ADAPTATION OF THE SOLCONCER TOOL TO REFURBISHMENT

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ABSTRACT

The SOLCONCER tool allows assessment of construction solutions, with both ceramic and alternative materials. The main purpose of the assessment is to enable the most appropriate solution to be chosen, based on certain selection criteria, from the possibilities analysed [i].

Although the tool initially focused on **construction solutions** in new building work [ii], work began in 2018 on a further stage that sought to extend the procedures used until then. This extension has led to an increase in the tool's functionality by introducing construction solutions for horizontal partitions, wet vertical partitions, and façades in a **refurbishment** context.

This paper sets out the **characterisation** of the **construction solutions** assessed in refurbishment, based on the one hand on selection of the most appropriate materials and systems for these types of operations and, on the other, on the selection of the components making up the existing construction solutions. New **scenarios** are also defined that allow the user to maximise the customisation of these construction solutions specifically in the refurbishment context.

These scenarios are also accompanied by the definition of a series of **assumptions** that are adopted by default in the tool and affect the assessment of the construction solutions. These assumptions determine, as a function of the existing cladding material and of the cladding material to be installed, which **construction process** is to be followed in refurbishment. These processes include all actions required for proper installation of the new claddings and the incorporation of all components needed for the systems used in refurbishment to work appropriately.

The **adaptation of the methodology** used to date in new building work to assess construction solutions is also described. The adaptation focuses on obtaining the **results** that reflect the most noteworthy aspects of building refurbishment work. These results characterise, just as in new building work, the different cladding materials from three different viewpoints: environmental, economic, and performance-based.

1. INTRODUCTION

Adaptation of the Solconcer tool to refurbishment has required redefining construction solutions and revising the methodology used to date in new building work in order to include the singularities involved in refurbishment building work.

The first step in redefining the construction solutions was to exclude **urban floorings** from this assessment. Refurbishment of these domains is considered to involve, generally speaking, modification of the different layers making up the construction solution, owing to the changes in dimensions, installations crossing the structure, etc., these being conditions similar to those of new building work, which can already be assessed in the tool.

The tool extension was thus restricted to refurbishment, to construction solutions for horizontal partitions, wet vertical partitions, and façades. However, for the sake of brevity, this presentation focuses solely on explaining the actions carried out for the adaptation of the construction solutions for **façades** and **horizontal partitions** to refurbishment, thus excluding wet vertical partitions (whose adaptation process and calculation methodology resembles that of horizontal partitions).

2. CHARACTERISATION OF THE CONSTRUCTION SOLUTIONS

This first section defines the components, characteristics, and systems used in assessing construction solutions for façades and horizontal partitions in refurbishment.

2.1. HORIZONTAL PARTITIONS

In Solconcer, refurbishment of a horizontal partition is viewed as the installation of a new floor covering material. Depending on the characteristics of the project, existing construction solution, and finish material to be installed, two types of refurbishment are addressed:

- **Type 1.** Installation of the new cladding material directly on the existing flooring.
- **Type 2.** Removal of the existing flooring and of the necessary underlying layers before installing the new cladding material.

<u>Type of existing base substrate</u>

In assessing refurbishment construction solutions, it was decided to perform a simplification compared to new building work. The simplification consisted of **eliminating** the calculation of the economic and environmental indicators of all the components making up the **base substrate** (deck) and of the **rear face cladding**. Only those materials were considered that made up both the existing and the new cladding materials and intermediate layers.

This decision was based on the need to focus on the uppermost components which, in refurbishment building work, are of the greatest interest to the user. In addition, in view of the uncertainty involved in working in refurbishment contexts, in most cases it would be almost impossible to define and characterise rigorously the types of decks on which new floorings are installed.

