazione per caratteristiche tipologiche e tecniche costruttive ha consentito di valutare le metodiche di riuso per categorie omogenee di edifici attraverso la compilazione di apposite schede intervento. Lo studio svolto ha consentito di misurare la diffusione degli interventi applicati e la loro tipologia. I dati raccolti sono funzionali alla stesura di una metodologia di retrofit attenta alla protezione e valorizzazione dei beni materiali e immateriali del patrimonio industriale di Valencia.

Keywords: Riuso, Retrofit, Architettura Industriale, Valorizzazione Sostenibile, Valencia.

INTRODUCTION

L'industrializzazione spagnola si è sviluppata attraverso varie fasi alle quali corrispondono, architettonicamente, le caratteristiche che contraddistinguono gli edifici industriali nei diversi periodi produttivi: ciò è dipeso sia da esigenze socio-culturali ed economiche, anch'esse in evoluzione, che dai materiali da costruzione e dalle tecniche costruttive in uso. Nel libro Metodología para la recuperación y puesta en valor del padrimonio industrial arquitectónico viene descritta accuratamente l'evoluzione degli stili architettonici negli anni della rivoluzione industriale: Diana Sánchez distingue cinque periodi fondamentali, definendo per ognuno le tipologie costruttive e le caratteristiche salienti degli edifici realizzati.

Nel periodo pre-industriale, e fino al XVIII secolo, per attività produttive si intendono per di PIÙ laboratori artigianali, ubicati all'interno della vivienda, l'abitazione dell'artigiano. Durante il periodo medievale vennero costruiti i primi edifici destinati al commercio las lonjas e los mercados luoghi dove mercati e commercianti si riunivano e svolgevano anche funzioni amministrative. Nella città di Valencia è possibile ammirare la Lonja de la Seda Fig. 1, costruita intorno al 1483, e dichiarata

Figure 1. Valencia, Lonja de la Seda, XV secolo, vista della facciata principale e vista interna della Sala de Contratacion Source. Massari, G. (2020)

Patrimonio dell'Umanità dall'UNESCO nel 1996, esempio di architettura tardo-gotica con decorazioni sgargianti, porte monumentali e pilastri scultorei. Rappresenta l'antica prosperità di Valencia, un tempo una delle città mercantili PIÙ potenti del Mediterraneo. È composta da quattro ambienti principali: la Torre – luogo di detenzione per i ladri di seta e i mercanti disonesti la Sala del Consulado del Mar, il Patio de los Naranjos e la Sala de Contratacion. Quest'ultima è un'ampia sala al piano terra, costituita da colonne elicoidali che sostengono la copertura a volte, mentre con una monumentale scalinata in pietra, passando per il giardino, si accede alla sala del mare, ornata da un tetto in legno, in cui è rappresentato lo stemma della città.

Bisogna attendere il 1700 per veder costruire quelle che vengono considerate come le prime vere fabbriche spagnole, ispirate ai grandi palazzi reali francesi: le Reales Fabricas. Sono edifici in stile classico che imponenti, simulando le residenze reali, proponevano la simmetria in facciata e il patio centrale. Erano fabbriche in cui si producevano principalmente armi, monete, tabacco, ceramica, carta e beni di prima necessità per la nazione tutta. Citiamo la Fábrica Real de Tabacos di Siviglia, costruita in circa 40 anni dal 1728 al 1763 la PIÙ grande di tutta la Spagna-, la Real Fábrica de Tapices di Madrid del 1721 in cui si producevano arazzi e la Fábrica de Armas di Toledo, che iniziò la sua produzione di spade nel 1761.

Il periodo della rivoluzione industriale (XIX sec.) è invece caratterizzato dalla disconnessione della fabbrica dal luogo in cui si trovano le materie prime, generando così dei nuclei industriali a se stanti. Edifici simbolo di questo periodo furono le stazioni ferroviarie come la Estación de las Delicias di Madrid, costruita del 1880, e la Estación de Norte di Valencia, realizzata agli inizi del 1900 dal noto architetto Demetrio Ribes.

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In tutta la storia architettonica industriale spagnola si possono individuare due principali tipologie costruttive che, ancora oggi, nel paese vengono identificate con lo svolgersi di attività produttive. Queste sono:

- *La Fábrica de pisos*: edifici sviluppati in altezza, con pianta rettangolare e uno stile assimilabile alle viviendas. Avevano un carattere severo, con aperture ripetute e modulari e facciate scarsamente decorate. I materiali PIÙ utilizzati erano il legno, la muratura e la pietra.

- *La Fábrica-nave*: edifici a pianta rettangolare e un solo livello. La copertura era in capriate lignee o metalliche. Questa tipologia consentiva ampie luci, libertà distributiva interna e quindi una grande flessibilità nell'utilizzo della struttura e nell'organizzazione del lavoro.

Caratteristiche costruttive dell'architettura industriale valenciana

Sistema costruttivo

Il sistema costruttivo della tradizione valenciana ha subito l'evoluzione delle tecniche e della tecnologia utilizzate in relazione alle diverse esigenze e funzioni richieste da ogni fase storica legata all'industrializzazione. I sistemi costruttivi principali sono di seguito classificati in 4 gruppi Fig. 2, Fig. 3, Fig. 4, Fig. 5-, discriminati in funzione della tipologia di copertura adottata:

- Le travi della copertura inclinata poggiano sui muri perimetrali e su un muro centrale più alto generando due falde simmetriche;
- Per evitare la partizione centrale coincidente con il muro di sostegno del colmo della copertura, viene inserita una trave orizzontale appoggiata ai maschi murari perimetrali;
- Per aumentare l'altezza fruibile dell'edificio la trave orizzontale viene sostituita con il puente, traslando la posizione del tirante più in alto;
- Per le naves industriales, edifici con notevoli superfici di sviluppo, viene introdotta la capriata.

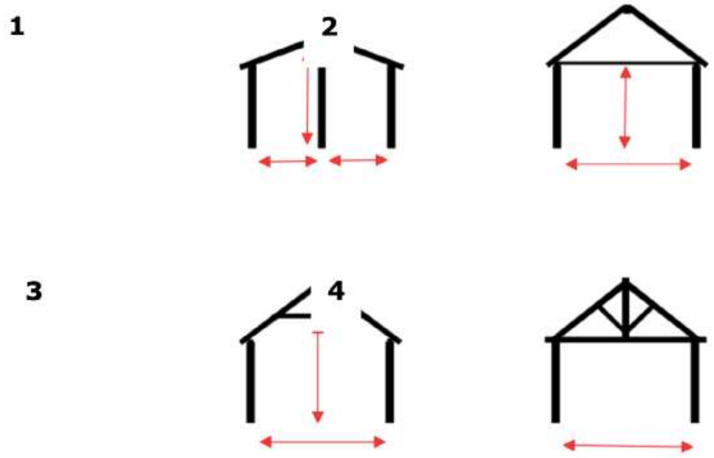


Figure 2. Tipologie costruttive per gli edifice industriali a Valencia
Source. Massari, G. (2020)

La copertura inclinata

Le falde inclinate appertenenti alle 4 tipologie di coperture descritte sono composte dai seguenti elementi:

- Par: ogni elemento principale della struttura di una copertura che segue la direzione della pendenza;
- Correas: elementi collocati trasversalmente alla pendenza, generalmente appoggiati a los pares;
- Cabios: situati sopra las correas nella direzione di massima pendenza;
- Latas o listones: posizionati sopra los cabios, servono da supporto o da fissaggio per il manto della copertura.

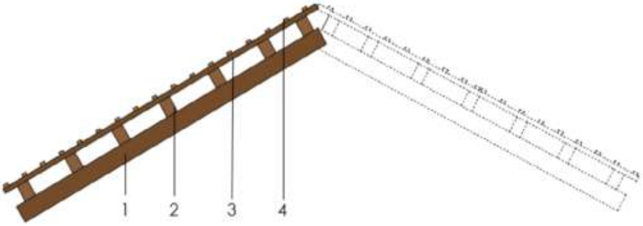


Figure 3. Elementi principali di un tetto in legno utilizzato nella copertura di edifici industriali a Valencia
Source: Massari, G. (2020)

Per quanto riguarda i materiali, la caña è molto utilizzata fin dall'antichità, per la facile lavorazione e la diffusione nella valle del Turia soprattutto nella realizzazione di controsoffitti.

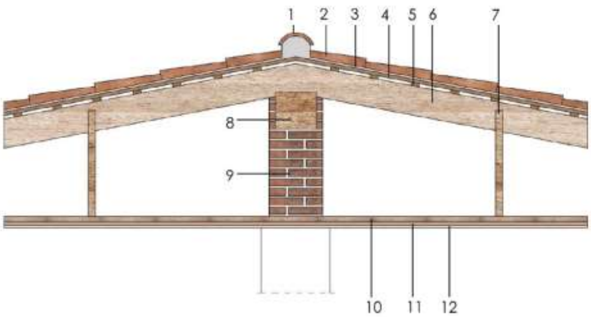


Figure 4 .Tetto in legno a cañizo. 1-Coppo di colmo; 2-Manto di copertura in tegole o in coppi; 3-Malta di allettamento; 4-Pianellato; 5-Correnti; 6-Travi; 7-Supporto controsoffitto; 8-Trave di colmo 30x24cm; 9-Piedritto; 10-Listello in legno di appoggio; 11-Incannucciato; 12-Strato di gesso 1.5 cm
Source: Massari, G. (2020)

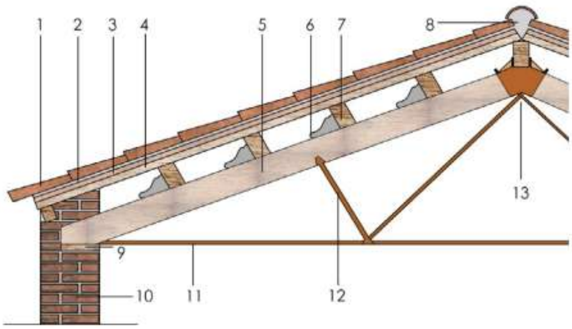
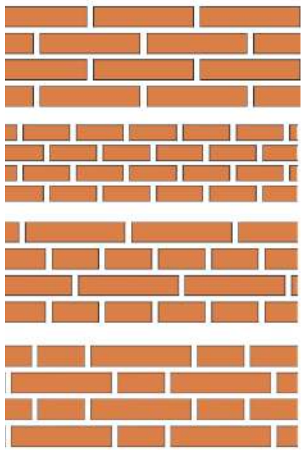


Figure 5. Tetto in legno con tiranti in ferro. 1-Manto di copertura in tegole o in coppi; 2-Malta di allettamento; 3-Pianelle; 4-Correnti; 5-Gattello; 6-Arcareccio; 7-Puntone; 8Coppo di colmo; 9-Giunto in ferro; 10-Dormiente; 11-Pilastro in laterizio; 12-Tirante in ferro; 13Contraffisso in ferro.
Source: Massari, G. (2020)

Tipologie di aparejos

Per quanto riguarda le strutture verticali, queste sono costituite da pilastri o murature in mattoni, più raramente, e a seconda del periodo di realizzazione, vediamo l'utilizzo di pilastri metallici. Esistono vari modi – aparejos di disporre il singolo mattone in accordo con la tradizione locale o secondo criteri estetici e costruttivi. Per quanto riguarda la posizione del ladrillo nella composizione della muratura, la tradizione propone varie tipologie; le principali vengono riportate di seguito:

- Aparejo de Soga: i mattoni sono disposti in direzione longitudinale rispetto allo sviluppo della parete, in modo che siano a vista las sogas;
- Aparejo de Tizón: i mattoni sono disposti in direzione trasversale rispetto allo sviluppo della parete, in modo che siano a vista los tizón;
- Aparejo Belga: i mattoni sono disposti a file alternate in senso longitudinale (soga) e in senso trasversale (tizón), con una corrispondenza di giunti verticali tra le file disposte a tizón;
- Aparejo Flamenco: i mattoni sono disposti in modo alternato a soga e a tizón, con corrispondenza dei giunti verticali.



RISULTATI

A partire dallo studio delle tipologie e degli elementi costruttivi dell'architettura industriale valenciana, attraverso ispezioni in situ e ricerche d'archivio, è stata svolta una ricognizione del patrimonio industriale valenciano per conoscere lo stato di conservazione dei fabbricati. L'analisi ha consentito una classificazione delle principali strutture presenti sul territorio in funzione dello stato di degrado/danno e del tipo di riuso applicato/applicabile. A partire dalla tipologia costruttiva Fig. 6, è stata svolta una successiva catalogazione in base al sistema strutturale Fig. 7. Nell'analisi svolta, oltre alla divisione per tipologia costruttiva, è stato indicato, per ogni edificio, lo stato attuale e la presenza o meno della ciminiera, la quale rappresenta un elemento tanto di vulnerabilità strutturale quanto di pregio per il suo valore storico-documentale. Per gli edifici già riqualificati e recuperati è attualmente in corso la redazione di schede approfondite sulla tipologia di intervento svolto Fig. 8.

FRABRICA NAVE			
Tipología	Nome	Stato Attuale	Ciminiera
	Almacén S.A. Cross	Riqualificata (SCHEDA R-01)	
	Naves Abonos Azamón		
	Fábrica de Bombas Gens	Riqualificata (SCHEDA R-02)	
	Matadero de Valencia-La Petxina	Riqualificata (SCHEDA R-03)	●
	La Fábrica de Hielo	Riqualificata (SCHEDA R-04)	
	Naves de Cross	Riqualificata (SCHEDA R-05)	
	Naves Castellano	Riqualificata (SCHEDA R-06)	
	Naves de Abonos Campos Crespo	Riqualificata (SCHEDA R-07)	
	Naves Demetrio Ribes 1-4	Riqualificata (SCHEDA R-08)	
	Serrería el Carmen	Riqualificata (SCHEDA R-09)	
	Tingaldo 2 Puerto de Valencia	Riqualificata (SCHEDA R-10)	
	Tinglado 4-5 Puerto de Valencia		
	Molí Nou (o de la Saïda)		●
	Fábrica Japonés Català	Riqualificata (SCHEDA R-11)	●
	El Almudin	Riqualificata (SCHEDA R-12)	
	Almacén de la Noguera		
	Aceitera Vidal		●
	Naves Castellano	Riqualificata (SCHEDA R-06)	

Figure 6. Stralcio della catalogazione degli edifici industriali valenciani per tipologia costruttiva
Source: Massari, G. (2020)

FRABRICA DE PISOS	
Sistema puntiforme	Muri portanti
Fábrica de Harinas	Almecén de metales
Lonia de pescadores de la Marina Auxiliante	Matadero del Grao
Aceitera Marxalenes	Magatzements Plaspel (Sugein)
Fábrica la Ceramo	Alquería de Albors
Imprenta Vila	Fábrica Nacional de tabacos
Fábrica de Mobles Pamaber	Antigua estación térmica transformadora H.F
Fábrica Harinas Berenguer	Molino Arrocero Serra
Fábrica Harineras Levantinas	Alquería de SS Llorenc, Molí de S. Miguel
Central eléctrica Nou Moles	Casa dels Bous
	Fábrica de tabacos (Tabacalera)
	La Batifora

Figure 7. Stralcio della catalogazione degli edifici industriali valenciani per tipologia strutturale
Source: Massari, G. (2020)

CONCLUSION

Il lavoro presentato ha messo in luce come nel riuso del patrimonio industriale sono diversi i filoni tematici che meritano ulteriore approfondimento da parte della ricerca scientifica, tutti interdipendenti tra loro. Questi riguardano la conservazione e tutela del patrimonio di architettura industriale attraverso l'individuazione di metodologie di recupero compatibili con i valori mobili e immobili; la possibilità di valorizzare tale patrimonio attraverso un riuso sostenibile; la possibilità di contribuire al miglioramento prestazionale degli edifice della città di Valencia attraverso il retrofit di un'ingente porzione di patrimonio.

lo sviluppo delle analisi descritte, consultabile in "La tutela dei valori materiali e immateriali nel retrofit dell'architettura industriale di Valencia (parte 2)", sarà l'individuazione di una metodologia volta alla riqualificazione dei siti industriali che vertono ancora in stato di grave danno e abbandono. Infatti l'architettura industriale della città di Valencia, per la cospicua presenza di manufatti in disuso e grazie ai sempre PIÙ numerosi interventi di riuso, si presenta come una delle leve strategiche per il rilancio socio-economico della città attraverso l'applicazione di un retrofit multidisciplinare e multiobiettivo.

