SOLCONCER. CHARACTERIZING CONSTRUCTION SOLUTIONS FOR FAÇADES

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1. ABSTRACT

The SOLCONCER tool enables different construction solutions to be evaluated, whether they use ceramics or alternative materials. The main objective of this evaluation is to enable users to choose which of the potential solutions analysed is the most appropriate, on the basis of fixed selection criteria and in terms of three different (environmental, economic and performance-related) aspects.

In order to carry out this evaluation, a number of indicators are specified which relate to these three aspects of analysis. A series of scenarios is also defined for each of the solutions to be evaluated (climatic zone, type of internal structure, type of thermal insulation material, etc.), allowing users to adjust the initial assumptions which will affect calculation of the construction solutions' characteristics.

Performance is characterized using a methodology based on the requirements for construction solutions in the EOTA's[i] Technical Approval Guidelines (ETAGs), which in turn are derived from six of the seven essential requirements in the EU Construction Products Directive; also incorporating an eighth requirement which considers durability and finish (i.e. technical and/or aesthetic obsolescence with regard to "impaired appearance"). Using this set of requirements, a series of indicators are drawn up which establish the quality of the construction solution's performance.

Characterization of the façade construction solutions' environmental impacts and associated costs has been organized according to their various life-cycle stages, following the modular system set out in the UNE-EN 15804 and 15978 (AENOR - Spain)

standards on Sustainability in Construction. The construction solution is therefore analysed in its entirety, including the costs and impacts associated with extraction of its raw materials, installation, usage and its end-of-life process.

The SOLCONCER tool is currently focused on horizontal partitions, wet vertical partitions and street paving construction solutions. We have been working on a new phase since the end of 2016, which aims to expand and optimize the procedures used by SOLCONCER, increasing its functionality by introducing construction solutions for façades. This will enable the project to be extended, by beginning the program's adaptation for use in renovation projects.

This presentation will describe the procedure by which construction solutions for façades have been integrated into the tool. This process involved a detailed study of types of cladding, varieties of façade, and the applicable regulations, to enable characterization of all the construction solutions for façades, as well as the scenarios used in calculating indicators.

2. CHARACTERIZING CONSTRUCTION SOLUTIONS

When we began this new stage in SOLCONCER's development, one of the first issues to resolve was selecting the types of façades and cladding materials that would be included in the tool. The aim is for the tool to provide as accurate a representation as possible of the types of materials and construction solutions that are most commonly used in current façade systems, as is the case for the other construction solutions analysed to date.

2.2. TYPES OF FAÇADE

In recent decades, the most common type of façade used in Spanish residential buildings has been the double-leaf ceramic façade[ii]. This traditional type of façade has undergone changes over the years, for two main reasons: the construction sector's incorporation of technical improvements and the regulations' inclusion of increasingly strict requirements on limiting energy consumption. This has resulted in a reduction in thickness of the ceramic leaves (given that they have lost their load-bearing function) and a considerable increase in the thickness of the intervening thermal insulation material.

A development of this conventional façade, which occurred in parallel to the former, is known as the ventilated façade: an external wall system characterized by the inclusion of a ventilation cavity separating the two leaves. This façade system helps to improve buildings' energy efficiency and also offers superior technical and aesthetic performance. In recent years it has been consolidated as one of the systems which best meets the new requirements made of building envelopes.

These energy-saving requirements, together with the recent development in Spain of sectors such as renovation, have meant that façade systems like ETICS (*External Thermal Insulation Composite Systems*) are also starting to find their place in the national construction sector.

As one of this tool's aims is to be adaptable for use in renovation, when selecting the types of façade that would be included in the analysis, we thought it useful to include those that best suit this type of intervention. Apart from the double-leaf façade (the inclusion of which is more than justified by its extensive use in residential buildings), it was therefore decided also to include the ventilated façade and the ETICS façade in the tool.