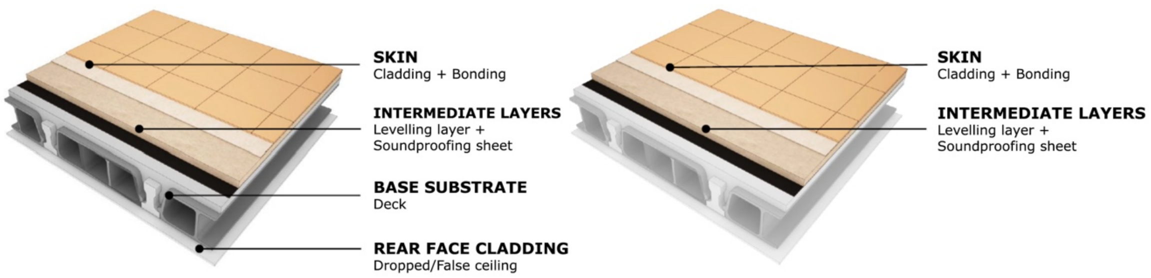

Figure 1. *Components considered in new building work (left) and in refurbishment (right)*

Type of existing covering material

The existing covering materials envisaged are the same as those considered in new building work (carpeting, PVC, natural stone, terrazzo, ceramic tile, multilayer parquet, and laminate flooring), except for ceramic slab and *Luxury Vinyl Tile* (LVT). This is because these innovative materials have recently entered the market and are therefore not frequently found as existing coverings in refurbishment building work.

Analysis of the most widely used construction solutions in the 20th century, set out in the *Catalogue of types of residential building construction* (IVE, 2016) [iii], reveals that most existing floorings are installed on a layer of rodded mortar applied on the deck as regularising layer. This assumption has therefore been made in assessing construction solutions.

New covering material to be installed

The materials addressed by the tool as new floorings to be installed in the refurbishment process are the same as those considered in new building work (multilayer parquet, laminate flooring, PVC, LVT, carpeting, natural stone, ceramic slab, and ceramic tile), except for terrazzo. It was decided to eliminate terrazzo as refurbishment material because its high thickness can lead to incompatibilities in regard to interior clear heights, in addition to causing overloads that may sometimes be incompatible with the existing structural substrate.

Soundproofing

In none of the cases was the existing construction solution considered to include a sound-absorbing layer as anti-impact sheet, because the incorporation of this type of element only began to become widespread in Spain on entry into force of DB-HR[1] of the Spanish Technical Building Code (CTE) (2007), which meant a qualitative leap in regard to soundproofing in building construction in Spain [iv].

However, the refurbishment process will consider the introduction of the necessary elements to meet current regulatory demands. Thus, the required characteristics of the intermediate layer are defined as a function of the new finish material and the existing flooring, in order to assure a proper insulation against impact sound. The selection of the different covering materials for refurbishment, in some cases, involves installation of a **soundproofing sheet membrane** on the existing base substrate. In other cases, the finish material itself, owing to its intrinsic characteristics, performs the role of soundproofing sheet membrane.

2.2. FAÇADES

In the case of construction solutions for façades, of the different systems currently available in the refurbishment market, the tool considers the following:

- **Ventilated façade system**: this consists of the incorporation of an ancillary substructure secured to the existing base substrate or background, which allows the cladding pieces to be mounted, generating a ventilated cavity between the outer face of the insulating material and the inner face of the

[1] MFOM, Ministry of Development (2009). Basic Document on Protection against noise (DB-HR) of the Technical Building Code (CTE).

cladding piece. The thermal insulation is installed between the existing structural background and the new cladding.

- **Exterior insulation and finish system (ETICS):** this consists of incorporation of exterior thermal insulation secured by adhesive and mechanical fastenings. Various glass-fibre-reinforced mortar layers are applied on the insulation on which the finish material is installed.

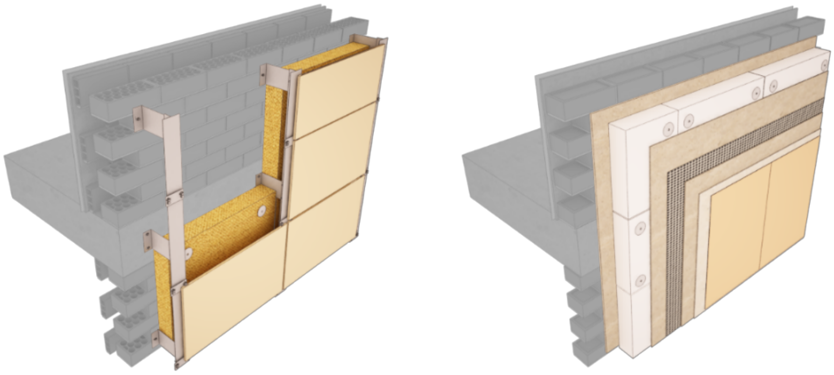

Figure 2. *Ventilated façade system (left) and ETICS façade (right)*

These two refurbishment systems, in which the insulation is placed on the outside of the main structural substrate, were chosen because both:

- Completely eliminate thermal bridges and, therefore, reduce energy consumption.
- Upgrade the exterior image of the building, valorising the building.
- Cause no annoyance to tenants during the refurbishment work.