NOME: **BOMBAS GENS**

LUOGO: Barrio: Marxalenes - Av. de Burjassot, 54

ANNO DI COSTRUZIONE : **1930**

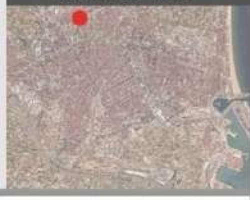
TIPOLOGIA DI FABBRICA: **NAVES**

DESTINAZIONE D'USO ORIGINALE: Fabbrica di pompe idrauliche

STATO DI PROTEZIONE: **BRL**

STATO: **RIQUALIFICATO**

SCHEDA R-02



Fonte: www.bombasgens.com

DESCRIZIONE

Siamo nel 1930 quando la vecchia officina di famiglia di Carlos Gens Minguet è diventata con il tempo molto nota e richiede una nuova sede che soddisfi le nuove esigenze. Per la sua costruzione, Gens incarica un noto architetto dell'epoca, Cayetano Borso di Carminati, il quale realizza una fabbrica dal design diverso e innovativo. Nel progetto, oltre che a tener in considerazione il processo produttivo della fonderia, si tiene conto della vita dei lavoratori all'interno della fabbrica, progettando per loro spogliatoi con docce e una sala da pranzo. E' dotata anche di giardino. La fabbrica è stata chiusa definitivamente nel 1991, con il susseguirsi di un lento declino della struttura, a seguito dell'abbandono e della mancanza di manutenzione, che culminerá nell'incendio di una parte del complesso nel 2014.

SISTEMA STRUTTURALE E MATERIALI

SIST. STRUTTURALE: Sistema Puntiforme

MATERIALI: ***LADRILLO***

TIPO DI *APAREJOS: Aparejo de Tizón*

COPERTURA: A due falde

STRUTTURA: Capriate in acciaio

MANTO: Tegole arabe in ceramica

DOCUMENTAZIONE FOTOGRAFICA STATO ATTUALE

Fonte: propria

INTERVENTO DI RIQUALIFICAZIONE

NUOVA DESTINAZIONE D'USO: Sede della fondazione *Per Amor a L'Art*, Centro d'arte

ANNO DI INTERVENTO: 2017

AGGIUNTE DI CORPI: **SI,** è stato aggiunto un edificio in perfetta armonia con il contesto utilizzando i medesimi materiali

DESCRIZIONE DELL'INTERVENTO: sono stati effettuati interventi nel rispetto del costruito. Sono stati preservati i materiali originali, rinforzandoli e sostituendo solo gli elementi deteriorati. a livello strutturale sono state rinforate le pareti e ripristinata la copertura, mantenendo gle elementi originali. Come si può vedere dalle immagini a lato, sono stati ripristinati anche il rifugio costruito durante la guerra per ospitare i lavoratori in caso di bombardamenti e una antica alqueria, di cui il primo piano non si è conservato.

Figure 8. Sheda del riuso redatta per la fabbrica Bombas Gens
Source: Massari, G. (2020)

ACKNOWLEDGEMENTS

Il lavoro di ricerca nasce dalla collaborazione tra il Dipartimento di Ingegneria Civile, Edile-Architettura e Ambientale dell'Università degli Studi dell'Aquila, l'Istituto per le Tecnologie della Costruzione del CNR e l'Università Politecnica di Valencia. In particolare la ricerca presentata è stata svolta grazie al finanziamento Short Term Mobility 2019 fruitore post-doc fellow Mariangela De Vita e al finanziamento Fondazione Filauro 2019/2020 fruitore Ing. Giulia Massari.

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LA TUTELA DEI VALORI MATERIALI E IMMATERIALI NEL RETROFIT DELL'ARCHITETTURA INDUSTRIALE DI VALENCIA (PARTE 2)

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ABSTRACT

Il riuso dell'architettura industriale è divenuto in breve tempo una delle leve strategiche per il rilancio di città e territori con benefici di natura economica e sociale. Nella città spagnola di Valencia il processo di recupero e riuso di questo patrimonio ha avuto un grande impatto sull'assetto urbano e ha contribuito a modificare sostanzialmente la vita socio-culturale della popolazione. Questo paper porta ad esempio alcuni edifici, recuperati o in fase di restauro, simbolo del passato industriale della città di Valencia: qui la storia dei luoghi e delle tecniche costruttive del tempo hanno lasciato un'eredità forte che prepotentemente riecheggia in un'architettura storicizzata e allo stesso tempo resa contemporanea dal riuso per mezzo di interventi dal gravoso impatto estetico, materiale ed economico. Tali caratteristiche rendono l'oggetto della ricerca uno stimolante campo di indagine in cui è necessario l'approccio multidisciplinare al retrofit con la finalità del cambio di uso. La progettazione consapevole deve essere guidata dagli obiettivi della tutela dei valori, materiali e immateriali, e della sostenibilità dell'intervento. A tale scopo in questo lavoro si presenta una metodologia di intervento da applicare in coerenza con l'attuale Plan Nacional de Patrimonio Industrial.

Keywords: Riuso, Retrofit, Architettura Industriale, Valorizzazione Sostenibile, Valencia.

INTRODUCTION

Il concetto di patrimonio industriale è stato definito nella Carta di Nizhny Tagil nel Luglio del 2003: "Il patrimonio industriale è costituito da resti di cultura industriale di valore storico, tecnologico, sociale, architettonico o scientifico. Questi resti sono costituiti da edifici e macchinari, officine, mulini e fabbriche, miniere e siti per la lavorazione e la raffinazione, magazzini e negozi, luoghi in cui viene generata energia, trasmessa e utilizzata, trasporti e tutte le sue infrastrutture, nonché luoghi utilizzati per attività sociali legati all'industria come l'alloggio, il culto religioso e l'istruzione" (Olivares, 1996).

In Spagna, tra il 2011 e 2012, è stato messo a punto e attuato il Piano Nazionale per il Patrimonio Industriale, che ha come obiettivo quello di preservare e conservare l'eredità storica dell'industrializzazione presente sull'intera nazione. Nel PNPI, il patrimonio industriale viene definito come segue: "Il patrimonio industriale è inteso come l'insieme di sistemi mobili, immobili e di socialità legati alla cultura del lavoro che sono stati generati dalle attività di estrazione, trasformazione, trasporto, distribuzione e gestione derivate dal sistema economico emerso durante la "rivoluzione industriale". Questi beni dovrebbero essere intesi come un insieme integrale composto dal paesaggio in cui sono inseriti, dalle relazioni industriali in cui sono strutturati, dalle architetture che li caratterizzano, dalle tecniche utilizzate nelle loro procedure, dai file generati durante la loro attività e dalle loro pratiche." (Martinez Pino, 2018).

Il concetto di "Patrimonio Industriale" si presenta dunque come molto ampio, includendo nelle realtà produttive di interesse anche le relative infrastrutture e i luoghi di produzione, oltre al contesto, territoriale e culturale, necessario all'attività di lavorazione.

Il Plan Nacional de Patrimonio Industrial è dunque il principale strumento normativo spagnolo per la conservazione del vasto patrimonio industriale presente sul territorio nazionale. El Instituto de Patrimonio Cultural de Espana, nel 1999, iniziò a redigerlo in seguito alla progressiva perdita di una parte di patrimonio: l'obiettivo del Piano era quello di preservarlo in tutte le sue forme e di diffonderne la conoscenza. Nel 2011 la revisione del PNPI, attualizzata poi nel 2016, è atta a promuovere gli studi sulla storia dell'industrializzazione, il turismo industriale, la valorizzazione dei beni e la rigenerazione dei quartieri su cui tali beni insistono. Approcciare la valorizzazione rese necessario affrontare la definizione dei valori da tutelare prima e potenziare poi, elencando quali fossero i beni immobili, mobili e immateriali oggetto del Piano.

Nei beni immobili troviamo:

- Elementos industriales (elementi industriali): possono essere resti di complessi industriali o elementi nati isolati chetestimoniano un'attività produttiva passata (ad esempio le ciminiere);
- Conjuntos industriales (complessi industriali): sono le fabbriche di cui sono conservati la maggior parte degli elementi caratteristici;

- Paisaje Industrial (paesaggio industriale): è il territorio dove si conservano gli elementi essenziali ad esempio lematerie prime di un processo industriale;
- Sistemas y redes industriales (sistemi e reti industriali): sono la testimonianza della pianificazione territoriale per il trasporto di materie prime.
- I beni mobili si distinguono in quattro categorie:
- Artefactos (artefatti): dispositivi atti a ottenere, trasformare e produrre energia per l'attività produttiva;
- Utillajes (strumenti): tutti gli strumenti necessari all'esecuzione del lavoro associato all'attività produttiva;
- Moliliario y accesorios (attrezzature e accessori): tutte le attrezzature e il mobilio degli ambienti legati al luogo di lavoro;
- Archivos (documenti): i registri e i documenti generati per le attività economiche.
- Infine, nei beni immateriali troviamo:
- Entidades de memoria de industria (memoria dell'attività industriale): tradizioni, tecniche e testimonianze legateal mondo dell'industria.
- Nel Piano vengono definiti alcuni aspetti metodologici individuando area tematiche, criteri di intervento, fasi di attuazione e inserendo allegati, aggiornati nella revisione del 2016, con la lista di tutti gli oggetti di riferimento del piano, la normativa specifica e gli interventi già realizzati.

Nel Piano vengono definiti alcuni aspetti metodologici individuando area tematiche, criteri di intervento, fasi di attuazione e inserendo allegati, aggiornati nella revisione del 2016, con la lista di tutti gli oggetti di riferimento del piano, la normativa specifica e gli interventi già realizzati.

Sulla base della normativa vigente si attende, dunque, nella città di Valencia, un recupero del patrimonio industriale orientato alla tutela dei valori materiali e immateriali citati dalla norma. Di contro, dalle analisi effettuate sulle principali architetture industriali della città, recuperate e non, si è rilevato come, sebbene si evidenzi un'attenzione al recupero dei valori culturali, la progettazione manca di una metodologia condivisa per la valorizzazione degli stessi con uno sguardo alla sostenibilità e alla reversibilità degli interventi.

Lo stato dell'architettura industriale valenciana

Nel corso del 2020, grazie alla collaborazione tra L'Università degli Studi dell'Aquila, L'Università Politecnica di Valencia e L'Istituto per le Tecnologie della Costruzione del CNR è stato svolto uno studio preliminare dell'architettura industriale presente sul territorio della città di Valencia con il fine di acquisire lo stato dell'arte riguardo la conservazione ed il riuso dei fabbricati[1].

In seguito alla ricognizione dei manufatti e all'analisi sulle tipologie costruttive e sugli interventi prevalenti, al fine di comprendere il rapporto generatosi tra riuso del patrimonio, retrofit, tutela dei valori e sostenibilità ambientale, la ricerca è stata approfondita attraverso indagini non distruttive in situ effettuate su alcuni casi studio selezionati. Le indagini e i sopralluoghi si sono svolti presso La Aceitera de Marxalenes Fig. 1. e 2., La Biblioteca Municipal Joanot Martorell, L'Almudín Fig. 3. e La Fábrica del Hielo.

Figure 1. Valencia, Aceitera de Marxalenes, XVIII secolo, vista del cortile comune alla biblioteca municipale e alle naves; viste interne del magazzino e dei laboratori, in fase di riqualificazione
Source: De Vita, M. (2020)

1 *Consultare "La tutela dei valori materiali e immateriali nel retrofit dell'architettura industriale di Valencia (parte 1)" e la pubblicazione De Berardinis, P., De Vita, M., Palmero Iglesias, L. M., & Trizio, I. (2019). Valorizzazione del patrimonio industriale del XX secolo: esperienze di riuso nella città di Valencia. Restauro Archeologico (Online), 27(2), 70-91.*

Figure 2. Valencia, Aceitera de Marxalenes, XVIII secolo, vista del vista del forno e della ciminiera adiacenti la nave principale
Source: De Vita, M. (2020)

Figure 3. Valencia, Almudìn, XIV secolo, prospetto principale e vista interna dell'aula – originariamente cortile
Source: De Vita, M. (2020)

La campagna di analisi termografiche ha consentito di avere una conoscenza dettagliata dell'involucro dei manufatti indagati. I dati raccolti hanno permesso di diagnosticare lo stato di conservazione della muratura, il degrado dovuto alle infiltrazioni di acqua e al fenomeno di risalita capillare che in molti casi stanno provocando rigonfiamento e distacco superficiale dell'intonaco originario e lesioni/fratture dei laterizi a causa di efflorescenze saline. Tutte le patologie citate sono state riscontrate in edifici oggetto di recenti restauri o del riuso dei fabbricati, il che testimonia come un'attenzione al retrofit e alla prestazione ambientale delle strutture coinvolte sarebbe stata necessaria, a differenza di quanto comunemente accaduto negli interventi già applicati. Inoltre, porre la sostenibilità ambientale come una questione centrale del riuso consentirebbe una maggiore tutela dei valori materiali e immateriali presenti, spesso riportati in luce più per finalità estetico compositive che non per ragioni di conservazione, valorizzazione e trasmissione dell'identità culturale dei luoghi.

Esemplificativo, a tal proposito, è il caso dell' Almudín, antico granaio nel cuore della città storica, sul quale le immagini termiche hanno rivelato la presenza di un arco tamponato, non visibile ad occhio nudo, all'interno della muratura orientata a ovest Fig. 4. e 5. In questo caso, non si comprende la ragione dell'aver privilegiato, in occasione del restauro del manufatto, di lasciare a vista alcuni archi tamponati a scapito di altri, tradendo l'identità costruttiva del bene immobile con una discriminazione su valori invece assimilabili tra loro.

Un ulteriore aspetto da considerare riguarda le destinazioni d'uso dei manufatti, che se nel passato prediligevano le attività industriali e/o commerciali, oggi si aprono alle più disparate funzioni: dai centri polisportivi e culturali, fino a comprendere club, musei e luoghi di culto. Il cambio di destinazione d'uso ha, infatti, un impatto sull'utilizzo dei sistemi di condizionamento dell'aria che, a loro volta, comportano una variazione del microclima interno originario minando potenzialmente lo stato di conservazione dell'involucro storico e del suo pregio.

Paradossale è l'esempio della Fabrica de Hielo, in cui il degrado superficiale sembra essere il presupposto irrinunciabile dell'estetica richiesta alla nuova destinazione d'uso di "pub underground" Fig. 6.