Specific definitions of the components of these façades were based on the solutions in the *Building Components Catalogue* of the Spanish Technical Building Code (CTE). The following figures illustrate the types of façade included in the program:

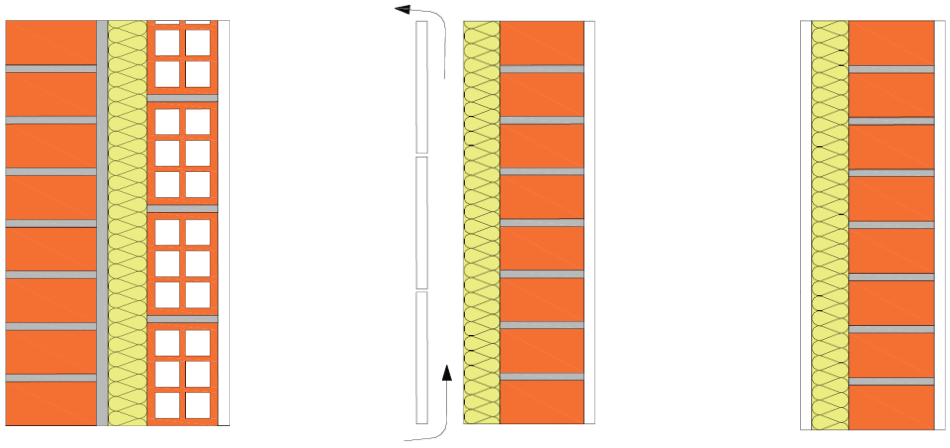


Figure 1. *Types of façade*[iii]

2.2. CLADDING

Once the types of façade had been defined, the next issue to resolve was selecting the cladding materials used in each of them. When choosing these materials, the porcelain stoneware tile (ceramic material par excellence) was considered essential, given the sectoral nature of the tool. Other forms of ceramic cladding were also considered indispensable, such as ceramic sheets and extruded ceramic panels.

The aim is for the tool's users to always be able to choose one of these three materials as the base cladding material in the comparison, and so evaluate it alongside the rest of the proposed materials. When selecting the other cladding materials, we chose those considered the most common in each of the selected types of façade. The proposed non-ceramic cladding materials are:

Ceramic Tiles	Other Common Materials			
	Ceramic	Stone	Metallic	Others
Porcelain stoneware ceramic tiles	Thin ceramic sheets	Natural stone	Galvanised steel sheet	Phenolic panels (HPL)
	Hollow-core ceramic panels	Single-layer mortar	Multi-layered aluminium panels	Fibre cement panels
	Face brick			

Table 1. *Cladding materials*

3. ASSUMPTIONS AND SCENARIO SELECTION

Once the cladding materials and types of façade had been defined, the next step in developing this part of the tool was testing the construction solutions against the Technical Building Code (CTE), and adapting them to its requirements.

To do so, it was necessary to fully define all the different variants of construction solution for façades, including all the possible characteristics which the user may select. This characterization process is carried out in the program through:

- The **scenarios** used in the tool (which the user can modify).
- The **assumptions** automatically made by the program (which the user cannot modify).

In order to select the characteristics of the components and fully define each construction solution, we took into account the requirements set out in the various *Basic Documents* of the *CTE: HE Ahorro de Energía* (Energy Saving), *HS Salubridad* (Health and Sanitation), *SI Seguridad en caso de Incendio* (Fire Safety) y *HR Protección frente al Ruido* (Noise Protection).

3.1. SCENARIOS WHICH THE USER CAN MODIFY:

The scenarios used in the tool consist of a series of attributes which the user must define to characterize the construction solutions they want to analyse. To do so, they must choose between various options which are provided by the tool in order to create the most personalized and realistic evaluation possible. Two different types of scenario are presented: those shared by both of the construction solutions under evaluation, and those which are specific to each of them.

3.1.1 CLIMATIC ZONE

Once the cladding materials and the type of façade to be evaluated have been chosen, the first scenario presented to the user is selecting the climatic zone in which the building façade they want to analyse is located. This choice, which will apply to both of the cladding options, will affect the thickness of the type of insulation material chosen for each construction solution.

A series of tables in the CTE's Basic Document on *Energy Saving (DB-HE)* allow a location's climatic zone to be identified, with reference to the provincial capital and the height above sea level (h). This methodology allows different climatic zones to be determined, using a letter for winter (a, A, B C, D, and E), and a number to classify their summer climate (1, 2, 3 and 4). However, it was decided to simplify the climatic zones in order to facilitate the user's entry of data into the tool, reducing them to the 6 general zones defined in the DB-HE: climatic zone α, A, B, C, D and E.

Depending on the climatic zone in which it is located, a particular thermal transmittance value is required of each façade. The *DB-HE* provides approximate thermal transmittance values for façade walls (U_M) in each of the six general zones. This is a simplification provided in the regulations for establishing the initial dimensions of residential construction solutions, which has been used in the tool to characterize the construction solutions.

