EVALUATION OF COVERING MATERIALS USING THE SOLCONCER TOOL: TWO CASE STUDIES FOR REHABILITATION

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1. ABSTRACT

In recent years, the maintenance, renovation, and rehabilitation of buildings have become part of the most widely demanded jobs in the construction industry. In addition, users are known to have growing concern about the building's entire life cycle, which encompasses all stages, from the production of building materials to the construction, use and maintenance of the property and, finally, its dismantling.

In this sense, the choice of certain construction materials in general, and specifically of coverings, for use in rehabilitation projects could reduce the environmental impacts involved in this type of job and control the economic costs associated with the building's full life cycle, while also helping to improve residents' quality of life and health thanks to the benefits such materials afford.

As a means of backing the sales process or of aiding end-users or specifiers with their decision-making, this paper presents a comparative evaluation of two different coverings for two common construction projects in the reform sector: façades and floorings. Part of this evaluation includes identifying the most relevant aspects from the environmental, economic and performance point of view for each of the materials and systems evaluated.

The analysis is performed using SOLCONCER, an online, free-of-charge tool that provides evaluation of various construction solutions with ceramic or alternative covering materials. The main aim of this evaluation is to be able to select, on the basis of certain choice criteria, the most appropriate solution from the various options analysed. Development of the SOLCONCER tool has been funded by the Castellón County Council.

This paper undertakes an evaluation of two different rehabilitation processes:

- Replacement of a current indoor floor covering with a new one, where the strengths and weaknesses of a ceramic slab and of a luxury vinyl tile floor will be analysed.
- Energy rehabilitation of a façade by installing a ventilated façade system: where the advantages and drawbacks of fitting a porcelain stoneware tile and a multi-layer aluminium panel as the outer covering will be studied.

These evaluations demonstrate how, depending on the parameters or scenarios, certain construction solutions and types of materials can offer better or worse response to users' growing concerns.

2. INTRODUCTION

The European Commission's 2050 Roadmap states that by 2050, the European Union must have reduced its emissions levels to a level 80% lower than in 1990 to achieve "energy neutrality". The building sector is one of the most responsible for emissions in Europe. Buildings in our country account for 40% of energy demand and 36% of CO_2 emissions. Nevertheless, at present, only 1% of the Spanish building stock has been given energy rehabilitation.

The European recovery funds following the COVID-19 crisis have been the perfect instrument for the Government of Spain to present its Recovery, Transformation and Resilience Plan (PRTR). Among the main investment programmes included there is the Housing Rehabilitation and Urban Regeneration Programme, which plans almost €7 billion in investment, the objectives of which are to rehabilitate 1.2 million homes by 2030. Furthermore, the 2021 National Budget (PGE) reserves a heading for Housing and Urban Agenda of about €2.25 billion, of which €81 million are destined to the sustainable rehabilitation of public buildings and €30 million are earmarked for architectural rehabilitation [1].

Given such financial backing, it is logical to imagine that the housing reform and rehabilitation sector is clearly bound to benefit. In this sense, the National Association of Ceramic and Construction Materials Wholesalers (Andimac) estimates that about 1.5 million homes will be reformed in 2021, which represents 5.7% of the total, and so the reform and rehabilitation sector will grow by around 6% this year [2].

Within such a context, it is key for the ceramic industry to position its products as one of the best options in rehabilitation work [3]. To do so, it is essential to identify those characteristics that make each ceramic product the best alternative when a covering material is being chosen for a building rehabilitation project. With that aim in mind, this paper looks at two case studies to identify the main advantages and disadvantages of using ceramic materials in two different rehabilitation scenarios.