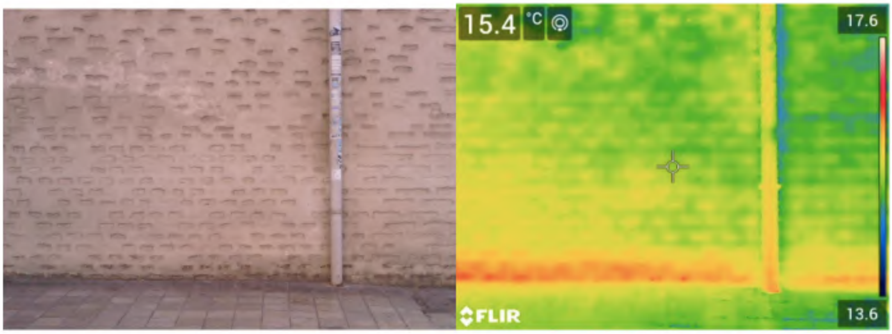

Figure 4. Valencia, Almudìn, XIV secolo, prospetto nord. Confronto tra immagine digitale e immagine termografica che mostra la reale conformazione della muratura (laterizi e pietrame misto)
Source: De Vita, M. (2020)

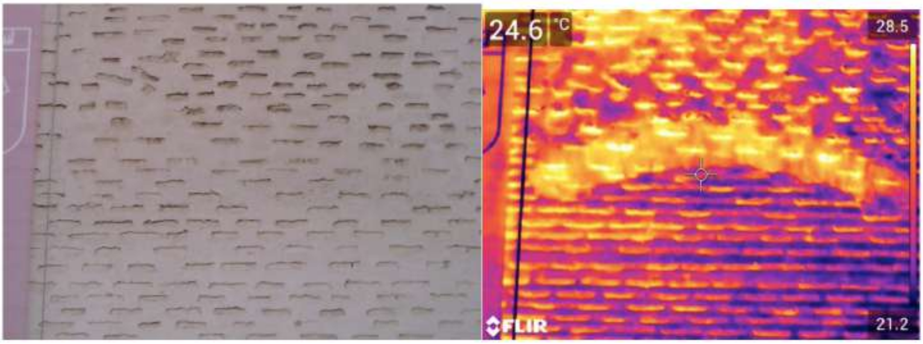

Figure 5. Valencia, Almudìn, XIV secolo, prospetto ovest. Confronto tra immagine digitale e immagine termografica che mostra la presenza di un arco tamponato e nascosto dalla finitura
Source: De Vita, M. (2020)

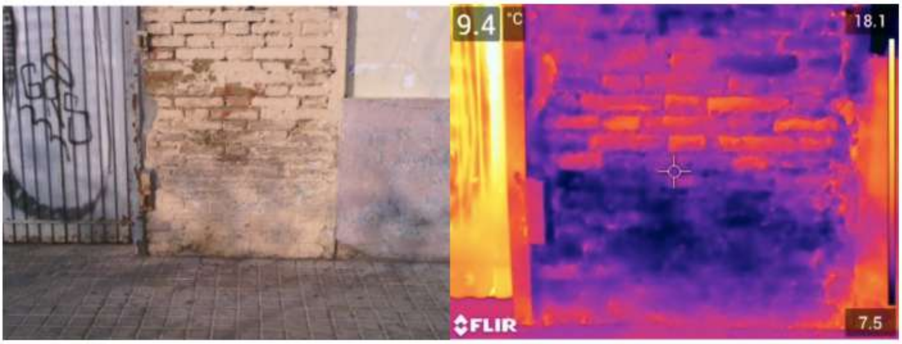

Figure 6. Valencia, la Fabrica de Hielo, XIX secolo, ingresso su prospetto principale della nave. Confronto tra immagine digitale e immagine termografica che mostra la presenza del fenomeno di risalita capillare, causa dell'evidente distacco dell'intonaco originario
Source: De Vita, M. (2020)

A partire dalle criticità rilevate, si riporta di seguito la sintesi di una metodologia di intervento atta a definire un possibile approccio di riuso sostenibile del patrimonio industriale che possa tenere conto, già in fase di progetto, delle problematiche legate ad una tutela consapevole dei valori costruttivi, materiali e immateriali. Seguendo la metodologia possono essere individuati scenari di intervento compatibili con l'architettura storica, verificando inoltre la possibilità di adozione e/o potenziamento dei sistemi di controllo passivi atti al raggiungimento delle condizioni di comfort minimizzando l'utilizzo degli impianti di condizionamento dell'aria e il loro impatto ambientale e materiale sui beni. Gli scenari di intervento ipotizzati seguendo la metodologia possono essere verificati attraverso modelli energetici sviluppati a monte del processo, in modo da poter valutare gli effettivi miglioramenti prestazionali dell'edificio rispetto allo stato ante operam.

Tale metodologia può essere così di seguito sintetizzata in 3 step principali Fig. 7:

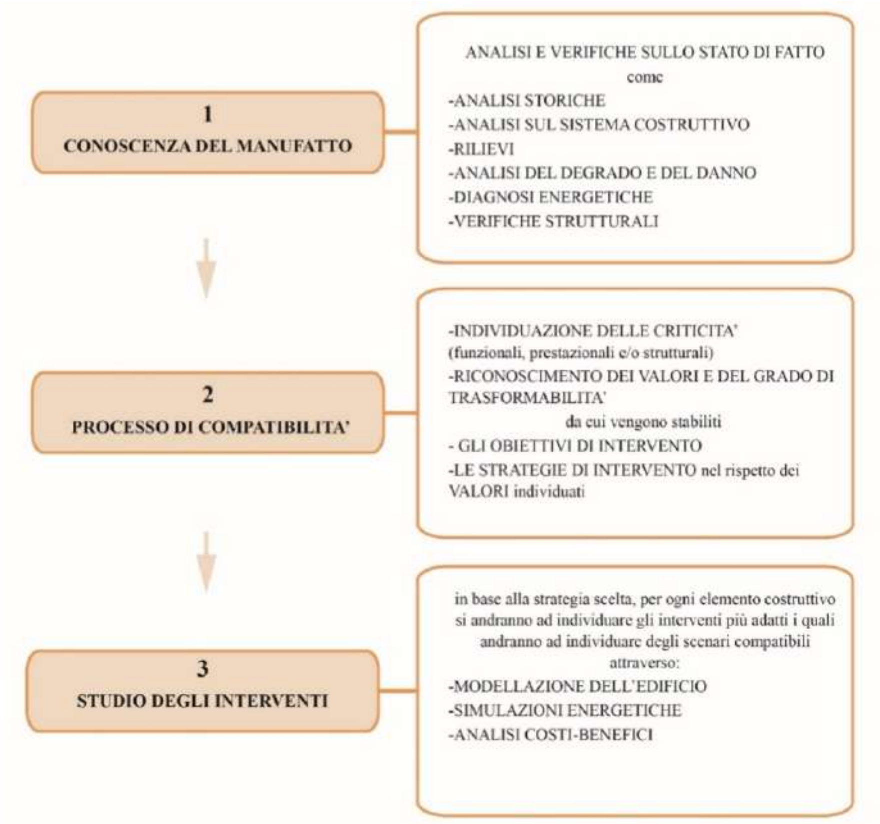

Figure 7. Percorso metodologico per la progettazione del riuso sostenibile dell'architettura industriale dismessa
Source: De Vita, M.; Massari, G. (2020)

Il percorso metodologico individuate in figura 7 include già nelle fasi progettuali di conoscenza del manufatto la diagnosi energetica. Questa, posta alla base del processo di design, contribuirà alla definizione degli obiettivi di intervento in opportune analisi critiche che includeranno i risultati delle analisi sui valori da tutelare e gli obiettivi di un riuso più prettamente funzionale.

CONCLUSION

Il lavoro di ricerca svolto sul patrimonio industriale ha evidenziato la necessità di far convivere, nella riqualificazione e nel riuso delle architetture industriali, i diversi approcci progettuali legati al restauro e al potenziamento prestazionale. Scopo del lavoro, tutt'ora in corso, è quello di dimostrare, attraverso una metodologia, coerente agli obbiettivi dei diversi approcci, come l'intervento di riuso sostenibile possa garantire tanto la tutela dei valori espressi dal patrimonio quanto la valorizzazione degli stessi. In questo senso, la sostenibilità del retrofit non dovrebbe essere volta al mero miglioramento prestazionale delle strutture oggetto di intervento, bensì ad una programmazione oculata del ciclo di vita dell'edificio e dei suoi componenti, originari e di nuova introduzione. L'obiettivo di un riuso che possa avere il minor impatto materiale sul bene e il maggior beneficio in termini di sfruttamento delle risorse impiegate nel retrofit è in questo modo PIÙ facilmente perseguibile.

Ad oggi, l'analisi dettagliata e critica dello stato dell'arte ha portato alla conoscenza degli elementi e dei sistemi coinvolti nel patrimonio industriale che interagiscono a diversa scala. Grazie a questo sarà possibile individuare quelle soluzioni di retrofit energetico compatibili con la valorizzazione delle testimonianze legate all' industrializzazione, dall'eccezionale valore documentale, materiale e immateriale.

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CONTRIBUTO DEGLI AUTORI

Mariangela De Vita ha scritto e ideato la ricerca e il paper. Giulia Massari ha scritto l'introduzione e svolto le analisi termografiche insieme a Mariangela De Vita. Luis Palmero Iglesias ha reso possibile le indagini sui casi di studio e contribuito significativamente alla definizione della ricerca e all'individuazione degli edifici idonei alle indagini. Pierluigi De Berardinis ha preso parte al gruppo di ricerca, consentito la sua costituzione, partecipato alla definizione del progetto supervisionandone l'andamento e i risultati.

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THE INTRINSIC TECHNIQUES OF TRADITIONAL ARCHITECTURE. CASE STUDY OF SMALL VILLAGES IN A MEDITERRANEAN REGION

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ABSTRACT

Traditional architecture represents the majority of the architectural heritage that surrounds any territory. This architecture is linked to a tradition, a link with the natural environment and knowledge that are part of the intangible heritage of any community. However, it is currently marked by abandonment, changes in use and the loss of the traditional trades that built it or made it evolve. This article is part of a larger project that highlights the more modest architecture of a region in the western Mediterranean Sea. The article outlines how popular knowledge directly related to construction techniques and the evolution of modest historical centres has been recovered. It studies the links with the heritage of the local population and artisans. It explains how a search for traditional trades has been carried out, the lessons they have taught researchers and the prospects that this heritage can have through participation and collective management.

Keywords: Traditional building techniques, historic centres, heritage values.

INTRODUCTION

Traditional architecture has shaped the landscapes and scenery of our history. In its enormous diversity, dazzling creativity, and perfect harmony with the natural environment, one of the richest and most varied areas of heritage. Its importance is enormous as an expression of a society, a reflection of geographical conditions, and a support for intangible heritage (IPCE, 2015).

However, traditional architecture has been abandoned for many decades (Marull *et al*., 2014), transformed and disappearing. Studies and research have been numerous for decades (Fuentes, 2010; García Hernández *et al*., 2017; Mualam and Alterman, 2020), but the process of disappearance of properties in cities, towns, villages and isolated nuclei is still a topical issue.

Historic centres have an important history to tell, highly influenced by the successive layers of each place's socioeconomic and cultural evolution. If we look at the building typologies in historical centres, the result is a very rich and diversified space. Throughout their history, the different societies that have passed through them have left their mark, giving rise to a harmoniously varied ensemble (Yildirim, 2012). The perception, appreciation, and recreation of abandoned cultural landscapes are based on the transmission of knowledge (Kastenholz *et al*., 2012). Since the landscape is a concept to be constructed, both physically and intellectually, knowing and helping others identify how a current layer responds to previous layers and the framework for subsequent changes will directly affect how a historic centre is managed. Indeed, one of the many ways to understand the history of landscape change is to recognize that change itself is a part of the landscape (Fairclough, 2012), even though change means abandonment.

Recent international studies on historic centres (UNESCO, 2011; English Heritage, 2010) posit them as areas resulting from an overlay of cultural and natural values and attributes that go beyond the notion of a historic centre or ensemble (Rey-Pérez and Siguencia, 2017). They aim to include a broader urban context and environment based on participation, knowledge, planning, current legislation, and places' traditional economic or financial tools (Ginzarly *et al*., 2019). In this regard, Ginzarly *et al*. (2019) conduct a systematic study of the management of historic centres through literature and cases evaluated over eight years and demonstrate that, while the debate is focused mainly on values, the implementation of an approach based on the values themselves analyzed is still lacking, as it is not fully contextualized concerning local heritage discourses and the dynamics of heritage management.

In many rural villages, social and cultural imbalances have led to abandonment, underutilization, or incompatible uses in the built environment (Ribera *et al*., 2020). On the other hand, historic areas in towns and cities are part of memory and have meaning because of their essential elements linked to tradition (Wang, 2012). As Ruda (1998) explains, in this area, attention should be paid to the specific techniques, materials and architectural details characteristic of the historic environment, being, at the same time, symbols of identity and evidence of knowledge of past technologies that speak of previous ways of life.

This study is located in a small region on the east coast of Spain, a rural area to the Mediterranean Sea (Fig. 1). The study includes ten municipalities with common characteristics: demography, economy, society, problems and constraints. Through the specific fieldwork of this and previous research directly related to this project, we present the hidden knowledge that remains in these small towns and how they would benefit the local heritage.

To study the link that continues to exist between artisans and the construction techniques that built the historic centres, the following hypotheses are put forward:

- Traditional architecture generates a link inseparable from the craftsmen who built it.
- There is a latent concern in the conservation of the historic centres of small mountain municipalities.
- It is possible to revalue the hidden intangible heritage through citizen participation.

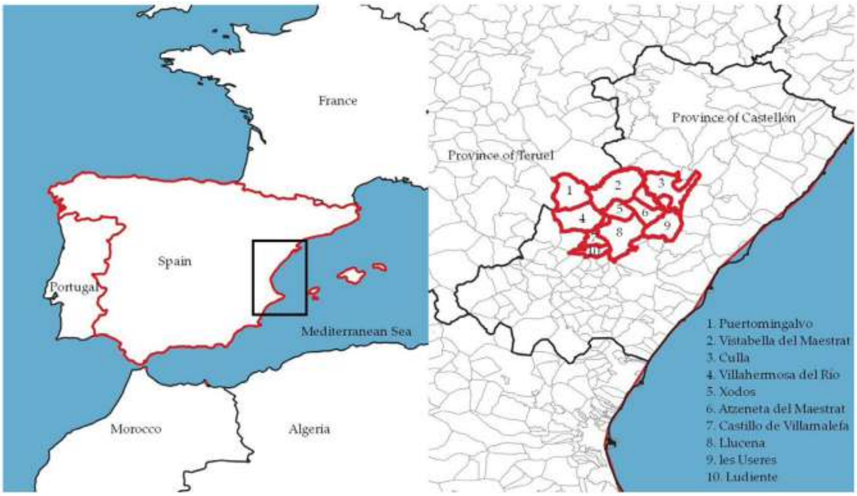

Figure 1. Study area.
Source. Authors.

STUDY AREA AND METHOD

Area characteristics

The region's architecture is characterized by vernacular dwellings that epitomize the medieval culture based on mobility and life on the land (Fig. 2). However, the historic urban centres still contain traditional buildings that use local materials and construction techniques inherited from the 17th century. These landmark settlements are built on rock, with masonry walls and small openings that have evolved into larger ones, hand-forged balustrades, and balconies, and wooden or ceramic eaves with curved tiles. The facades have a lime and sand-based mortar coating, whitewashed, and occasionally coloured with bluish, ochre or greenish tones. The primary materials are pine wood for the carpentry, beams and joists, and wood and iron trellies. Based on these essential elements, there are numerous variations, depending on the different periods of prosperity, decline and migration, and knowledge, climate, and materials' availability. Thus, today's historic urban centres have changed. They are now the result of continuous evolution and adaptation based on interpretation and deregulation.