Climatic zone	α	A	B	Q	D	E
U_M ($W/m^2 \cdot K$)	0.94	0.50	0.38	0.29	0.27	0.25

Table 2.*Thermal transmittance of façade walls*

3.1.2 TYPE OF FAÇADE

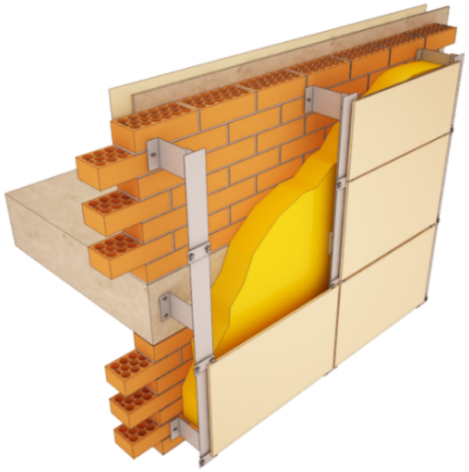
When the climatic zone has been chosen, the next step the user will take is selecting the type of façade, which will be determined by the type of cladding material chosen. The following table shows the types of façade available for each of the cladding materials:

Cladding	Type of façade		
	Double-leaf	Ventilated	ETICS
Porcelain Stoneware	●	●	●
Thin sheets		●	●
Extruded ceramic panels		●	
Natural stone	●	●	
Face brick	●		
Single-layer mortar	●		●
Phenolic panels (HPL)		●	
Fibre cement panels		●	
Galvanized steel panels		●	
Multi-layered aluminium panels		●	

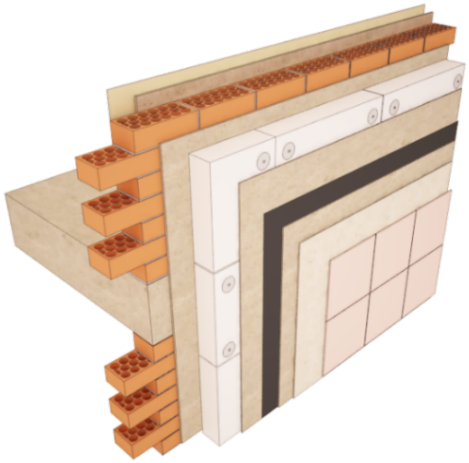
Table 3. *Types of cladding associated with each type of façade*

Although the user may select the type of façade they wish to analyse along with the chosen cladding materials, the types of façade included in the tool have been previously defined, and their base components cannot be modified by the user. These different types of façade consist of[3]:

- **Ventilated façade:** formed by a masonry wall of perforated clay bricks, of 11.5cm thickness, with non-continuous exterior cladding fixed to a metal substructure, with a barrier of very high level of resistance to water penetration (B3) formed by the highly-ventilated air cavity and hydrophobic thermal insulation on the outside of the external wall, and interior cladding of plaster.
- **ETICS façade:** formed by a masonry wall of perforated clay bricks, of 11.5cm thickness, with continuous exterior cladding that has a very high level of resistance to water penetration (R3), and thermal insulation fixed mechanically to the wall support. Interior cladding of plaster.
- **Face brick, double-leaf façade:** formed by a masonry wall of perforated clay face bricks, of 11.5cm thickness, with cement mortar joints with a high level of resistance to water penetration (J2), and intermediary cladding with a high level of resistance to water penetration (N2). [Type of interior leaf to be chosen by the user]