3. METHOD USED FOR EVALUATION

To evaluate the materials, the method used by the Solconcer tool [4] [5] for building rehabilitation solutions [6] was adopted. Solconcer is a platform that assesses construction solutions with different covering materials from an environmental, economic and performance point of view. The procedure used to carry out this study consisted of:

- Selecting two construction projects involving renovation work during the reform and/or rehabilitation of residential buildings: interior flooring and façades.
- Identifying the optimal type of ceramic material, in this regard, for each of the selected construction projects, and also identifying alternative covering materials considered to be direct competitors to ceramics in those applications.
- Searching for and selecting three commercial products from three different companies for each of the identified materials.
- Gathering data on the characteristics of the selected products.
- Defining the scenarios and/or context in which the evaluation was to be carried out.
- Uploading all this information into Solconcer for environmental, economic and performance characterisation of the materials forming part of the construction project and analysing the results thereby obtained.

Data type	Flooring	Façades
Environmental	Product Environmental Declarations / Solconcer	Environmental Product Declarations / Solconcer
Economic	Online retailers / Solconcer	Construction Price Database / Solconcer
Performance	Technical data sheets	European Technical Evaluations (ETEs) & Technical Suitability Documents (DITs)

Table 1. *Sources used to gather data for the evaluation of the materials [7]*

4. INDOOR FLOORING REHABILITATION

This section presents the first case study, namely an environmental, economic and performance analysis of the renovation of existing indoor flooring by installing a ceramic slab and a luxury vinyl tile (hereinafter LVT) floor.

4.1 DESCRIPTION AND SELECTION OF MATERIALS

Ceramic slab is the commercial name given to ceramic tiles of reduced thickness in relation to the rest of their dimensions and whose characteristics are equivalent to those of porcelain stoneware. As this material is thin, it is the ideal ceramic choice for installing in building reforms where the intention is to avoid demolition of the existing hard floor (terrazzo, natural stone or ceramic tile).

LVT is a superior quality multi-layer vinyl floor formed by self-supporting tongue-and-groove tiles that are easy to install as they come with a click-in assembly system. This type of dry installation and its reduced thickness make the material an ideal choice for installation over existing floors.

4.2 PRELIMINARY CONSIDERATIONS

Durability is the ability of a material to retain the technical, aesthetic, and functional characteristics for which they were initially selected throughout its service life. Both the Solconcer tool and our own evaluation take a reference period of 50 years over which to compare the various construction solutions under study.

The service life of a ceramic tile can be estimated at 50 years for any type of use, which significantly limits the number of replacements, as well as the fact that it does not call for any surface treatment operations during this period [8], except for standard cleaning. For its part, the service life of LVT may vary depending on the intended use it is given - residential (low traffic) or public (high traffic). As a result, there exist products designed for a service life ranging from 15 to 20-25 years. For our evaluation, an average service life of 20 years was considered. This means that, after that length of time, the material is no longer expected to fulfil the function for which it was created and will need to be replaced.

At this point, it should be noted that the following scenarios, which will affect the results obtained to a greater or lesser extent, were defined to evaluate the construction solutions using the Solconcer tool:

Scenarios	
Use	Residential
Maintenance frequency	Low
Traffic intensity	Low
Type of premises	Dry
Current floor	Terrazzo
Place of manufacture	Ceramic slab: Spain / LVT: Europe

Table 2. *Scenarios defined in the Solconcer tool for evaluation of the materials*

Floor maintenance comprises all operations that take place from its installation until its removal. In general, such operations consist of cleaning and spot repairs and replacement of material. Specifically, for cleaning, three different frequencies were set up in the Solconcer method: high, medium, and low, depending on the use for which the flooring is intended (high/low traffic). To define those operations, the most common conditions included in the Environmental Product Declarations (hereinafter, EPDs) were used as a reference, as well as the most common recommendations made by actual manufacturers [9].

Finally, one should remember that, in the environmental and economic evaluation, although the data entered in Solconcer refers only to the covering material, the information provided by the tool also includes the impact produced by other materials needed to correctly fit the product. In the case of ceramic slab, both the bonding and grouting material are taken into consideration, as is the anti-impact underlay in the case of the LVT.