Figure 2. Sample of the historic centre of Atzeneta del Maestrat. Traditional houses and rehabilitated houses.
Source. Authors (2019)

METHOD

Previous work describes the work prior to these interviews with artisans and some post-interview results. We talk about methodologies to evaluate architecture (García-Esparza, 2011, 2014; García-Esparza *et al*. 2018), landscapes (García-Esparza, 2018), society (Altaba and García-Esparza, 2018), the regulation of heterogeneous manifestations (García-Esparza, 2019) or the results of an exhaustive cataloguing (García-Esparza and Altaba, 2020).

An essential part of these works is the culture and social development involved in conserving ancient crafts. To understand this background in villages with low population density, we interviewed retired artisans or artisans who still work with traditional techniques. In this case, semi-structured interviews were used (Arias, 2011; Bignante, 2010). This work consists of raising common themes for all artisans (origin, dedication to the craft, place of work, etc.), a specific part of each craft (construction techniques, obtaining materials, etc.) and a free part where the conversation would derive (anecdotes, stories, particular details of the work, etc.).

To obtain this contact with the artisans, and through previous work, we contacted neighbours who had already participated in the project. They were the ones who spoke with the researchers to determine which people were appropriate for this type of interview. As a result, a total of one painter, eight masons, three blacksmiths, four carpenters and one stonemason were contacted. The interviews were generally conducted in their workshops (Fig. 3). Therefore, in addition to talking about their trade, samples of their work and practical explanations were also obtained and could be documented. In some cases, after the interviews, a tour of the municipality was conducted where the artisans showed their work.

Figure 3. Interview with J. Gimeno, blacksmith from Villahermosa del Río.
Source. Authors (2019)

The interviews lasted approximately two hours and were recorded. Subsequently, they were transcribed to be able to review them in-depth. During the previous work, it was observed that the constructive elements that have more value for the population were the openings, carpentry, balconies, railings and coatings, among others. So, from the beginning, the interviews were conducted in that direction.

RESULTS

The first result obtained was the linkage and attachment that these people continue to have with their trades. Workshops, tools and knowledge acquired through experience are still preserved in each of the artisans. However, although they coincided with the rest of the population in the most characteristic elements of their architecture, they broadened our spectrum much more. In the following table, it could see the main questions that were addressed in the interviews with the masons:

CATEGORY	SUBCATEGORY
Vertical structure	Ashlar masonry walls
	Masonry walls
	Rammed earth walls
	Pillars
Openings	Round arches
	Pointed arches
	Basket-handle arch
	Flat arches
Balconies	Wall flush balconies
	Partly projecting balconies
	Projecting balconies
Coatings	Coating mortars
Floor and ceiling frameworks	Ceilings made of gypsum jack vaults
	Frameworks with brick jack vaults
	Frameworks with wooden boards
Eaves	Eave made of joists
	Eave made of curved ceramic tiles
	Eave made of solid brick
	Eave made of curved ceramic tiles
	Stone eave
	Cornices
Roofs	Reed frameworks
	Wooden decking
	The bark technique
	Jack vaults for roofing
Staircases	Tiled vault staircases
	Reed vault staircase
	Stairs with wooden stringers
	Access stairways

Table 1. Construction techniques analyzed in the interviews with the masons.
Source. Authors.

For each of the subcategories, an explanation was obtained as in the following text, in this case of the tiled vault staircases:

"The most widespread use of this vaulting technique was to construct load-bearing structures for stairs. The vaults were built in independent stages, generally locking and resting on the previous ones until they reached the desired height. The staircase vaults consisted of three layers, although two were more common. In the first layer, bricks were fixed with gypsum and no centring, while the other layers were fixed with lime or cement mortar intermittently between the brick courses.

As previously mentioned, the first vault of a staircase was generally supported at one end by a mass acting as a counterweight at ground level. At the other end it was supported by a recessed groove in the corresponding structural element of the upper storey, either a load-bearing wall or a beam. On the second stretch of tile-vaulting the first layer rested on the second course of bricks of the previous stage, and so on. When designing vaults, it was essential to take into account:

- Limiting overloads with slight curves,
- The fact that the vault supported not only steps and landings, but also the upper section of the vault,
- If possible, loads were to be balanced symmetrically on both sides of the closest point to the tangent, between the arch directrix and the underside of the steps."

In the case of the carpenters, they talked about how they built doors and windows by hand. They talked about types of wood, tools and the construction techniques they used to facilitate their work.

The blacksmiths talked about the construction of railings and balconies from an artisan point of view, how they joined the metal to the forge, using rivets, obtaining the metal to do their work, etc. They talked about the construction of details and ornaments, their tools and how they made them themselves and details such as bolts or handles for the doors. In the following fragment, you can read how a trellis was built:

"The construction of trellises is exact work as square or round metal bars of about 18 mm are heated, shaped and perforated on the anvil. The task varied depending on the type of bar. Artisans used rounded bars for assembly, making holes in both vertical and horizontal ones with a blacksmith's punch and a hammer. This work required precision since the assembly depended on the position of all the openings in the trellis. As the trellis was held together by its shape it required no riveting or welding.

Another type of trellis was riveted at the ends and constructed like a metal balustrade, with plates of about 30 mm and square bars roughly half that thick. Holes were also made with a punch and needed to be square to fit the square bars. Plates were finished at the ends with rivets, heating the metal and striking it repeatedly.

There are also simpler trellises where plates of a given thickness were drilled together and joined with riveted bolts. In the same way, there are some fine examples of rounded trellises made by heating the vertical bar. These particular decorations were made in two or more specific parts of the bar with a blacksmith's chisel, or later by adding welded or riveted artisan decoration."

DISCUSSION AND CONCLUSIONS

This work is an intermediate point of other parallel investigations in the same area. In this case, it shows a brushstroke of the much information acquired in the fieldwork. In this study, it has obtained evidence that there is still interest in conserving construction techniques and historical centres of small mountain villages.

In many cases, traditional architecture has been the driving force, together with other activities of the small villages. It is associated with many trades: masons, stonemasons, carpenters, blacksmiths, mountain workers, and from the 20th century onwards, other works related to installations.

In the small municipalities covered by this study, the heritage is still preserved and recreated by the population. The inhabitants account for how the different cultural values have been maintained and transmitted through the generations. In line with Beel *et al*. (2017), they have allowed us to clearly describe a set of relationships and connections that continue to maintain these cultural values today. The resilience of rural communities and their understanding of heritage has enabled the enhancement of local culture. It is based on the idea of resilient preservation, which is reflected in the concepts of esteem and attachment to places (Hammitt *et al*., 2009).

The work of interviewing retired artisans or those who have dedicated most of their lives to a craft reflects the evolution of these trades. For example, techniques have been modernized, new sources of materials, greater job security, and decoupling what was considered a craft from what is merely a job.

In this sense, the concern in this area is worth mentioning for the abandonment of the modest heritage that historic centres represent. In the same way, it is faced in the line of objectives that reflect both the Historical Urban Landscape (UNESCO, 2011), Historic Area Assessments (English Heritage, 2010) and the National Plan for Traditional Architecture (IPCE, 2015) seeking citizen participation, research and the enhancement of a heritage hidden for most of the citizenship.

Finally, we should highlight the paradigm shift that participation in municipalities with few inhabitants implies. Bringing the population the concerns and knowledge of those who have been part of the dynamic evolution of local heritage is a turning point both for the people and for heritage managers. This means recognizing that the historic environment is linked to popular culture and humble contemporary minorities. Therefore, connecting citizens to this reality has created authentic and meaningful practices in which tangible and intangible heritage act to unify interests and expectations.

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DESIGN AND CONSTRUCTION OF LARGE SUSTAINABLE INDUSTRIAL PLANTS: A CASE STUDY

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ABSTRACT

This article is based on the case study of an industrial plant with design based on parameters such as the improvement of reliability, maintainence and efficient operation, as well as energy efficiency and environmental concerns. Key decisions like the reliability of facilities, and installations, cutting down time intervals, energy efficiency and environmental impact analysis impact the design of a new industrial plant. The prominent steps are listed by the Directorate of Engineering and Maintenance, supported by the President and the General Direction of the industry. The factory has set a benchmark for the industry and currently is one of the first companies in its sector in the national and European level.

Keywords: Industrial plant, industrial management, energy efficiency, environmental management.

INTRODUCTION

In the industrial construction sector, planning new industries mainly depend on the economic factor (in the short term), avoiding factors that promote the best exploitation and maintenance of the industry, a higher degree reliability, as well as proposing a greater number of actions to improve respect for the environment for a longer term.

This industrial sector faces constant transformations towards better quality actions, economy in production and user acceptance with challenges that have a greater incidence on processes compared to other types of manufacturing industries. When a process of building new industrial plants is proposed in order to increase the level of production or service, the decisions made marks the trajectory of the company in the medium and long term. In this article, the facilities, experiences and decisions taken are presented, and proposed by the company's own engineering and maintenance management, and supported by the president and general management of the company. In the implementation of an industrial complex, with a goal oriented towards the proper operation and maintenance (Cárcel *et al*., 2021a; Cárcel *et al*., 2021b), with a fundamental commitment to appropriate maintenance, operational and energy efficiency and respect for the environment. In this case study, some of the main decisions to realize a model industrial plant are shown, which demonstrates an advance with respect to the typical solutions for this domain. The authors of this article argue their experience, given that they have participated directly in the design of this plant, the design was analyzed for the reliability and improvement of operational maintenance.

Principles of Sustainability

The design of an industrial plant should be based on the best operation for a reliable and economic process (González, 2005; Tavares, 2004; Sols,2000) adequate maintenance to achieve its goals and respect for the environment (Corral *et el*., 2007; Cárcel *et al*., 2021c; Cárcel *et al*., 2021d)

It is because of the above that the current industrial trend has strived to make production facilities increasingly efficient (Amorós, 2003) with the maximum possible availability (Ogaji, 2002) departments are distributed in such a way as to positively influence the way in which the plant operates (Sule, 2001)

Based on the operational experience. (in an industrial plant previously built in another town and currently in operation), and taking into account the general considerations for the adequate project of the production process, and a philosophy of total quality control, they were pointed out as fundamental principles of the design and implementation of their facilities the following:

- Design based on reliability.
    - *Redundant systems to avoid production stoppages.*
    - *Possibility of quick actions in the event of breakdowns.*
- Design based on Maintainability.
    - *Efficient and economical maintenance.*
    - *Adequate maintenance spaces.*
    - *Design to organizational maintenance techniques (TPM, RCM).*
    - *Involved and motivated maintenance staff.*

- Design based on energy efficiency and alternative energies.
  - *Thermal, fluid and electrical systems with less energy need.*
  - *Support through renewable energies.*
- Design based on respect for the environment.
  - *Degradable and environmentally friendly plant materials.*
  - *Reusable wastewater.*
  - *Collection of rainwater for use in secondary activities.*
- Design based on information and knowledge management.
  - *Compilation of operating experiences manoeuvres of facilities*
  - *Scada technical information system for the entire factory.*
  - *Managing maintenance operational knowledge of technicians.*

Design processes and execution of installations

In the industry, the necessary quality parameters are broad and continuous improvement, with constant evaluation of energy demand. It is logical that in the approach to the design of a new factory (Fig. 1), these values should be implicit from the beginning. A phase of the beginning of success is to amplify the synergy between the intervening groups: Engineering, installation, and assembly companies, and above all, the organization's own knowledge (which are the ones who really know what they want, need, and how they operate), and that promote collaboration and optimize the supply chain in execution (Whipple et. al.,2007), allowing an improvement in communication and information exchange (Carr et. al.2007).

Figure 1: Implementation of news factories.
Source: own elaboration.

Based on this, we participated with the design of the industrial estate, where the factories would be located, the environmental regulations required, and the guidelines for energy supply and fluids, based on the reliability of the quality of the electricity supply (redundant systems both in lines and in medium voltage switchgear, with remote controlled systems).

The second phase consisted of the design of the factories and their facilities with the criteria based on the previous section, in an environment of total reliability, maintainability and agile and structured operation, respect for the environment and maximum energy efficiency, as well as the consideration of the mechanisms for capturing useful information and knowledge of proper management.

Reliable Design

Reliability is the fundamental idea to maximize the efficiency of production equipment and facilities and minimize the number and type of failures that can cause production stop (Sols,2000)

It was initiated with the following criteria in reference to electrical energy (in order to increase reliability), which led to the development of electrical distribution projects:

Redundant supplies from the substation itself, with power availability up to 35,000 kW.

- Possibility of alternative supply from different substations, evaluating cost and reliability, with an optimized model that is optimal for service requirements.

- Redundant delivery centers in the urbanization itself.

- Remote remote control systems and automatic network switching, for use in critical actions.

In the same way, within the internal distribution of the factory, some of the important decisions to increase said reliability in all the facilities and services were the following:

a) Increase in electrical reliability:

With an installed power of more than 25,000 kW, the internal distribution is made up of 16 dry transformers of 1250 kVA each, centralized in three independent transformation centers, with a design based on the centers of gravity of the loads. Some of the general characteristics taken are:

Redundant systems in medium voltage electrical installations (20 kV), both at the level of lines and power transformers, as well as redundancy in the main LV networks (400 / 230V).

Replacement of LV power cables by prefabricated electrified conducts (Fig. 2), in order to reduce the probability of failure by said components and load capacity at any given time.

Figure 2. Detail of electrified pipeline system and dry transformers.
Source: own elaboration.

- OKKEN type electrical power panels, with removable power switches, in order to foresee, possible substitutions without affecting production in a fast and efficient way.

- Uninterruptible power supply systems through dynamic UPS (flywheels).

- System for monitoring and control of electrical distribution. Control of lighting installations.

b) Increased thermal reliability, industrial cold and water distribution:

- Thermal systems (water and steam)

With an installed thermal power for customer water service and steam production of 15,200 kW, made up of 4 boilers with a regulation of thermal needs (Fig. 3), it serves the needs of hot water and steam for production activities, with a design based on energy optimization and specific needs.

Figure 3. Detail of the boiler thermal technical room, designed for the correct maintenance functions.
Source: own elaboration.

- Redundant water distribution systems

Sanitary, cleaning, osmosis water drive systems, made up of 2 osmosis plants, with centralized computerized control, and systems with a variator regulator to achieve constant pressures and a high level of energy efficiency. In addition to the redundancy in the pumping systems, ringed systems have been implemented in the distribution, with multiple bypass valves (possibility of other supply routes, manoeuvres and maintenance).

- Industrial cold systems

Combined industrial refrigeration system using ammonia and CO2 compressors, with an energy efficient cycle with heat recovery. With an installed cooling power of 17,660 kW, made up of 11 compressors with automatic regulation of cooling needs, it serves the production and storage needs of cold rooms, with a design based on energy optimization and specific needs. With reserve capacity for substitutions, shutdowns, and maintenance actions.

Maintenancebased Design

Maintainability was one of the fundamental criteria in the design of the industrial plant: To achieve the necessary requirements for efficient, agile, and economical maintenance for maximum operational availability.

The options for to achieve this were:

- The standardization and uniformity of the largest number of equipment and components used in industrial facilities.

- The application of maintenance tactics, with TPM (Total Productive Maintenance) techniques at production levels, with the incorporation of productive mechanics, up to the requirements of reliability-based maintenance (RCM) used in the most advanced equipment and facilities and criticism, with the incorporation of knowledge management techniques as elements of self-learning and decision (database with the best experiences of the operators, the actions carried out, and the criteria for the different maneuvers), for the reduction of times of action against breakdowns.