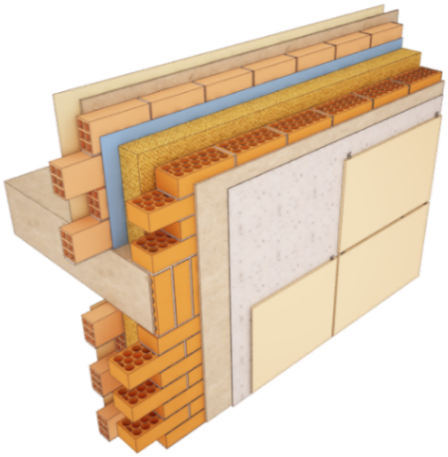
Ventilated façade
Porcelain Stoneware



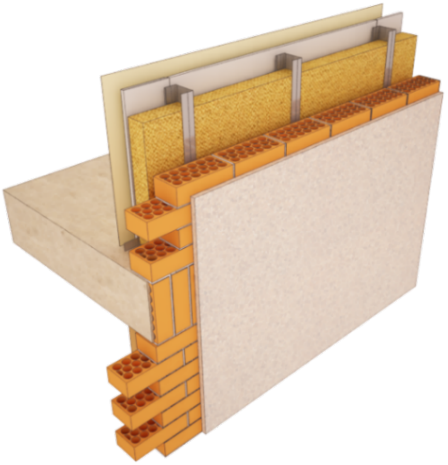
ETICS façade
Porcelain Stoneware

- Panelled, double-leaf façade: consists of a masonry wall
- of perforated clay bricks, of 11.5cm thickness, with non-continuous exterior cladding that has a high level of resistance to water penetration (R2), fixed mechanically to a layer of cement render and thermal insulation. [Type of interior leaf to be chosen by the user]
- Double-leaf façade with continuous cladding: consists of a masonry wall of perforated clay bricks, of 11.5cm thickness, with continuous exterior

cladding that has a very high level of resistance to water penetration (R3) and thermal insulation. [Type of interior leaf to be chosen by the user]



Panelled, double-leaf façade
Porcelain Stoneware



Double-leaf façade with continuous cladding
Single-layer mortar

3.1.3 TYPE OF INTERIOR SUPPORTING STRUCTURE

If the options chosen for the type of façade include a double-leaf façade, the program will allow the user to choose the type of interior leaf they wish to incorporate into this façade. The user will be able to choose between two options[3]:

- **Interior masonry wall,** made of double hollow masonry bricks of 7 cm thickness with interior plaster cladding.
- **Light interior leaf,** made of a galvanized steel framework, thermal insulation and a panel of laminated plasterboard which is mechanically fixed to the framework.

3.1.4 TYPE OF THERMAL INSULATION

Once the types of façade and interior leaf have been defined, the next step towards the complete characterization of the construction solution is the selection of the type of thermal insulation.

There are a wide variety of thermal insulation materials currently on the market, which are sold in many formats (panels, rolls, spray foam). However, to keep the construction solution variants to a reasonable number, while attempting to be as representative as possible, it was decided to include only three types of thermal insulation in the program: **mineral wool**, **expanded polystyrene** and **spray polyurethane foam**. These three types of material have been chosen because of their frequent use as insulators in the proposed types of façade.

The user will therefore be able to choose between a minimum of two and a maximum of three types of insulating material, depending on the façade selected. This is because not all of the insulators, due to their differing properties and the characteristics of each specific construction solution, are appropriate for all of the façades included in the tool.

Insulating material proposed for each type of façade			
Double-leaf façade	Interior leaf: masonry wall	MW	Mineral Wool
		EPS	Expanded Polystyrene
		PUR	Spray polyurethane foam
	Light interior leaf	MW	Mineral Wool
Ventilated façade		MW	Mineral Wool
		PUR	Spray polyurethane foam
ETICS façade		MW	Mineral Wool
		EPS	Expanded Polystyrene

Table 4.*Insulating material proposed for each type of façade*

3.1.5 VAPOUR BARRIER

Upon completing all these stages, the construction solutions to be analysed will be fully defined, except for the double-leaf façades, for which the tool will give the user the option to decide whether to incorporate a vapour barrier.

The Basic Document on *Energy Saving (DB-HE)* sets out the obligation to limit the potential condensation - both surface and interstitial - which may occur in the external walls, to avoid a significant potential deterioration in the thermal performance of the elements of which the façade is composed.

For the double-leaf façade construction solutions the potential condensation has therefore been calculated, using the method described in one of the *Supporting Documents* of the DB-HE. When required by the results of these calculations, the tool will automatically incorporate a vapour barrier in the construction solution (always giving the user the option to remove it if they consider it appropriate). In cases for which the calculation does not stipulate the incorporation of a vapour barrier, the tool will automatically disregard this option for the construction solution (but it will give the user the option to incorporate it if deemed necessary).

For those façades in which the thermal insulation material is situated on the outside of the main leaf, as in the ventilated façade and the ETICS façade, the option to include a vapour barrier will not be given, as the risk of condensation in this type of construction solution is limited.