4.3 ANALYSIS OF THE RESULTS

ENVIRONMENTAL

Environmental impact in Solconcer is defined on the basis of 7 environmental indicators, determined after carrying out a Life Cycle Assessment of each construction solution. Solconcer shows the results associated with the environmental profile over the entire life cycle of both the coverings and the entire construction system.

Recommendations proposed by standards on sustainability in buildings and construction sites and Regulation (EU) No 305/2011 on construction products call for environmental impact to be assessed from the life-cycle perspective, i.e., construction products should always be compared with the same installation conditions in the building and over the same periods of time.

As mentioned above, the reference life cycle established in Solconcer is 50 years, with a (low) intensity of pedestrian traffic, which determines specific maintenance operations and frequency.

In general, the categories of environmental impact associated with fitting 1 sq. metre of these two coverings do not vary greatly; however, from the life cycle perspective, ceramic tiles are seen to be environmentally preferable to LVT. These results are mainly determined by the number of LVT replacements required over the time span set in Solconcer (50 years).

Impact category	Units	Ceramic slab	LVT
Global warming potential	kg CO_2 Eq.	1.18 E1	2.91 E1
Potential for depletion of the stratospheric ozone layer	kg CFC-11 Eq.	8.56 E-7	8.22 E-7
Acidification potential	kg SO_2 Eq.	3.86 E-2	7.37 E-2
Eutrophication potential	kg PO_4^{3-} Eq.	6.54 E-3	2.29 E-2
Tropospheric ozone formation potential	kg C_2H_4 Eq.	2.77 E-3	1.90 E-2
Potential for abiotic resource depletion for fossil resources	MJ	2.00 E2	5.18 E2
Potential for abiotic resource depletion for non-fossil resources	kg Sb Eq.	3.08 E-5	1.84 E-4

Eq.: equivalent

Table 3. *Environmental impact associated with 1 m^2 flooring over the reference period*

ECONOMIC

The economic results obtained in Solconcer are organised by the various stages in the life cycle, following the module structure set down in UNE-EN standard 15643 on Sustainability in Construction and bearing in mind certain considerations.

Life cycle stages	Ceramic slab	LVT
Manufacturing	40.29	38.27
Transport	0.30	0.95
Construction	11.71	3.71
Subtotal	**52.30**	**42.93**
Maintenance	1.74	2.36
Repair	0	0
Replacement	0	141.00
End of life	5.49	4.07
Total	**59.53**	**190.36**

Table 4. *Economic costs (€/m^2) associated with 1 m^2 flooring over the reference period*

The above table shows how the first difference to be noticed is the cost associated with the initial stages (subtotal). While for residential use in a dry space, the price per square metre of LVT is around €43 per m^2, in the case of ceramic slab, the cost rises slightly to over €52 per m^2. This is mainly due to higher installation and/or commissioning costs of the ceramic material.

However, this initial barrier can be overcome if the in-use stage of the materials' life after installation is included in the reckoning. In this sense, it is essential to highlight the cost impact of replacing the LVT, which, with a service life of 20 years, needs to be replaced at least twice in the 50 years that make up the reference period of time. All this translates into considerable replacement costs, which in this case would reach €140 per m^2. For its part, the ceramic slab, with a service life of 50 years, has a replacement cost of zero.

So, when all the stages in the life cycle are considered, the analysis shows an economic cost difference of more than €130 per m^2 between a ceramic slab and an LVT.