The design of the technical rooms, skids and possible areas of maintenance, with the criteria of sufficient space, and practicable access at any time, which allows possible substitutions and common maintenance manoeuvres. This aspect, normally forgotten in designs, is vital for future operation, profitability in operation and efficiency in activities in case of failures or routine maintenance.

Design-based on Energy efficiency and Alternative Energies

A fundamental determination of the company was the design based on maximum energy efficiency and the use of alternative energies.

Among the many criteria used and executed, the following could be highlighted:

- Centralized and computerized control of the electrical installation and instantaneous control of general and local consumption, with the implementation of measurement systems in all the general lines in the designed panels (Fig. 5).

Figure 5. Detail of control and monitoring systems in general tables.
Source: own elaboration.

Computerized control of the lighting systems of the entire factory and its sectorisation remotely, and locally through partial sectorisation (only in operation with an access card). The entire fluorescent interior lighting system has a flow regulation system, for greater optimization in use and longer operational life of the lamps.

- Implementation in the design and execution of variable speed drives with electronic control in pumping and fluid distribution systems (Fig. 6), in order to optimize energy efficiency, fine regulation of pressures and flows, less wear and tear on equipment and consequently reduction of the maintenance costs and increase of the operational life.

Figure 6. Detail of fluid rooms, with regulation systems using electronic drives.
Source: own elaboration.

In the industrial refrigeration systems (Fig. 7), one of the main resources of the factory, in order to increase the energy efficiency and reliability of the system, a combined industrial refrigeration system was installed using ammonia and CO2 compressors, with energy efficiency cycle with heat recovery. With heat recovery, it is possible to use the discharge from the ammonia compressors, which is 70ºC, and pass it through an ammonia / water exchanger, which for safety is passed through another water / water exchanger, ensuring that this residual energy is used. so that the water that comes to us from the distribution network at 15ºC is heated to about 30ºC, this increase of 15ºC, in addition to achieving energy savings, helps the condensation of ammonia saving energy in the condensing towers. Likewise, all compressors are equipped with electronic speed variators to optimize their performance and maximize energy efficiency.

Figure 7. Detail of the technical industrial refrigeration room, designed for optimal energy efficiency conditions.
Source: own elaboration.

- In the commitment to the use of alternative energies, we proceeded to the design of a photovoltaic installation integrated in the industrial zone with power within the factory of 1,200 kW (400 kW on the ground and 800 kW on roofs) (Fig. 8). This confers a fundamental contribution of solar energy, in addition to achieving other aspects such as uniformity in the autonomy of the electrical energy supplied (Stabilizes the voltage drops and the quality of the electrical energy coming from the substations).

Figure 8. Detail of photovoltaic systems installed on the ground and on the roof.
Source: own elaboration.

Design based on the Environment

Another important aspect is Environmental restrictions, not only in what is mandatory by sectoral regulations, but also adopting the greatest additional measures, which would make the project a factory with an environment – centric design. Some of the measures taken:

- The first phase was to obtain an Integrated Environmental Authorization for the industrial complex, building a state-of-the-art treatment plant, with a treatment capacity of 2000m3/day and a load of 66,700 equivalent inhabitants (h.e.).

For greater use of the wastewater, once it has been treated in optimal conditions, it is supplied by means of pumping stations to an artificial lake that is in the area of the entrance to the polygon (Fig.9), from that water, in addition to making an ornamental function, it is used to irrigate all the gardening of the industrial complex.

Figure 9. Detail of artificial lake: aimed to improve purification, ornamental and irrigation use.
Source: own elaboration.

Rainwater usage from inside the factory, with authorization from the Júcar Hydrographic Confederation. Hence, a rainwater collection network was built, enabling a pumping well and three tanks of 1000m3 each to store rainwater (Fig. 10). These tanks have a hypochlorite control and adjustment system to keep the water in optimal conditions. The fundamental uses of this water are:

Figure 10. Detail of rainwater storage tanks.
Source: own elaboration.

1. Production of softened water for cooling evaporative condensers (cooling towers)

2. Supply of water for washing and cleaning the exteriors, and irrigation of the interior gardening of the plot

3. Cleaning of solar panels.

4. Supply to the existing ornamental fountain on the plot

- Industrial installation, free of batteries for uninterrupted power supply systems, which are of the dynamic type with flywheels.

- All transformers have been considered dry, to avoid the treatment and toxicity of the oils.

Design based on Information and Knowledge Management

Information and data is vital for the optimal functionality of maintenance services. In complex facilities, data collection is required, in order to adapt the maintenance, control and operation programs of facilities and monitoring of stops or failures.

From the very definition of the project, in maintenance activities, a greater incidence has been made for the adaptation of knowledge management processes, favoring the generation, codification, transfer and use of knowledge, given that said tactical activity It can be considered from a Kantian approach in which people, facilities and the environment interact in which all variables must be studied together.

As a result, a fundamental phase is the adequate capture of information, for subsequent processing and treatment, generator of own knowledge in the organization and a fundamental maintenance tool, integrating the useful and strategic information of the service, improving the chain of the service to be provided.

A knowledge management model has been developed and implemented for the maintenance activity, with the capture of strategic knowledge of the technicians and operators (Cárcel et. al., 2013), as well as the capture and management of technical information of the facilities and equipment, for the control, visualization, obtaining operational data and fault log. All this allows to have controlled all the fundamental parameters of the facilities and equipment, which optimize the control of the reliability of the facilities, the forecast of maintenance programs, as well as a control and optimization of energy efficiency, demonstrating that the application of Knowledge management models within the maintenance department of the company, allows to optimize the processes and improve the availability of the service and better economic results for the company.

Although according to sector surveys (AEM, 2010), the technical maintenance services of most companies dedicate little investment to the knowledge and development of said activity, in the case of Martinez Loriente S.A., a commitment has been made with a commitment to research and development in the technical areas of maintenance, with an agreement with the Polytechnic University of Valencia for the development and improvement of the operation and maintenance services, seeking in this way, a deepening and improvement in these activities.

CONCLUSION

The general principles of a new industrial plant implantation have been described, where decisions and considerations taken at first by the awareness and decision of a general management, with criteria of quality, efficiency and medium-term views, have achieved an industrial implantation which sets a benchmark in the food industry.

Starting from fundamental principles that seek maximum efficiency, with a design based on reliability, maintainability, energy efficiency and alternative energies, respect for the environment and information-based design and knowledge management, an industry has been achieved, which, fulfilling all production expectations (a fundamental requirement in any industrial plant), has gone one step further, fulfilling the conditions of effective maintainability in the future, along with respect for the environment.

The synergy with the bodies involved in the execution of the industrial plant, together with the determination and commitment of the engineering management of the company itself, have been decisive to achieve, at an appropriate level of investment and costs, to achieve a plant with capacity improvement and economic profitability, control of information and knowledge, for future operations and maintenance functions that must be fulfilled.

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DESIGN FOR DISASSEMBLY AND PLASTIC RECYCLING AGGREGATES: COMPARISON OF PERFORMANCE LEVELS

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ABSTRACT

In recent years there has been a strong advancement of research in the recycling sector. Experimentation has concerned both individual materials and their assembly with raw materials, in particular for concrete for the study of mixes with plastic aggregates. Similarly, important studies on construction systems that can be dismantled at the end of their useful life have encouraged the criterion of circularity that characterises this specific sector in function of a technological synthesis with prefabrication criteria. The results obtained have brought recycling technology to advanced performance levels, making it necessary for researchers to start a performance comparison to determine which of these possibilities has a greater capacity for design application. The paper compares the Design for Disassembly with concrete using plastic recycling aggregates in place of fine mineral aggregates, identifying the need for further study in order to improve performance levels.

Keywords: Circularity, plastic aggregates, sustainability.

INTRODUCTION

Environment, territory and sustainability, three themes around which institutions, both at national and European level, universities, the world of research and operators' orbit, in order to promote, disseminate the culture of innovation and undertake initiatives to ensure sustainable development capable of improving the quality of life. These are the key words to build a quality development, which can be reconciled with economic and employment growth, with social and cultural improvement, but above all with environmental protection.

At a time in history, such as the one we are living through, characterised by the uncertainty of the world economy, the theme of reusing and recycling materials seems to be a valid alternative for the world of architecture and for economic growth. While the development of research and industry has led to innovative and economic progress, it has also resulted in the increasing use of natural resources to the detriment of the quality of the environmental system, not least because of the lack of adequate laws to protect it. Widespread environmental degradation has led to the proliferation of laws and measures of various kinds and origins that now constitute modern environmental law. Italy's membership of the European Union has undoubtedly contributed to the growth of regulations that dictate obligations and quality standards that must be complied with.

A heterogeneous mix of different materials (from windows, to rubble, to plastic pipes) cannot be recycled without the aid of separation and treatment of each of them with the appropriate techniques to obtain recycled products that can have a useful use. It is also clear that, in this case, the separation of these materials is not only difficult but also very costly, which is why it cannot be done at a later stage and independently of demolition.

The demolition of the building shall be carried out in such a way as to keep the materials that are progressively removed as separate as possible, and to collect them in an orderly manner. Recovering the maximum possible number of materials therefore depends directly on demolition techniques and site organisation. Obviously, the homogeneity to be achieved should not be understood as the separation of all materials into all their basic "ingredients". This would be unnecessarily complex and costly, as well as often technically impossible, since each element of a building is the result of a series of processes that have combined different materials, in many cases using techniques that make the process irreversible. For example, once a mortar has set, it is no longer possible to separate the sand and cement that have been mixed to form it.

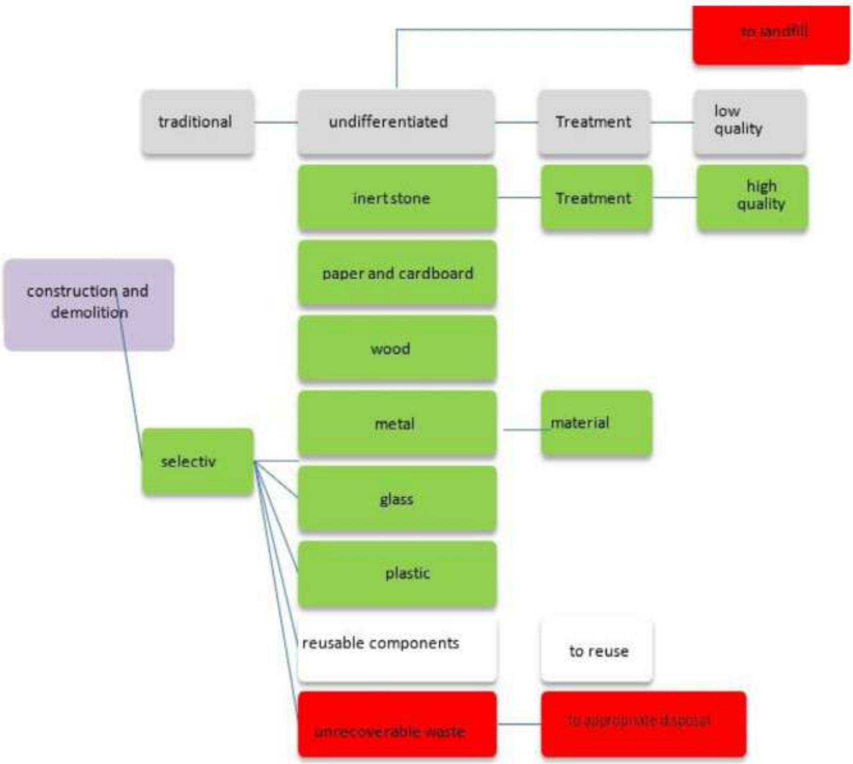

Figure 1: Construction and demolition waste management scheme

A realistic and efficient concept is the one proposed by the differentiation of materials, residues divided into as many different types as there are possible recoveries to be made. A preliminary investigation should be carried out, in agreement with the client, planners, owners, etc., to assess:

- The type and characteristics of the structure being addressed.
- The activities carried out in the facility to verify whether and how they affected the quality characteristics of the materials being demolished.
- Characteristics of the site and the surrounding area (e.g., access spaces, proximity of houses and other buildings, possibility of handling and storage on site, etc.).
- The presence of possible criticalities caused, for example, by the presence of asbestos, underground tanks, pipelines, installations, abandoned hazardous and non-hazardous waste, etc.

Design for Disassembly

Selective demolition involves a specific step to identify disused building materials and components that can be reused. Once the selected elements have been checked for possible reuse, they are excluded from the waste regime and treated as any other construction material and have to be managed as such. It follows that the reusable element must be dismantled in such a way as to preserve its residual performance or aesthetic and artistic value, avoiding handling and bulk accumulation. This practice has been applied for a long time in particular for the valorisation of those elements that can have an aesthetic-historical value and is a typical case for building elements that can be "disassembled" in a modular way, remaining intact: structural elements in wood or metal, bricks or stone blocks, tiles, roof tiles, hollow tiles, steps, thresholds. Their reuse within the construction activity can also provide a lower performance or aesthetic purpose.

It can be said that in the design of energy-efficient buildings it is necessary to select construction elements characterised by a design management which foresees the recovery of materials in function of their re-introduction into the production cycle for a "circularity" integrated with an end of life assessment for the end of waste. In short, it is clear that a design aimed at the disassembly and reuse of materials favours the cyclical nature of construction elements. This approach, characterised by a mix based on "Design for Disassembly" and an assessment of LCA impacts, creates a project of good building quality, but not necessarily architectural, aimed at a broad ecological concept of environmental protection.

To achieve a design concept of this kind, the most appropriate technology appears to be prefabrication, modular and flexible with attention to sustainability performance. From this point of view, the most usable material is wood according to X-LAM elements with connectors to make components that are repeatable and can be dismantled at the end of their useful life and adapted to particular organisational needs. A sort of technological module that can be "reused" at any time. according to the "Design for Disassembly" practice, with the reversibility of the connectors adopted. This allows a reconversion of the structural elements to create a structure characterised by easy disassembly and flexibility of reconfiguration. It has been calculated that this procedure produces a construction system in which 89% of the materials are reusable with an extension of the useful life of 96% of the components which, therefore, are not to be considered as waste to be disposed of [Palumbo, Rossetti, Incelli, Camerin, Panozzo, 2021].

A typical example of this is the “Wikihouse” construction system, which is based on so-called "fins", plywood fins, evenly spaced according to the pitch chosen for the construction grid. These fins can vary in size and shape. Wikihouse does not need to have a single structural grid, but it does because you have standard-sized panels. Once the fins are connected together using connectors and covered with panels, they form a strong wooden structure. The length of the Wikihouse is theoretically unlimited and the roof profile can take various shapes, but the maximum span of the room can be 3.6 metres at the moment and the lights can be combined horizontally. The size of the grid can vary depending on the desired standard building module (Figure 2).

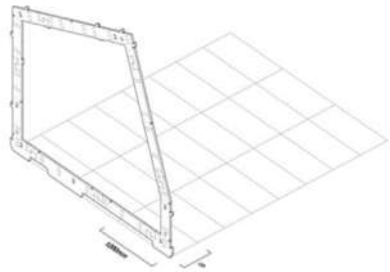

Figure 2: Wikihouse system: construction grid
Figure 3: Wikihouse system: fixing bolts

At the moment three types of fasteners are used, M8 steel bolts with threaded shanks and two types of wood nails. All internal corners must have a so-called "Dog Bones" indentation to overcome the fact that the circular cutting head can only cut rounded internal corners (Figure 4).