3.2. DEFAULT ASSUMPTIONS:

Apart from the scenarios that the user can modify, the tool uses a series of premises which it automatically adopts in the definition of the construction solutions, the objectives of which are:

1) To simplify, as far as possible, the regulations which would apply to this type of construction solution.
2) To minimize the data which the user has to enter so that the tool is easier to use, given that this is a program aimed at different types of users, not all of whom will be familiar with the relevant regulations.
3) To limit the total number of variables to be analysed in order to facilitate, as far as possible, the calculations made by the tool.

3.2.1 TYPE OF BUILDING AND LOCATION OF THE FAÇADE

As for horizontal partitions, street paving and wet vertical partitions, the comparative analysis of the different types of façade will be carried out on $1m^2$ of façade surface area, without taking into account any structural elements or cavities. For the purpose of calculating the indicators, this m^2 of façade is considered to be on the top floor of a detached building which has one ground floor and three subsequent floors.

3.2.2 THICKNESS OF THE THERMAL INSULATION MATERIAL

Once the user has characterized the construction solution in terms of the transmittance values required for façade walls, as seen in the *climatic zones* section, the tool will automatically define the thickness of the thermal insulation material.

In order to reduce the wide variety of options available for insulation material thickness, some standard thickness values have been established to cover the thermal requirements of all the climatic zones. To determine these thickness values, the characteristics of all the types of façade have been taken into account, so as to adapt to the specific features of each one, while also aiming for standardization. The thickness of each material included will be:

- Mineral Wool (MW):80, 100, 120 and 140mm.
- Expanded Polystyrene (EPS):80, 120 and 140mm.
- Spray polyurethane foam (PUR):60, 80 and 100mm.

Using these thickness values, the tool will include insulation of a determined thickness, based on the thermal conductivity of each insulation material, the thermal transmittance of each construction solution, and the climatic zone defined by the user.

The thickness of insulation materials according to climatic zones					
Type of Insulation Material	Type of Façade	Thermal Conductivity (λ) (W/K·m)	Thermal Transmittance (U) ($W/m^2 \cdot K$)	Climatic Zone	Thickness of Insulation Material
Mineral Wool (MW)	Face Brick Panelled Single-layer	λ = 0.037	0.37	α – A – B	80 mm
			0.26	C - D	120 mm
			0.23	E	140 mm
	Ventilated	λ = 0.036	0.35	α – A – B	80 mm
			0.29	Q	100 mm
			0.25	D – E	120 mm
	ETICS	λ = 0.034	0.38	α – A – B	80 mm
			0.27	C – D	120 mm
			0.23	E	140 mm
Expanded Polystyrene (EPS)	Face Brick Panelled Single-layer	λ = 0.036	0.36	α – A – B	80 mm
			0.26	C – D	120 mm
			0.23	E	140 mm
	ETICS	λ = 0.038	0.40	α – A	80 mm
			0.28	B – C – D	120 mm
			0.25	E	140 mm
Spray Polyurethane Foam (PUR)	Face Brick Panelled Single-layer	λ = 0.028	0.37	α – A – B	60 mm
			0.27	C – D	90 mm
			0.24	E	100 mm
	VENTILATED	λ = 0.028	0.38	α – A – B	60 mm
			0.27	C – D	90 mm
			0.25	E	100 mm

Table 5. *Thickness of insulation materials according to climatic zone*

3.2.3 THE FIRE REACTION CLASS OF THE MATERIALS

The *Basic Document (DB) on Fire Safety* defines, given certain circumstances, different classes of reaction to fire for the façade cladding materials and the materials inside the ventilated cavities. A model building has been designed which takes into consideration this DB's requirements, with the following characteristics:

- A building with a ground floor and three other floors, with a total height of less than 18m.
- The first 3.5m of this model building consists of a standard construction solution, which is different to that involved in the study, with a fire reaction class of at least B-s3,d2.
- The façades that the tool evaluates will be developed above these first 3.5m of height.
- The vertical extension of a potential ventilated cavity will be less than 10m.
- Interior wall cladding in habitable zones will have a fire reaction class of at least C-s2,d0.

The materials and systems in the façades to be analysed (cladding and insulation materials), as well as any ventilated cavities, will have to meet the aforementioned requirements, both in terms of height and fire reaction class. The study façade will therefore not have any requirements for minimum classification or airtight cavities.