PERFORMANCE

All the products under study have technical data sheets published by their manufacturers that provide information about the main characteristics of the products applicable to the intended use. From the information given for the selected products, only the values of characteristics available for both materials and included in the Solconcer method were extracted:

Characteristic	Ceramic slab Standard	Value	Score		LVT Value	Standard
Reaction to fire	UNE-EN 13501-1	$A1_{fl}$	*10*	*8*	$B_{fl\text{-}s1}$	UNE-EN 13501-1
Hazardous substances: VOCs	UNE-EN 16000	No testing required	*10*	8	≤10-20 µg/m^3	UNE-EN 16000
Hazardous substances: formaldehyde	IN 717-1	No testing required	*10*	*8*	Class E1	IN 717-1
Slipperiness	UNE 41901: 2017 EX	Class 1	*7*	*10*	Class 2	UNE 41901: 2017 EX
Stain resistance	UNE-EN 10545-14	Class 5	*10*	*10*	Class 0	UNE-EN ISO 26987
Chemical resistance	UNE-EN 10545-13	A/LA/HA	*10*	*9*	Class 5	UNE-EN 438-2

Table 5. *Technical characteristics of the materials under evaluation*

Both materials meet the requirements made for installation in indoor spaces for domestic use; however, they have slightly differentiated characteristics:

Safety in the event of fire: as far as materials' reaction to fire goes, their behaviour differs since the ceramic slab is Class A (better behaviour), whereas the LVT is classified as Class B (a lower category, which means worse behaviour). Emission of hazardous substances: LVTs, which use formaldehyde in their manufacturing process, are subject to testing for possible emissions of this substance in the end product. In this sense, the documents consulted show that laminate floors are usually given Class E1 (≤ 0.01 mg/m^3) and although that is the class for the lowest emissions, they can still occur. As for VOC emissions, ceramics do not emit any VOCs given their inert nature and, in fact no regulations call for tests to be performed to prove such a lack of emissions. On the other hand, the LVT products consulted declare an emission rate of between 10 and 20 µg/m^3.

Safety of use: although no minimum requirement is made by Building Code DB-SUA1 in regard to slipperiness for privately used floors in dry indoor spaces, both materials meet the minimum requirements for such use in public spaces (class 1).

Durability and service: from the information obtained, it is clear that, as far as stain and chemical resistance are concerned and despite the fact that the ceramic slab has optimal behaviour, the LVT also declares remarkable characteristics.

4.4 CONCLUSIONS

- When evaluation is performed from the life cycle perspective, ceramic tiles are found to be environmentally preferable to LVT in six of the seven categories of environmental impact analysed.
- Economic analysis from a life cycle perspective also shows that the use of a ceramic slab is preferable to a laminate floor. In this specific case, taking into account all the stages evaluated, the price gap between both materials extends to €130 per m^2 due to the shorter declared service life for the LVT.
- At performance level, the results are less obvious and, despite the ceramic tile performing better in terms of fire resistance or emission of hazardous substances, the LVT presents a better response to slipping and a stain resistance practically equivalent to that of the ceramic slab.
- Our analysis and search for technical characteristics has made the problem of comparing the performance declared by covering materials of different natures more visible. This problem has made it impossible to carry out a more thorough comparative evaluation of the characteristics of each of the flooring systems in the study.

5 FAÇADE REHABILITATION

This section presents the second case study, which looks at the energy rehabilitation of an existing façade by installing a ventilated façade system. In this instance, the advantages and drawbacks of fitting a porcelain stoneware tile and a multilayer aluminium panel as a covering system will be evaluated.

5.1 DESCRIPTION AND SELECTION OF MATERIALS

Multilayer aluminium panels are panels comprising two outer sheets of aluminium with a rigid core. The thickness of the aluminium layers is 0.5 mm, while that of the middle core varies (3-7mm). Its main advantages include its rigidity, lightness, lack of ageing as it is protected by aluminium, and the fact it can be folded and creased to many shapes and forms.

Porcelain stoneware is the definition used in standards and on a technical/commercial level for dry pressed or, to a lesser extent, extruded ceramic tiles with very low water absorption. They can be glazed or non-glazed and are normally made by single firing [10]. They can be anchored to ventilated façades by means of chemical adhesive or mechanical clip fastenings and horizontal profiles.