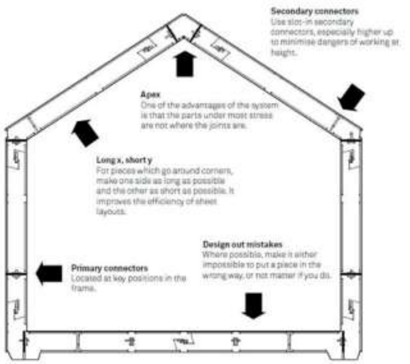

Figure 4: Wikihouse system: detail of internal corners in "Dog Bones".
Figure 5: Wikihouse system: diagram of connections in a grid

For this reason, it is important during modelling to mark these "Dog Bones" by drawing an indentation of 5 millimetres and a depth of 10 millimetres. This will allow the required Dog Bones shape to be obtained during the cutting phase. Figure 5 shows a complete view of the construction details.

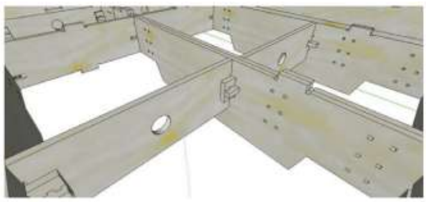
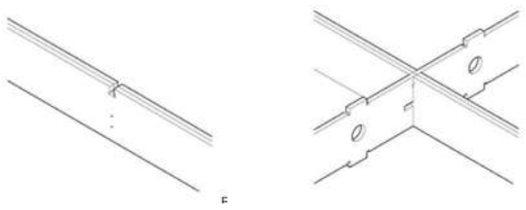

Figure 6: Wikihouse system: detail of main connectors
Figure 7: Wikihouse system: detail of secondary connectors

Figures 6 and 7 show details of the main and secondary connectors.

The technological approach of "Design for Disassembly" appears at the moment to be more substantial than other methodologies derived from "Construction and Demolition" such as, for example, "Urban Mining", as these are still unsuitable approaches to be used in a circular design process, in which the results of pre-demolition analyses "inform" the process itself [Cernaro et Fiandaca, 2021].

Concretes with recycled aggregates

The same applies to the use of recycled plastic elements to produce new mixes in concrete mixing plants. In this recycling sector, the weak point of the process is the water absorption index, a parameter which can have a negative effect on the w/c ratio and thus on the mechanical strength of the concrete.

The evaluation of the results emerging from Italian studies on lightweight structural concretes in which plastic aggregates have been mixed to replace the medium to coarse components of mineral concretes has made the need for further investigation in this sense evident, since the experimental data were insufficient. In particular, two different experimental interpretations emerged for workability. The first concerns the consistency of the concrete obtained by replacing percentages of sand and this, according to Féret's first law[2] , tends to increase the lowering of the slump test due to a greater volume of free water which, together with the null absorption of the plastic aggregate, produces a higher water/cement ratio with a consequent decrease

2 "The amount of water required for mixing is greater the finer the grains of aggregate and is proportional to the amount of aggregate".

in mechanical strength. The other argues that the consistency decreases the higher the percentage of plastic aggregate due to the angularity of the material. Another experimental gap concerns the LCA assessment. In fact, the treatments following or at the same time as granulation remain highly undetermined in terms of their effects on adhesion properties, but also on water absorption and environmental sustainability of the process. In addition to a sub-process analysis for recycled plastic aggregates, a more complete LCA assessment of lightweight structural concretes would be required, which would include them compared to those with natural aggregates, with the same mechanical strength class. All this makes the use of plastic aggregates an area of research that has yet to be decisively developed [Fiandaca, 2015].

Once the technological and productive advantages of concretes using recycled aggregates have been established, as well as the static advantages of using fly ash in the mix to reduce porosity, the problem of sustainable architecture remains linked to durability. The first phase in the life of the mix is particularly important, as it is linked to the phenomena of shrinkage, at the moment of transition from the liquid to the solid phase, which can compromise the durability and useful life of the mixes used in construction. This is a very delicate phase which requires analyses which still need to be carried out in depth and behavioural studies. The concept of rheology, the science that studies the flow and deformation of concrete mixes, aims to optimise concretes for their deformability and flow properties. However, the right choice of aggregates to ensure that the required performance levels are achieved remains essential. If this is the scientific content of shrinkage phenomena, it seems appropriate to study concrete mixes for recycling from the point of view of their compliance with the performance requirements needed to reduce negative rheoplastic effects such as excessive shrinkage. To this end, the author conducted an experiment with test specimens made of recycling aggregates and different classes of cement using different water/cement ratios. At the end of the experiment, it was noted that the loss of strength relative to the use of recycled aggregate in place of the natural aggregate is less as the water/cement ratio tends to increase and the shrinkage effects are reduced. With the same water/cement ratio, in ordinary concretes the cement matrix is the element of least strength, with a very low water/cement ratio, while in concretes made with recycled aggregate the aggregate is the element of least strength due to a greater volume of recycled aggregate compared to the volume of cement matrix [Catalano, 2015].

CONCLUSION

For some time now, the re-use of building demolition materials has been one of the most important research areas in terms of its impact on the economy and the environment. So-called "selective demolition", to be planned with scientific and applied research criteria, makes it possible to "dismantle" parts of buildings to be demolished for reuse on others undergoing renovation, with cost savings for both contracting authorities and construction companies. Another possible and very popular application is the recycling of demolished concrete mixes with the recovery of inert material and reinforcing bars. This procedure makes it possible to produce new concretes that can be used, for example, for industrial flooring or airport runways, but are still too limited in terms of structure. The aim is to find ways of perfecting the criteria of selective demolition and the use of mixes made in this way in the static field as well, through the study of specialised grain size curves. Now, it appears that circularity is widely verified in the field of "Design for Disassembly" in which wood is the only material to verify the feasibility of this technology. On the other hand, in the case of the reuse of recycled aggregates, despite the great progress achieved by the research also for structures in seismic areas, to produce concretes it appears to be a sector still to be investigated both from the point of view of mechanical resistance and rheological behaviour.

ACKNOWLEDGEMENT

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ASSESSMENT OF ECO-TOXICITY AND HUMAN HEALTH RELATED ASPECTS OF CONSTRUCTION MATERIALS IN EPDS AND PEFS

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ABSTRACT

Modern buildings face various and interdependent challenges in terms of innovation, design, energy and resource efficiency, sustainable materials and construction, durability and potential for waste recovery and recycling. Construction materials play an important role in the assessment of building's sustainability and their significance is recognized by the intensive development and use of the methodology for environmental product declarations (EPDs). In addition to that, the European commission published guidance and category rules on product environmental footprint assessment (PEFs) that also address environmental and toxicological issues.

This paper discusses the health-related indicators in EPDs and PEFs and their application to some construction materials. An overview is done on the nature of the indicators and the approaches for their assessment and applicability in EPDs and PEFs. While EPDs of construction products are prepared based on a well-developed methodology and specific standard (EN 15804) that act as core product category rules (PCR) for all types of products, PEF guidelines treat each product separately and their scope is quite limited in terms of construction materials. This study outlines both the common features of both approaches for assessment eco-toxicity and human health impacts and provides a discussion on their relevant fields of application, including on construction and demolition waste (CDW) management.

Keywords: Sustainable materials, life cycle assessment (LCA), EPD, PEF, CDW.

INTRODUCTION

Selection of construction products is a task that meets multiple challenging requirements for technical properties, aesthetics, ease of use, durability, maintenance and cost. Nowadays, building materials need to respond also to the increased concern about environmental performance and sustainability, including in terms of CDW management at the end of the product's life cycle. The environmental impacts of materials are assessed by various indicators: CO2 emissions, ozone depletion, smog creation, eutrophication, acidification, radiation, toxicity, etc. and the primary impacts are known to be occurring during the manufacturing stage. The use of resources is a significant issue for construction materials since around 50% of all extracted natural resources are transformed and consumed by the construction industry (Petrović, Vale, & Zari, 2017). This determines the huge and various types of CDW – more than a third of all generated waste in the EU (EC) and underlines the need for proper attitude towards this waste by exploiting the potential for reuse, recycling and recovery.

Whether we consider the material itself during production and use or the waste formed by this material when the building is demolished, the issue with toxicity to humans and natural habitats needs to be addressed. Toxicity of construction materials can be presented and declared either by an environmental production declaration (EPD) or by a certificate of the product environmental footprint (PEF).

This paper provides a summarised overview on the methodologies for toxicity evaluation used in EPDs and PEFs, and their relevance to construction materials and CDW. The better understanding of toxicological mechanisms can help us outline potential hotspots in the health-related issues of construction materials and recovery of CDW.

CONTEXT OF EPDS AND PEFS

Environmental Product Declarations (EPDs)

A large share of the environmental impacts from a building's life cycle originates from the manufacturing and processing of materials and products. For example, the embodied energy of materials can reach up to 60% of the total life cycle energy consumption of a building (Liu, Li, & Yao, 2010; Meng, Baizhan, & Runming, 2010). This justifies the important role of materials from a building's perspective and implies that good knowledge on their environmental impacts is a prerequisite for achieving a required sustainability level. So far, EPDs are proven to be an accessible and reliable tool to declare environmental performance.

An environmental product declaration (EPD) of type III is defined by (EN 15804+A2, 2019) as a declaration that provides "quantified environmental data using predetermined indicators and, where relevant, additional environmental information" about products. EPDs are based on the life-cycle assessment approach (LCA) standardised in the ISO 14000 series. The information in EPDs can be considered a substantial source of information for assessment of the whole building because by default all life stages of a building are included: product stage, construction (installation, assembly), use and end-of-life stage. The mandatory scope of an EPD covers the product stage (modules A1-A3), end-of-life processes (modules C1-C4 in regards with deconstruction/demolition and CDW management) and relationships to other product systems through recovery/recycling activities (module D).

EPDs provide information about numerous environmental indicators grouped in four primary fields: core environmental impacts, additional environmental impacts (toxicity), resource use and output (waste) flows. In order to encompass in broad sense the variety of materials and products, EN 15804 serves as a core product category rules (PCRs) establishing the framework for construction products and outlining the evaluation methodologies for the impact categories and indicators. However, despite the common methodological basis, the EPDs cannot serve as a comparison basis between products because certain cut-offs in assessed data are allowed and declared life cycle stages may vary from one EPD to another.

Product environmental footprint (PEF)

The product environmental footprint (PEF) is also a life cycle-based method for measuring environmental performance developed and recommended by the European Commission (Recommendation 2013/179/EU, 2013). PEF is defined as a "general method to measure and communicate the potential life cycle environmental impact of a product". The emergence of PEF aims at providing a single unified method for substantiating the environmental aspects of products and enabling a green market for all kind of products. The PEF initiative is the proposal of the EC to overcome eventual misleading claims of certain green labels by establishing a reliable framework. Product Environmental Footprint Category Rules Guidance (PEFCR Guidance 6.3) is published as a result from the pilot stage of the PEF project (2013-2018). Like EPDs, PEFs follow the modular approach and use the same life cycle stages structure. The PEFCR resembles the function of EN 15804 as a core category rules document. It describes the procedure for PEF development and technical specifications (scope, impact assessment categories, modelling of specific aspects and stages, etc.). A cardinal difference between PEFCR and EN 15804 is that PEFCR targets all kinds of products, while EN 15804 is focused only on construction materials.

The PEFCR Guidance requires sixteen indicators to be evaluated and they correspond to the core and additional (toxicity) environmental impacts categories in EN 15804. PEF in general should cover the whole life cycle of the product with possible exceptions for specific products. Because of the complexity of products in the human life, PEFCR are expected to be developed for representative products. Nineteen PEFCRs for various product groups (e.g. foods, drinks, clothes, paper, metal sheets, pipe systems, IT equipment, etc.) are published during the pilot phase and are valid until the end of 2021. From the available PEFCRs only few are relevant to construction – for decorative paints, hot and cold water supply systems, metal sheets and some thermal insulation products (cellulose insulation, EPS, PU and foamed glass). New PEFCR are expected to be developed (EPLCA, 2021).

The PEFCR proposes specific scenarios about the end-of-life stage regarding dismantling/demolition, transport of waste, treatment activities, energy recovery and landfill rates per country. E.g., for non-mineral insulation products in Bulgaria it is assumed that 0% of the thermal insulation would be recycled, 7% would be subjected to energy recovery and 93% would be landfilled, while mineral insulations are considered to be directed for landfilling in full (JRC-EC, 2019). In contrast, the scenarios for countries with well-developed CDW recovery practices (Austria, Belgium, Denmark, Germany) consider 100% energy recovery of the insulation.

Assessment of toxicity in EPDs and PEFs

EPDs and PEFs share the same approach for evaluation of toxicity indicators. Technically, the PEF approach is adopted in EN 15804 and the indicators are included as additional environmental impacts. They are currently mandatory for the project report supporting the EPD but optional for the EPD itself, so they are not transparent to the large public. It can be assumed that when PEF methodologies are fully developed, the toxicity would be an integral part of the EPDs. The impact categories and indicators describing potential toxicological issues of products target human toxicity (cancer and non-cancer effects), ecotoxicity for freshwater environments, particulate matter (PM) and ionising radiation (health effects).

Assessment of human toxicity and ecotoxicity

Assessment of toxicity is a specific aspect in the LCA model because of the high uncertainty and because the number of contributing flows is many times more than the flows for the usual environmental impacts (around 1000 substances for human toxicity and more than 2500 substances for aquatic ecotoxicity) (Fantke, *et al*., 2018). The USEtox model is used to characterise direct human toxicological and ecotoxicological impacts in the LCA. It is developed under the UNEP[3]-SETAC[4] Life Cycle Initiative (Hauschild, *et al*., 2008; Rosenbaum, *et al*., 2008) and its aim is to provide a scientific basis for a "comparative assessment of chemicals based on their impacts on human health and on ecosystems" (Fantke, *et al*., 2018). The model describes the environmental distribution, exposure of humans and ecosystem populations, and toxicity-related effects from this exposure by using data from existing databases and peer reviewed sources. The characterisation factors (CFs) in USEtox vary widely and there are vast differences from substance to substance (up to 12 orders of magnitude) determined by the variations in production, emittance, distribution mechanisms, fraction intake by humans and/or ecosystem species and differences in the sensitivity to the different compounds (Rosenbaum, *et al*., 2008). USEtox allows for distinguishing between products with negligible and products with higher toxicity impact potentials by analysing even a large number of chemicals – more than 30000 different substances are frequently used in products (Wambaugh, *et al*., 2013) most of which pose potential risk of toxicological effects on humans and ecosystems. Both human toxicity and ecotoxicity are expressed in comparative toxic units (CTUs) which indicates the comparative character of the indicators.

Assessment of impacts from particulate matter (PM)

The methodology used to calculate this impact is adopted by (Fantke, *et al*., 2016) in the Global Guidance for Life Cycle Impact Assessment Indicators by SETAC-UNEP. To characterise the impacts, the emissions are expressed as mass of PM2.5 and their advective distribution and transformation within air (indoors and outdoors) is modelled to assess the concentration of PM2.5. A fraction of this mass is later inhaled by exposed population and the cumulative population risk is measured in disease incidences among the exposed population. Disease incidences are transformed into a metric of damage by accounting for disease severity. Some sources (Hoek, *et al*., 2013) indicate that a 1 mg/m3 increase in PM2.5 leads to 0.6% increase in all-cause mortality, and 1.1% increase in cardiovascular mortality (with certain variability). Several factors can influence inhalation intake fraction (iF), a summary for which is presented in table 2 for PM2.5 of outdoor and indoor origin:

3 UNEP – United Nations Environmental Program

4 SETAC – Society of Environmental Toxicology and Chemistry

OUTDOOR ORIGIN	INDOOR ORIGIN
- Population density; - Breathing rate; - Wind speed; - Mixing height; - Source-to-recipient distance; - Infiltration (leaks in building envelope, active filtration by ventilation system, deposition within the room)	- Building air exchange rate; - Building volume; - Inter- and intra-zonal air flows and mixing; - PM2.5 removal mechanisms (deposition to surfaces and filtration in HVAC systems that recirculate air); - Breathing rate; - Time spent in indoor environments.