After defining the systems, the scenarios were defined that characterised the construction solutions for façades under refurbishment:

Type of existing base substrate. Construction year of the building to be refurbished

Taking as reference different studies on the most common types of residential buildings in Spain in the 20th century [iii], [v], [vi], and [vii], the most frequent façade construction solutions in each period of time were analysed, to thus be able to define the most common types of base substrates to be found on carrying out building refurbishment work.

When it came to selecting these periods, aspects such as the amount of housing built during those years and the existing regulations regarding the required energy efficiency at each time were also taken into account. This enabled identification of those periods with greater housing construction and with façade construction solutions with poorer energy efficiency.

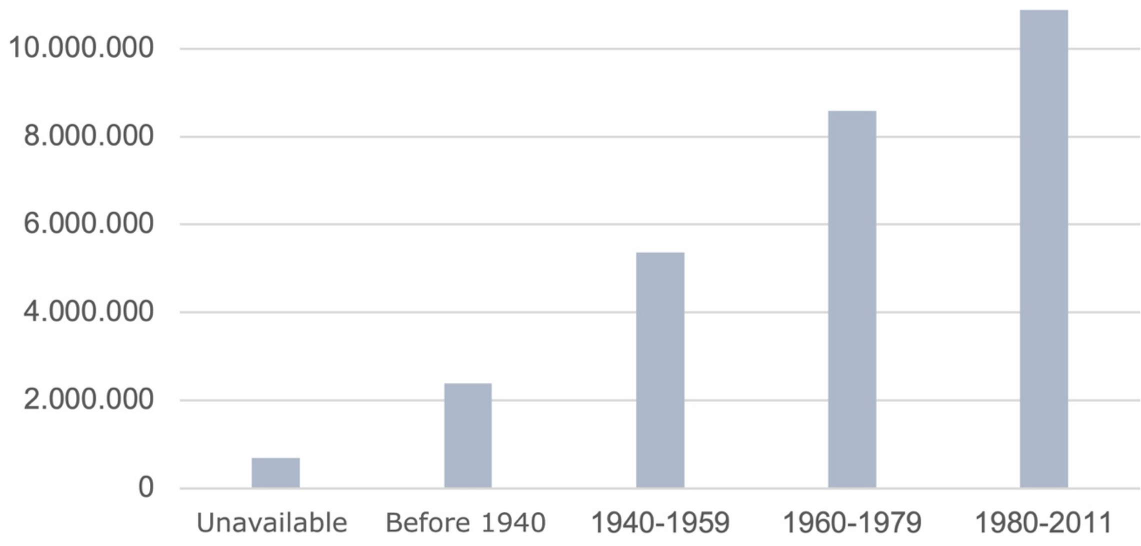

***Figure 3**. Distribution of housing per year of construction in Spain*
(Source: Compiled by authors from INE (Spanish Statistical Office) data)

All buildings constructed in Spain before the 1980s were designed without any specific regulations regarding energy saving, so they are most likely to have no type of thermal insulation incorporated into their façades [viii]. This makes them the main group of interest in the field of refurbishment because of the potential energy saving that could be achieved.

Not until 1979, with the entry into force of standard NBE-CT-79[2], did thermal insulation start to become incorporated into façade construction solutions. These regulations were in force until the Technical Building Code (CTE) appeared in 2006, in which the DB-HE[3] document upgraded the requirements. This document has been updated on different occasions (2013 and 2018) to adapt it to the European requirements set out in Directive 2010/31/UE[4], which pursues buildings with high energy efficiency and moves towards nearly Zero Energy Buildings (nZEBs), a mandatory condition from 2020 on.

In this context, **three periods of time** with their corresponding, potentially refurbishable, standard façades (base substrate) have been defined:

[2] Royal Decree 2429/1979, of 8 July, by which the basic building construction standard, NBE-CT-79, on thermal conditions in buildings is approved.