5.2 PRELIMINARY CONSIDERATIONS

As was the case above, for ventilated façade systems, a reference period of 50 years was considered in our analysis. However, on this occasion, all the products selected declare a service life of 50 years, which makes considering any replacements unnecessary.

For its part, maintenance of a façade includes all those operations that take place once it has been installed up until it is removed. In general, such activities usually consist of cleaning and spot repairs and replacement of panels. Specifically, the Solconcer method does not contemplate a cleaning stage in a façade's life cycle for environmental and economic evaluation because, despite exhaustive research of various sources, no verified and reliable data were obtained concerning the frequency and nature of maintenance recommended for the types of façades and covering materials under study.

To evaluate these two construction systems, the following scenarios were defined, which will affect the results obtained to a greater or lesser extent:

Scenarios	
Type of façade	Ventilated façade
Place of manufacture	Porcelain stoneware: Spain / Multilayer aluminium panels: Europe

Table 6. *Scenarios defined in the Solconcer tool for evaluation of the materials*

One should bear in mind that the output information provided by Solconcer from its environmental and economic analysis includes the impact of the other materials required to properly install the products. In the case of ventilated façade systems, they include the metal sub-structure it is fixed to and all the necessary anchoring items (screws, angles, clip fastenings, etc.).

5.3 ANALYSIS OF THE RESULTS

ENVIRONMENTAL

As mentioned above, the environmental impacts given by Solconcer are defined on the basis of 7 environmental indicators, that are subsequently standardised by applying the factors in the CML 2001 method.

In the two scenarios - ventilated aluminium panels and porcelain stoneware - under evaluation, from the life cycle perspective, the Solconcer tool determines that porcelain stoneware is environmentally preferable in all seven categories of environmental impact evaluated, as well as in the standardised end result.

In this regard, it is worth noting the significance of the manufacturing stage of both ventilated façade systems: the production of porcelain stoneware has a better environmental profile than that of aluminium panels.

Impact category	Units	Porcelain stoneware	Aluminium panels
Global warming potential	kg CO_2 Eq.	1.87 E1	3.57 E1
Potential for depletion of the stratospheric ozone layer	kg CFC-11 Eq.	1.66 E-6	1.79 E-6
Acidification potential	kg SO_2 Eq.	7.41 E-2	1.18 E-1
Eutrophication potential	kg PO_4^{3-} Eq.	8.13 E-3	7.42 E-2
Tropospheric ozone formation potential	kg C_2H_4 Eq.	4.66 E-3	1.96 E-2
Potential for abiotic resource depletion for fossil resources	MJ	2.66 E2	3.65 E2
Potential for abiotic resource depletion for non-fossil resources	kg Sb Eq.	1.17 E-4	1.21 E-4

Eq.: equivalent

Table 7. *Environmental impact associated with 1 m² ventilated façade over the reference period*

ECONOMIC

For façade construction solutions, the main economic costs are concentrated in both the early stages of the life cycle (subtotal) and in the later stages. That is because during the in-use stage, no maintenance operations (cleaning) are considered in the calculation and because repair and replacement operations are not necessary for this type of product.

Life cycle stages	Porcelain stoneware	Aluminium panels
Manufacturing	43.17	79.72
Transport	0.44	1.33
Instruction	48.82	39.62
Subtotal	**92.43**	**120.67**
Maintenance	–	–
Repairs	0	0
Replacement	0	0
End of life	76.33	76.36
Total	**168.76**	**197.03**

Table 8. *Economic costs (€/m²) associated 1 m² ventilated façade over the reference period*

It is clear from the information obtained from the calculation that the greatest economic variance is seen in product manufacturing costs. The cost per square metre of a ceramic ventilated façade is much lower than that of a ventilated façade using a multilayer aluminium panel covering (€43 per m² vs €80 per m²). It should be remembered that this cost includes both the price of the covering and of the metal sub-structure, anchors, brackets, and screws required to install it.