Table 1. Factors influencing the iF for PM2.5
Source: Fantke, *et al*., (2016)

CFs are expressed as change in disease incidences per kg emissions of PM2.5 or precursors [deaths/kg emitted] for premature all-cause mortality.

Assessment of impacts from ionising radiation on the human health

Currently, information on impacts from ionising radiation for some construction materials is provided as part of the data safety sheets. The model adopted in PEFs and EPDs for assessing the impact on human health from ionising radiation is developed by (Dreicer, Tort, & Manen, 1995) and updated by (Frischknecht, Braunschweig, Hofstetter, & Suter, 2000). The human health effects are described related to the routine releases of radioactive material to the environment, e.g. from man-made source such as nuclear and coal power plants, phosphate rock extraction, oil and gas extraction.

The discharge and distribution of radioactive materials in different media (atmosphere, rivers, lakes, the ocean and soil) is modelled. The health effects (cancer and severe hereditary effects) are calculated statistically, and their severity is weighted using the concept of disability adjusted life years (DALY) which calculates disability adjusted life years and years lived disabled.

Toxicological aspects of construction materials

Sources of toxicity in construction materials and CDW

The problem with toxicity of construction materials has broad aspects because of their complex chemical composition. A variety of stabilizers, plasticisers, pigments, etc. substances are added to a wide range of construction products (concrete, mortars, plastics, wood preservatives, finishing materials, materials for chemical treatment, sealants, paints, etc.). Toxicological impacts can arise from the release of persistent bio-accumulative and toxic chemicals (PTBs), chemicals that mimic or block the action of hormones (endocrine disruptors – ECDs), leachate of vinyl chloride monomer (e.g. from PVC pipes), phthalates (found in home dust emitted from PVC products); formaldehyde and volatile organic compounds (VOCs), polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), polybrominated diphenyl ethers (PBDEs), heavy metals and compounds (from pigments, fillers, UV stabilizers, and flame retardants); organic and inorganic substances in wood preservatives (copper compounds, chromium, boron compounds, arsenic, , etc); asbestos, moulds, fungi and algae, etc.

Sources of PM2.5 in construction materials and CDW

Fine particulate matter (PM2.5) poses a significant disease risk upon indoor and/or outdoor exposure. In construction, there is a number of activities that can release PM: land clearing, earth moving, equipment movement, machine operation (loading, unloading), site preparation, casting of concrete, mortar and plaster mixing, drilling, cutting, grinding, welding, sandblasting, traffic on unpaved roads, demolition, crushing, etc. Released PMs are mostly of mineral composition and resulting from mechanical operations (EEA, 2016). The dust emission depends on the material and moisture content. E.g., silica dust from demolition of concrete and mortars can pose a significant potential health issue because it is known to cause silicosis, a fibrotic disease of the lung and is also associated with lung cancer, pulmonary tuberculosis and, sometimes, cardio-vascular diseases (Cook & Velis, 2020). Moisture content is considered to have a preventive effect because the particles adhere together and cannot be released in air, so surface watering can be an effective method to reduce dust emissions, including from demolition processes (EEA, 2016).

Sources of ionising radiation from construction materials and CDW

Ionising radiation can affect the atoms in living organism by transferring energy in the body tissue. The effects can be described as deterministic effects (radiation burns resulting from high doses of radiation) and stochastic effects (cancer and heritable diseases due to cell mutations). In construction, potential risk of radiation impact can originate from the demolition of specific buildings factories (e.g. luminous products produced by radium luminising) and processing facilities (e.g. thorium extraction from monazite). Increased levels of radiation can be detected when the concrete in such buildings is jack-hammered because radioactive material from aggregates or additives (e.g. fly ash) is aerosolised and may release radon (Cook & Velis, 2020).

Health-related impacts of some construction products

To illustrate the magnitude of these impacts for some widely used construction materials, calculations of the impacts are made using the openLCA software for life cycle assessment and the methodologies described above (Table 2). The modelled products are representative datasets from the ecoinvent database.

	Human toxicity, cancer effects, CTU_h	Human toxicity, non-cancer effects, CTU_h	Ecotoxicity, freshwater, CTU_e	Particulate matter, disease incidence	Ionising radiation, kBq U-235 eq
Clay brick (1 kg)	2.81E-10	3.38E-09	0.02161	7.52E-09	0.0132
Concrete (30 MPa)	7.15E-08	5.35E-06	28.12989	9.15E-06	9.36482
Gypsum plasterboard (natural gypsum)	1.20E-10	1.02E-08	0.19451	3.23E-08	0.02248
PVC, window frame, (U-value of 1.6 W/m2K)	5.79E-07	2.59E-05	81.41643	1.40E-05	28.44228
EPS (30 kg/m3; λ=0.035-0.04 W/mK)	8.60E-10	3.82E-08	0.31549	1.55E-07	0.19364
Steel (low-alloyed, hot rolled)	1.39E-08	2.62E-07	0.55529	1.69E-07	0.12731

Table 2. Health-related impacts of some construction products

The results show high variance of the results, the highest values on all health-related impacts appear to be to produce the PVC window frame and the lowest are observed at the clay brick production.

It was mentioned that the CFs vary in a broad range for the different substances and the differences can reach up to 12 orders. The different origin, composition and production processes of the exemplary materials confirm this variance and could be useful solely for general comparative assessment. The sources of the toxicological impacts for most materials originate mostly from energy production, which means that national/regional mix could be a hotspot for these impacts. Since these calculations are done for referent averaged products, they could be considered generally indicative for the magnitude of the impacts that can be expected for the corresponding product group. The results would be more reliable with a more detailed regional representation of the model.

CONCLUSION

The paper presents an overview of the impact categories and indicators assessing toxicological effects for humans and aquatic ecosystems and other health-related issues. The models describing and estimating these impacts are the outcome of continuous research, so they have strong scientific background, and their reliability is claimed sufficient. The inclusion of toxicological impacts in EPDs, even as optional indicators, allows for a more comprehensive application of the assessment methods and would help for improving the calculation procedures. This, combined with the expected launching of new PEFCRs for construction products over the next few years would probably define the mandatory status of these indicators in time.

The setting of uniform prerequisites for various products under the same PEFCR makes the study largely controlled but, on the other hand, it sets the ground for possible comparisons of products because the differences would be mostly in the sourcing of raw materials and production process. Nevertheless, there would still be limitations to comparisons of construction products by their PEFs because it would only be relevant at building level when the product is part of a system. In this case, a reasonable basis for comparison demands a suitable reference about the application which means that PEFs would hardly be used as a direct comparison basis soon.

It is important to emphasise that the purpose of health-related impacts is to allow relative comparisons between products rather than being used to extrapolate and calculate health risk and potential disease occurrence. The assessment of toxicity and other health and ecosystem indicators is a serious step forward to drawing the attention to the hazardous substances in construction materials and to the accumulation and dispersion processes. This is particularly significant for the characterisation procedure of CDW so that end-of-life activities can be responsibly and safely implemented.

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CONSTRUCTION OF A FAÇADE WITH GEOPOLYMER

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ABSTRACT

This research explains the process of building a large-scale prototype with geopolymers for the manufacture of an 80m2 facade through pieces of more than 7m in length. This article describes the process that went into manufacturing, pouring, lifting, and installation.

Keywords: Sustainable materials, life cycle assessment (LCA), EPD, PEF, CDW.

INTRODUCTION

The alkaline activated cements known as geopolymers can be the answer to the demands of sustainability in the construction sector. The reduction of the environmental impact due to not using clinker as well as the use of waste promoting the circular economy make this material a firm bet to develop on an industrial scale.

On the other hand, prefabrication is increasingly present in the sector due to the multiple advantages it presents in terms of significant improvements in the process and quality, as well as the reduction of the carbon footprint.

However, although there are multiple precedents for the use of geopolymers in construction, this research has sought to combine geopolymers with prefabrication to achieve pieces of more than 7 m and understand the real behaviour of this material in the construction process and its subsequent evolution.

PAPER

INTRODUCTION

Alkaline activated cements also known as geopolymers are materials with properties similar to ordinary Portland concrete but with a much lower carbon footprint.

The use of geopolymers from waste implies a second chance at materials that contribute to the circular economy and the reduction of greenhouse effect emissions.

This research has sought to prototype a functional element of a building, for which a facade of 80m2 and 7m high has been chosen, due to its large size and exposure to the elements.

This article describes the manufacturing, assembly and evolution methodology of this geopolymer construction.

METHODOLOGY

The process has been organized to manufacture the 4 plates that make up thefacade of the building.

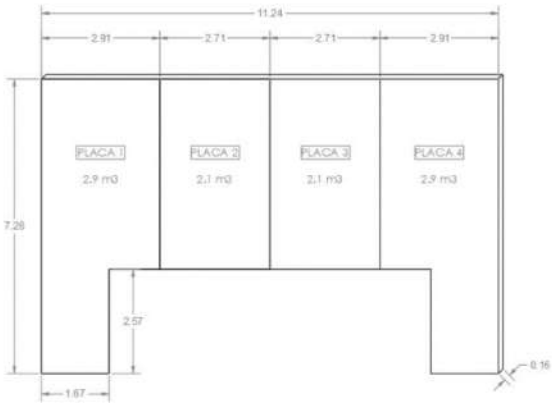

Figura 1. Description of the four units to be manufactured.

Preparation

The material is poured into the molds at the facilities of the Bortubo company and given the fluidity of the material and the materials that make up the mixture, it was decided to carry out the mixture in a concrete mixer truck at the facilities of Cementos Cruz and later. transfer and discharge to Bortubo.

The journey between the two facilities lasts 25 min with a concrete mixer. The materials preparation process is structured in bags and IBCS numbered with the exact amount of material to be deposited in the mixer truck, each number corresponding to the order of deposition in the materials. The use of individual bags is chosen and not a premix by silos to guarantee the accuracy of the mixture and the homogeneity of the material. Discharges are scheduled in a first transport of plates 1 and 2, adding a total of 5m3, to which 10% of waste and test tubes are added. A second trip would have the same amount of material.

The 5434Kg of slag necessary for the preparation of the mixture are divided into 10 bags of 500Kg and 2 bags of 217Kg, whose numbering corresponds to the first pour in bags S01 to S06 and to the second pour in bags S07 to S12.

Figure 2. Preparation of the numbered and weighed slag.

The 16302 Kg of aggregate 02 are distributed in 18 bags: 16 bags of 1000kg each and 2 bags of 151Kg each to distribute 8151Kg per pour.

Figure 3. Preparation of the numbered and weighed aggregate.

The total 3025Kg of the solution of soda in water is distributed in four containers of 1000kg and 512.5kg to dispose of 1512.5 Kg per trip. Likewise, a fifth container is prepared with 448 kg of the same diluted soda in case there is a need to adjust the formula.

Figure 4. Preparation of the numbered and weighed diluted soda.

Figure 5. Sequence of pouring the containers into the concrete mixer truck.

Manufacturing

Figure 6. Introduction of the materials inside the concrete mixer.
Figure 7. Process of pouring the diluted soda inside the truck.

It can be seen that the sample is fluid and there is no disintegration of the materials or differential kneading.


Figure 8. Appearance of the mixture at the time of pouring.
Figure 9. Fresh state test.

Once 24 hours have been reached from the spill, the resistance test begins to determine the behavior of the material. The specimens, as shown in the photograph, were stored together with the plates under the same manufacturing conditions.

Figure 10. Detail of the surface of the plates 24 hours after pouring.

Once the test specimens are obtained, a test is started whose programming seeks to determine the moment of safe lifting of the plates. The plates are made up of a 12mm diameter corrugated steel-based armor, 10mm diameter electrowelded mesh, anchoring points to the structure and hanging points for the movement of the plates.

The critical point of manufacture is in the lifting of the plates, where the pieces suffer a bending stress that finds its maximum in the perpendicular component of the tie, that is, the plate suffers a stress that decreases as it tilts, and thereby, the bending stress component is considerably reduced.

To guarantee a safe lifting, the most unfavourable situation was considered, this being one of the two largest plates. The maximum distance between the hanging points is 2m, and 2.9 between the hanging point and the support on which the plate is tilted.

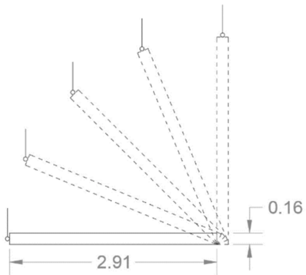

Figure 11. Calculation scheme for critical plate elevation.

$$q = \rho * section = 22.8\,\frac{KN^3}{m} * 3.158 * 0.160 = 11.52\,\frac{KN}{m}$$
$$Mmax = q * \frac{L^2}{8} = 11.52 * \frac{2.81^2}{8} = 11.37\,mKN$$
$$Md = Mmax * \gamma = 11.37 * 1.25 = 14.21\,mKN$$
$$W = \frac{b * h^2}{6} = \frac{3158 * 160^2}{6} = 13474133.33\,mm^3$$
$$\delta = \frac{Md}{W} = \frac{14.21 * 10^6}{13474133.33} = 1.05\,MPa$$
$$f_{ctm} = 0.3 * (0.3 * \sqrt[3]{fck^2}) = 1.74\,MPa$$
$$f_{ctmd} = \frac{f_{ctm}}{\gamma_c} = 1.34\,MPa$$
$$1.34\,MPa > 1.05\,MPa \rightarrow DOES\ NOT\ CRACK$$

Once it has been verified that the resistance at 48 hours is higher than the admissible one and it has been verified that the resistance at 72 hours offers a safety margin, the lifting of the plates begins at 72 hours.


Figure 12. Lifters to remove the plates from the mold 72 hours after pouring.
Figure 13. Plate fully raised and ready to move to storage point.

The plates are assembled 5 days after pouring. Of the four facades of the building, the 16mm geopolymer slabs under investigation make up the south façade, with the other three enclosures made with 12mm conventional concrete slabs. The placement of the geopolymer plates follows the order from left to right described in the image at the beginning of the text.

The plates are transported horizontally, and since their final placement will be vertical, you will have to carry out the lifting and turning manoeuvres.

First, the crane lifts the plate held by three points: one on the side edge of the plate (located at the top when its position is horizontal in the truck), and two on the upper edge of the plate (located on the right side when its position is horizontal in the truck). The hangers at the two points of the upper edge share a single pulley different from that of the side edge.

So in a first manoeuvre, the plate is raised in a horizontal position held by three points. Once the piece has been raised horizontally, the tilting manoeuvre begins, raising the points of the upper edge held by the same pulley and lowering the lateral anchoring point. In this way, the plate rotates slowly without increasing efforts and, finally, the side hanger stops working and is withdrawn, leaving the plate hanging by the two upper anchor points.

Figure 14. Placement of the fourth and last plate of the facade.

On the side you can see the difference in color between the geopolymer plates and the enclosure with OPC plates.

Figure 15. Appearance of the geopolymer façade on September 1, 2021, 138 days after its manufacture.

CONCLUSION

Geopolymer materials are a viable substitute for ordinary Portland concrete. The ease of integration into the conventional workflow together with the results assimilable to conventional concrete make this material a sustainable alternative to the demands of reducing the environmental impact of construction.