[3] MFOM, Ministry of Development (2017). *Basic Document on Energy Saving (DB-HE) of the Technical Building Code (CTE)*. Ministry of Development (MFOM).

[4] Directive 2010/31/EU of the European Parliament and of the Council, of 19 May 2010, on energy performance of buildings.

- **Façade Type 1** (1940–1960): the most common façade consisted of single-wythe brick masonry of half foot solid ceramic brick of 115mm with continuous mortar rendering on the outer face and gypsum plastering on the inner face.
- **Façade Type 2** (1960–1980): the most common façade consisted of two-wythe brick masonry: a ceramic brick outer wythe (perforated face brick or double hollow brick with cement roughcast) and an inner wythe of simple ceramic brick with gypsum plastering.
- **Façade Type 3** (1980–2006): the most common façade was a development of the previous type, which incorporated thermal insulation into the air cavity located between the two brick masonry wythes.

This entire classification was intended to provide the user with different options in regard to the year of construction of the building whose façade it is sought to refurbish. The selection of one period or another directly influences the calculation of the thickness of the thermal insulation to be incorporated. However, analogously to refurbishment of construction solutions of horizontal partitions, all components that were part of the base substrate (bricks, mortars…) were not included in the assessment.

<u>Type of existing covering material</u>

Based on a survey of the literature on the most widespread type of residential building in Spain last century [iii], [vi], [ix] and analysis of the most frequent façade claddings in each period of time, the most common materials were defined that are likely to be encountered when it comes to carrying out refurbishment building work.

The most common claddings in these periods were identified: continuous claddings (cement roughcasts, external renderings of mortar/lime, painting…) and face brick. The tool thus provides the user with the option of choosing between either of these two materials when it comes to defining the construction solutions to be analysed. This influences the preliminary actions to be carried out on the base substrate as a function of the type of façade system chosen for refurbishment.

<u>New covering material to be installed as a function of type of façade</u>

The materials addressed by the tool as new coverings to be installed in the refurbishment process are the same as those considered in new building work except for face brick. The type of façade to be chosen is conditioned by the type of previously selected cladding material.

3. ADOPTED ASSUMPTIONS AND SELECTION OF SCENARIOS

Once the construction solutions had been characterised, in this section the assumptions adopted by default were defined in order to calculate the indicators and scenarios in customising the construction solutions to be assessed in refurbishment.

3.1. HORIZONTAL PARTITIONS

The scenarios considered for customisation of the construction solutions of horizontal partitions in refurbishment were the same as those in new building work (traffic intensity, type of premises, special hygiene needs, and frequency of maintenance). The only new item is selection by the user of the type of existing cladding material it is sought to renew.

In turn, the assumptions adopted by default in calculating the indicators focus on defining the construction processes carried out in the flooring refurbishment.

3.2. FAÇADES

To customise façade construction solutions, a series of parameters have been added to the scenarios already used in new building work (province, altitude, climate zone). The main purpose of these parameters is to characterise the existing base substrate (year of construction, state of conservation of the façade, and existing cladding).

The assumptions adopted by default in the case of façade refurbishment were related, on the one hand, to defining the thickness of the thermal insulation adopted in the construction solution, which depended on the selection of the different scenarios (climate zone, year of construction of the existing base substrate, façade system, and type of insulation). In addition, a further series of assumptions were adopted in the calculation relating to the operations required for proper installation of the façade system and which depended on the state of conservation and on the existing type of material.

All the assumptions relating to the construction processes and operations required to carry out the refurbishment process are detailed below.

4. CONSTRUCTION PROCESS CONSIDERED IN REFURBISHMENT

The singularity of the assessment of refurbishment construction solutions lies in the necessary preliminary operations for proper installation of the new covering materials. Depending on the type of selected construction solution, on the cladding material chosen by the user, and on the scenarios defined, the operations needed to carry out proper installation of the new covering material differed. This section describes these operations, which largely influence calculation of the environmental and economic indicators.

4.1. HORIZONTAL PARTITIONS

In the case of construction solutions of horizontal partitions, these operations define the construction process to be carried out for flooring refurbishment. The construction process followed depends on the type of flooring to be installed in the refurbishment process and also on the existing cladding material.