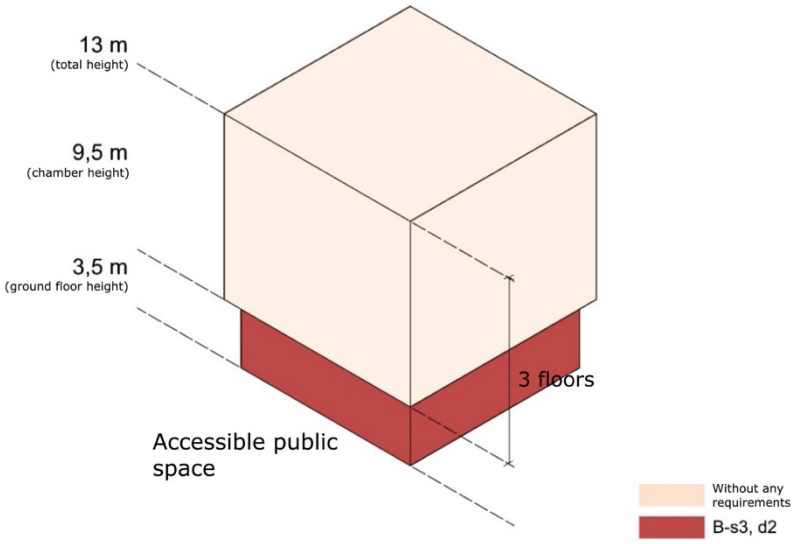


Figure 2. *Requirement for the fire reaction class of the materials*

3.2.4 LEVEL OF IMPERMEABILITY

According to the *Basic Document on Health and Sanitation (DB-HS)*, the minimum impermeability level required of façades is based on the pluviometric zone and the level of wind exposure which correspond to the building's location. It establishes 5 impermeability levels, according to the façade's behaviour in relation to rainwater penetration.

With the aim of facilitating the user's entry of data into the tool, it was decided to give all the façades the maximum possible level of impermeability, offering construction solutions whose materials have the characteristics required to achieve the best possible performance in terms of water penetration.

Most of the construction solutions included will therefore achieve impermeability level 5, but there are some whose characteristics will prevent this. In this case, the tool will inform the user of the impermeability level achieved by the façade, based on the construction solution which they have selected.

Type of façade	Impermeability level (IL)
Ventilated - ETICS	5
Double-leaf panelled and continuous cladding	5
Double-leaf face brick with light interior leaf	4
Double-leaf face brick with interior masonry wall	3

***Table 6**.IL achieved for each type of façade*[3]

3.2.5 SOUND INSULATION

The requirements of the CTE's *Basic Document (DB-HR)* on Noise Protection for insulation against airborne noise are calculated as a function of the daytime noise index and the use of the building. With the aim of facilitating the user's entry of data into the tool, and based on the comments provided in the *DB-HR,* a daytime noise index value, L_d, of 60dBA has been used, corresponding to an acoustic area of mainly residential land use. In these conditions, the regulations require a level of airborne noise insulation between a protected area and the outside of 30dBA, irrespective of the building's use. In these conditions, the R_{Atr} required for the windowless part of the facade is 33dBA or more.

CTE's *Building Components Catalogue* provides us with information on the level of insulation from airborne noise achieved by the façade construction solutions included. According to this data, all of them have a minimum R_{Atr} of 33dBA or more; they therefore comply with the regulations and may be employed for any of the various uses covered by the CTE.

4. CONCLUSIONS

We have presented the process used to integrate the construction solutions for façades into the SOLCONCER program. In this process:

- The cladding materials and types of façade have been defined, and their presence in the tool justified.
- An analysis has been made of the regulations currently in force that apply to this type of construction solutions. These construction solutions have been adapted to the appropriate requirements.

Through inclusion of the construction solutions for façades, it has been possible to expand and improve the program's functionality, which until now was focused on construction solutions for street paving, horizontal partitions and wet vertical partitions. Now that the construction solutions for façades have been incorporated into the program, the user will be able to evaluate more than 140 different construction solutions, and choose between 10 different cladding materials.

Moreover, this process will act as a basis for the adaptation of SOLCONCER to façade renovation, which together with the renovation of horizontal and wet vertical partitions will bring the tool to completion.

5. FINANCING

This project has been financed by Excma. Castellón Provincial Council.

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