A further difference is found in construction costs, i.e., in the cost of manpower required to install the system. From the results obtained, we noted a gap of about 10 €/m^2 in this heading, deriving from efficiency when installing the covering given the size of the panels (with standard formats, such as 45x90 cm, while for aluminium panels, the minimum size is around 100x200 cm).

In this specific case, taking all the life cycle stages analysed into account, the price gap between both materials reaches €28 per m^2.

PERFORMANCE

All the products in our evaluation come with documents (European or Spanish) that describe the evaluation of the system's technical performance compared to the essential characteristics applicable to the use intended by the manufacturer. From the ETEs and DITs for the selected products consulted, only data for characteristics available for both materials and included in the Solconcer method were extracted:

Characteristic		Porcelain stoneware			Aluminium panels
	Standard	Value	Score		Value
Reaction to fire	UNE-EN 13501-1	$A_{2\text{-}s1\text{-}d0}$ (with mesh)	*10*	*8*	$B_{s1\text{-}d0}$
Impact resistance	DEE 090062-00-0404 (2.2.11) and Annex G	Category IV	*2*	*10*	Category I
Resistance to wind load. Suction	DEE 090062-00-0404 (2.2.9) and Annex E	2000 Pa	*4.5*	*4*	1800 Pa
Anchorage: Frost resistance	DEE 090062-00-0404 p. 2.2.15.3	Groove breakage, deformed anchorage	-	*8*	No breaks, no cracks

Table 9. *Technical characteristics of the materials under evaluation*

Although both materials meet the requirements demanded for their use as ventilated façade systems, they do reveal certain differences, as highlighted below:

Safety in the event of fire: reaction to fire category: although porcelain stoneware is given a Class A_1 without any need for testing (according to Decision 96/603/EC, as amended), the ceramic tile in this type of system usually has a fibreglass mesh installed behind it to avoid parts falling if they break off and which brings its resistance to fire class slightly down ($A_{2\text{-}s1\text{-}d0}$). On the other hand, multilayer aluminium panels can have different reaction to fire classes depending on the material the inner core is made of. They are usually defined and classed as: PE, polyethylene core - Class E; FR, flame retardants - Class B; A2, mineral core - Class A2.

Safety of use: these systems' resistance to impact (from both hard and soft bodies) is sorted into four groups ranging from Category I (best behaviour) to Category IV (worst behaviour). In the case of ventilated façade systems made of multilayer aluminium panels, they are all declared to be Category I, whereas ceramic ventilated façade systems only reach Category IV. This category implies that the system is suitable for covering façade walls beyond reach from ground level. On the other hand, if the frost resistance of the fixings is taken into account, from the documentation consulted, the behaviour of both systems is seen to vary. While aluminium panel systems do not declare breaks or cracks as a result of freeze-thaw cycles, some ceramic systems have breakage in grooves (when concealed fixing systems are used), and deformation in the fixing mechanisms. Although as a single product, ceramic tiles comply with frost resistance tests as per UNE-EN ISO 10545-12, when they form part of a ventilated façade system, they can sometimes reveal certain weaknesses.

5.4 CONCLUSIONS

- It is concluded that ventilated façades using a porcelain stoneware ceramic covering are environmentally preferable to systems made from multilayer aluminium panels, as far as the evaluated impact categories go. These results are mainly determined at the manufacturing stage, where porcelain stoneware has a better environmental profile than aluminium panels.
- From an economic point of view, the use of a ceramic ventilated façade is also preferable than one made from multilayer aluminium panels, due to the associated costs at the product manufacturing stage.
- At the performance level, the ventilated façade systems made of multilayer aluminium panels evaluated here demonstrated better performance in characteristics relating to structural safety of the system, with the exception of fire resistance, where the ceramic ventilated façade scores better.
- In regard to the comparability of each system's technical performance, it is worth noting that analysing the results is much easier in this case, as all evaluations are carried out to the same standard quoted in the relevant European Evaluation Document.

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