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DEMOLITION AND COLLAPSE DEBRIS MANAGEMENT OF HISTORICAL BUILDINGS DUE TO EARTHQUAKES

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ABSTRACT

Most of historical buildings around the world have been constructed of different materials depending on their structural configuration, components, use and geographical location. This has led to a great variety of construction materials for the vertical resistant system, slabs and roof. These buildings are extremely vulnerable to suffer strong damage against earthquakes due to different factors regarding geometrical configuration and features, materials, total height, use, location, recent rehabilitations, conservation state, etc. This type of buildings may present in case of an earthquake partial or global collapses and generate different types of demolition and collapse debris depending on rehabilitations and damage degree. The main debris comes from collapses and demolitions with a variation of construction materials such as mud, masonry elements, mortar, concrete ties that serve to confine the masonry elements, furniture, plastic hoses, piping, dry-walls and garbage. This paper is objected at describing the main typologies of historical constructions that are commonly located around the world, structural configuration and architectonic features, construction materials, common seismic damage, and interventions, as well as waste management procedures and strategies. These strategies would be of great help for constructors and authorities to follow a better management procedure regarding the debris volume estimation, separation of waste, reuse, and recycling.

Keywords: Demolition, collapsed buildings, waste management, historical buildings, earthquakes, Introduction.

INTRODUCTION

Most of historical buildings (see Fig. 1) around the world have been constructed of different materials depending on their structural configuration, components and use (e.g. bell-towers, Cathedrals, minarets, naves, mosques and other monumental buildings), as well as their geographical location. This has led to a great variety of construction materials for the vertical resistant system (e.g. walls, columns, etc.), slabs and roof .

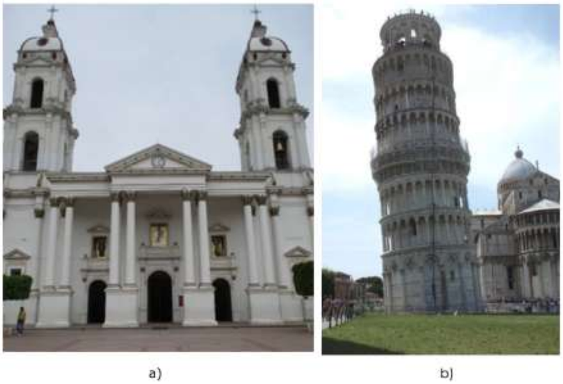

Figure 1. Some historical bell-towers and buildings around the world: a) the lined tower of Pisa, Italy, Source: Preciado (2011), and b) The Tlajomulco´s Church in Jalisco, Mexico, **Source**: Preciado and Colmenero (2021).

Figure 2. Different construction materials from demolitions and collapses.

This paper is objected at describing the main typologies of historical buildings that are commonly located around the world, structural configuration and architectonic features, construction materials, common seismic damage and interventions, as well as waste management procedures and strategies. This would be of great help for constructors and authorities to follow a better management procedure regarding the separation of debris, reuse and recycling.

Characteristic structural elements of historical buildings and main construction materials

The main structural components of historical buildings and bell-towers are walls, arches and columns as shown in Fig. 3, as well as different cover systems such as vaults (Fig. 4a) and domes (Fig. 4b).

Figure 3. typical masonry elements such as walls, columns, arches and columns.
Source: Preciado (2011)

Figure 4. Typical masonry vaults and monumental domes. a) vault system of a historical building in Pisa, Italy, **Source**: Preciado (2011) and b) the dome of Santa Maria del Fiore in Florence, Italy, **Source**: Foraboschi (2014)

It is worth noting in Fig. 4b, the presence of an old rehabilitation measure based on iron bars to avoid an opening of the supporting columns and the collapse of the building by overturning. This practice was very common in Italy and other European countries. These iron bars have been also replaced by timber ties that go across the building from one façade to another to prevent an overturning of walls in case of extreme seismic loading. The walls and columns are part of the vertical resisting system, and arches, vaults and domes of the cover system. In some cases, the floors and roof are made of other materials different than masonry such as timber and fired-clay tiling and other materials.

Masonry is the main construction material for most of historical buildings and bell-towers for the vertical resisting system, vaults and domes. This material is integrated by units of carved stones, natural stones and fired-clay bricks placed together with a mortar. In most cases bare masonry was a common practice, but for instance in Mexico, most of historical buildings are plastered (see Fig. 1b) with mortar to include different color painting and clay detailing. In case of slabs and roofs, timber joists and laminates of the same material are also common in these buildings.

Adobe with clay mortar (see Fig. 7) is another material that was commonly used for the resisting system of Churches and bell-towers in Mexico and also rammed earth (i.e. compressed soil). The correct understanding of the main construction materials of different structural components of historical buildings and bell-towers is a key component to the waste management of rehabilitation/restoration works on these buildings and seismic collapses (partial or global). The following section explain more in detail the typical seismic damage that may be exhibited by these patrimonial buildings and common materials used in the rehabilitation campaigns.

Typical seismic damage and materials used in rehabilitation works

The intrinsic vulnerability of masonry Churches (see Fig. 5) against seismic actions is determined by certain aspects such as tall bell towers, large halls, arches with different curvature, domes, vaults and annexes (Lagomarsino and Podesta, 2004a-b; Foraboschi, 2014; Preciado *et al*., 2020a). Furthermore, by the strong influence of geometrical features such as inclinations of bell-towers (see Fig. 1a and 6), slenderness, large openings, belfries and connecting regions with the Church (Valente and Milani, 2019).

Figure 5. Typical seismic collapses of masonry and timber covers and supporting elements by the L'Aquila, Italy EQ in 2009, Mw= 6.3,
Source: Modena *et al*. (2010).

Another important factor is the main construction material of the resisting system, masonry is made of the combination of units or bricks and mortar. The heterogeneity of both materials and the complex interaction between them makes a material with variations in properties from one segment to another, as well as a different behavior (anisotropy) when loaded along its main plane (in-plane) or perpendicularly (out-of-plane). This anisotropy and heterogeneity behaviour along with the elevated mass of masonry induces seismic forces that generate partial or total collapses mainly by the reduced tensile strength of this material. It is important to mention that the very low tensile strength of masonry induces cracking and the generation of a failure mechanism. Conversely, this material has a relatively good strength against compressive stresses such as the induced by its own weight in static conditions. In order to have a good resistance against vertical loading, these patrimonial buildings need resisting elements of large thickness, inducing more mass in seismic conditions (e.g. lateral pounding effect). Masonry has a typical density of 1600-2000 kg/m^3, and reinforced concrete of 2400 kg/m^3.

The large openings and corners of masonry buildings attract concentrations of shear stresses inducing cracks that may lead to partial or total collapses (Figs. 5-7).

Figure 6. typical seismic collapses of masonry bell-towers: a) damages by the 2011 Christchurch, New Zealand EQ Mw= 6.3, **Source**: Lester *et al*. (2012) and b) damages by the 2003 Colima, Mexico EQ Mw= 7.3, **Source**: Preciado (2011).

Earthen buildings are the most vulnerable structures due to its main construction material is adobe, rammed soil or combinations with masonry elements such as stone, fired-clay bricks and so on (see Fig. 7).

Figure 7. typical seismic damage in earthen constructions by the 2017 Puebla-Morelos EQ, Mw= 7.1 and 8.2,

Source: Preciado *et al*. (2020a)

In terms of compressive strength, these earthen buildings (Fig. 7) have a typical resistance of about 10-15% (2-5 kg/cm^2) or even less if compared to the presented by masonry buildings depending on the component materials (15-40 kg/cm^2). Adobe is also a very heavy material with a density of about 1800 kg/m^3. In conclusion, earthen patrimonial buildings are the most brittle structures due to the aforementioned characteristics mainly related to the reduced intrinsic strength of this material. Compared to fired-clay bricks, adobe is not subjected to high temperatures induced by firing, the units are dried to the light of sun and the fired-clay bricks in special or artisanal ovens, leading to a more homogeneous and higher strength material.

The typical rehabilitation works on damaged historical buildings depend on many factors such as structural element, materials, configuration and so on. The most common are sealing of cracks and restoration of damaged units, plasters of clay, lime and in some cases of Portland cement. The last material must be avoided when repairing patrimonial buildings due to this material has a higher strength than mortars of clay and lime and may induce concentration of stresses or other problems related to deformation by temperature due to the lack of compatibility. In some cases, it is used reinforced concrete ties and reinforcement of walls, vaults and cover systems with anchored steel welded wire mesh and plaster. These concrete ties and welded wire mesh should be also avoided. New developments in rehabilitation materials are suggesting the use of fiber reinforced polymers (FRPs) with a great variety of uses in historical buildings (e.g. Bischof and Suter, 2014; Rossetto *et al*., 2014). Moreover, timber flooring systems of historical masonry buildings are commonly rehabilitated with the use of timber joists in both orthogonal directions to improve the rigid diaphragm effect and to obtain the box-shape behavior.

Integrated construction and demolition waste management plans and strategies in European Union

Construction and demolition (C&D) waste is the largest waste stream by volume in the European Union (EU), accounting for around a third of all the generated waste. This waste consists of different types of materials that can be reused as a source of raw material or energy instead of being sent to landfill. Since the 1990s, several legislative initiatives have been implemented in the countries of the EU, both at EU level and in individual EU countries, which address the issue of waste management including waste collection, transport to treatment sites, recovery and landfill of the non-reusable fraction. In recent years, research activities have also established the technical feasibility of using demolition rubble from reinforced concrete constructions as an alternative to using natural aggregates (Moriconi and Corinaldesi, 2002; Corinaldesi and Moriconi, 2003; Ho *et al*., 2013; Santos *et al*., 2019; Nedeljković *et al*., 2021). Nevertheless, the rate of utilisation of demolition and construction waste is still modest in the countries of the EU and much of it is still taken to landfill or at best used as filling material in road and rail infrastructure construction. The most common obstacles to the effectiveness of C&D waste management within the Union are the lack of confidence in their technological properties and concern about their potential health hazards. As a part of the construction sector strategy to improve resource efficiency in construction, the EU has drawn up a protocol of action aiming at an integrated management of construction and demolition waste that considers the socio-economic and geographical conditions of the territories (European Commission, 2018). It is also part of the more recent and ambitious Circular Economy Package presented by the European Commission (2020). which contains revised legislative proposals on waste to stimulate Europe's transition to a circular economy and thus increase global competitiveness, promote sustainable economic growth and create new jobs. The general objective of this protocol is to increase confidence in the C&D waste management process and in the quality of the materials recycled from this waste through the following actions: (a) better waste identification, source separation and collection; (b) improved waste logistics; (c) better waste treatment; (d) quality management; (e) appropriate policy and framework conditions.

Seismic damage scenarios on historical buildings and debris volume estimation

In this research project, patrimonial buildings are integrated by Churches, monuments, mosques, bell-towers and non-religious structures such as museums, theatres and other historical buildings. It is proposed to manage the demolition and collapse debris by a classification of buildings according to their typology (bell-tower, Church, Mosque, non-religious buildings, etc.) vertical (walls, columns and buttresses) and horizontal resisting system (arches, vaulted cover, domes, timber slabs, etc.), structural elements, materials, etc. Regarding the seismic action, it is proposed to classify buildings and materials according to the common observed damage in structural elements, their material volume and geometrical configuration. In case of an intensive seismic action, the structural elements are subdivided into macro-elements due to the cracking propagation, leading to the formation of failure mechanisms in the main façade, lateral façades, dome, partial section of a vaulted cover, belfry of bell-towers, body of towers, parapets, arches, columns, etc.

The Mercalli modified intensity (MMI) may be useful to propose a link between the expected damage and the seismic intensity in different masonry and earthen patrimonial buildings as presented by Preciado *et al*. (2020b) to propose seismic damage scenarios at a territorial scale in 15000 houses in a seismic zone of Mexico (Table 1). The MMI may be also linked with the European Macroseismic Scale (EMS-98) proposed by Grüntal (1998) and the damage grades of the Eurocode-8 (2004). This relationship between expected damage (partial or total collapses) and different seismic intensities according to the MMI scale allow to propose different seismic damage scenarios and to estimate the level of debris volume depending on the building´s geometry and type of the structural element and materials.

MMI	Vulnerability class	15000 houses	Damage grade (EMS-98)	Damage limit states Eurocode-08	Observations
VI	Medium	12417	2	DLS	Minimum reparable damage
	High	1600	3	SDLS	Major reparable damage
	Very high	983	3	SDLS	Major reparable damage
VII	Medium	12417	2	DLS	Minimum reparable damage
	High	1600	3	SDLS	Major reparable damage
	Very high	983	4	ULS	Collapse, total loss

VIII	Medium	12417	3	SDLS	Major reparable damage
	High	1600	4	ULS	Collapse, total loss
	Very high	983	4	ULS	
>VIII	Medium	12417	4	ULS	
	High	1600	4	ULS	
	Very high	983	4	ULS	

DLS= damage limit state; SDLS= significant damage limit state and ULS= ultimate
Table 1. Proposed damage scenarios by correlating the MMI with the vulnerability classes, damage grades, limit states and type of damage
(Preciado *et al*., 2020b)

Regarding the debris volume, most of structural elements and materials are compacted and consolidated with the ageing of the building, as well as by the moisture which plays an important role in the estimated debris weight. It is proposed to implement strategies of geomechanics to estimate the increasing volume in uncompacted conditions which may range for debris between 40 to 80% depending on the intrinsic material such as carved stone and brickwork masonry, adobe and rammed soil, as well as the moisture conditions of the material. These ranges to estimate the uncompacted debris volume still need to consider other waste such as furniture, glasses, garbage, piping, wiring, drywalls, timber and plaster as shown in Fig. 2. However, the proposed procedure still needs to be verified with its application in different case studies such as Churches and bell-towers or other type of historical buildings to study and adjust the waste management strategy. The main goal is that these strategies may be of help to manage seismic disasters in patrimonial buildings in terms of waste management at a territorial scale and the possibility to separate the debris, reusing and recycling of materials for further rehabilitation/restoration woks and the reconstruction of other buildings.

CONCLUSION

The waste management of patrimonial buildings represents a complicated task due to it could be generated by different situations such as partial demolitions by rehabilitations or restorations, as well as by local collapse of some elements or the complete collapse by seismic action or static instability. The complexity in waste management is represented by the great diversity and heterogeneity of materials that conform the different structural elements (walls, arches, columns, vaults, domes, etc.), geometrical features, irregularities in plan and height, great thickness, heavy mass and structural vulnerability, furniture, decorations and so on. Moreover, the seismic vulnerability is increased by inclinations and slenderness of tall bell towers and façades, large openings attracting seismic damage, corners and intersections of walls and contact zones among elements. These vulnerability aspects may induce different damage degree and collapses depending on the structural element and intrinsic materials.

Masonry patrimonial buildings of carved stone and brick work are very likely to present partial or total collapses in case of an earthquake, but earthen buildings are the most vulnerable to present a complete collapse due to the brittleness of this material. The damage degree and intrinsic structural material are key components to decide about the rehabilitation/restoration materials and partial demolitions. These materials used in the rehabilitation works along with the partial or total collapse debris play an important role in the proposal of effective waste management procedures and strategies. In this paper, it is proposed the first stage of a procedure to classify the historical buildings in structural elements representing the vertical and horizontal resisting system, materials and level of expected damage in case of different seismic intensities in the MMI scale. These seismic damage scenarios are helpful to estimate the level of expected damage and debris volume depending on the geometry and type of structural element and materials. These strategies would be of great help for constructors and authorities to follow a better management procedure regarding the separation of debris, volume estimation, reuse and recycling. In further stages of this research project it will be studied the possibility of adding to the proposed strategy with the expected debris volume due to rehabilitation and restoration works by including common used materials and waste percentage in these interventions. Moreover, some practical examples will be also presented in an extended version of this paper regarding the application of the proposed waste management procedure in different case studies such as churches and bell-towers.

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