<table>
<tr><th rowspan="2">Existing material</th><th colspan="8">Flooring to be installed in refurbishment</th></tr>
<tr><th>Carpeting</th><th>PVC</th><th>Laminate flooring</th><th>Multilayer parquet</th><th>LVT</th><th>Ceramic slab</th><th>Ceramic tile</th><th>Stone</th></tr>
<tr><td>Carpeting</td><td colspan="5" rowspan="4">Process 3</td><td colspan="3" rowspan="4">Process 4</td></tr>
<tr><td>PVC</td></tr>
<tr><td>Laminate flooring</td></tr>
<tr><td>Multilayer parquet</td></tr>
<tr><td>Ceramic tile</td><td colspan="5" rowspan="3">Process 1</td><td rowspan="3">Process 2</td><td rowspan="3">Process 2 / Process 5</td><td rowspan="3">Process 5</td></tr>
<tr><td>Stone</td></tr>
<tr><td>Terrazzo</td></tr>
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Table 1. *Construction processes considered*

The construction processes considered for assessment of the different construction solutions are described below. In some of these, the installation and/or demolition process varies slightly as a function of the new flooring to be installed.

Construction process 1

If the new material to be installed is carpeting, the refurbishment process consists of direct installation of the carpeting on the existing flooring. In the case of PVC tiles, they are installed by gluing on the existing flooring. And, if the new flooring to be installed is sheets of laminate flooring, multilayer parquet, or LVT, these are installed in a floating manner on (low compressibility) polyethylene foam sheeting set directly on the existing flooring.

A level existing flooring and filled joints are assumed to ensure proper installation of the above materials without requiring demolition of the existing flooring.

Construction process 2

In this process, no demolition of the existing flooring is needed and, if the new material to be installed is ceramic tile or slab, the refurbishment process consists of fixing these materials by cementitious adhesive on (low compressibility) polyethylene foam sheeting previously installed with adhesive mortar on the existing flooring.

Construction process 3

If the new material to be installed is carpeting or PVC tiles, this construction process consists of pulling up the existing material by manual means followed by direct installation, in the case of carpeting, on the existing regularising mortar layer and, in the case of PVC tiles, fixing by gluing.

On the other hand, if the new material to be installed is sheets of laminate flooring, multilayer parquet, or LVT, the construction process consists of pulling up the existing material by manual means and installing the new material in a floating manner on (low compressibility) polyethylene foam sheeting set on the existing regularising mortar layer.

Construction process 4

In this case as well, demolition is required of the existing material, which in the case of carpeting or PVC consists of pulling up the existing material by manual means and, in the case of sheets of laminate flooring, multilayer parquet, or LVT, of pulling up the existing flooring and withdrawing the existing acoustic sheeting by manual means.

If the new material to be installed is ceramic slab, ceramic tile, or natural stone, the construction process consists of installing these materials by cementitious adhesive on (low compressibility) polyethylene foam sheeting fixed with adhesive mortar on the existing regularising layer.

Construction process 5

In this process, the existing flooring (ceramic, natural stone or terrazzo tile) needs to be demolished by chipping out the tiles and their corresponding bonding/levelling material with mechanical means. Once the demolition has been performed, a floating floor is built on the existing deck by installation of (high compressibility) polyethylene foam sheeting and subsequent pouring of a layer of self-levelling mortar. Installation then follows of the new finish material by cementitious adhesive on the new levelling layer.

4.2. FAÇADES

In the case of construction solutions for façades, the singularity of the refurbishment operations lies in the necessary preliminary actions for proper installation of the new systems. These operations, unlike for floorings, depend on the type of façade chosen and state of conservation of the existing façade.

External thermal insulation composite system, ETICS

In this case, the proper state of the base substrate must be assured for appropriate application and adhesive strength of the system in order to correct flaws and remove any dirt residues that could impede proper bonding of the system [x]. The following actions, depending on the existing finish material, are proposed:

- Continuous cladding: preparation of the base substrate by chipping away the existing external roughcast/rendering and subsequent application of a roughcast mortar layer reinforced with glass-fibre mesh at material changes.
- Face brick: thorough cleaning of the surface is required to assure there is no grease or dust on the base substrate and thus to ensure proper bonding of the materials of the new façade system.

Ventilated façade system

In the case of refurbishment by a ventilated façade system, no preliminary treatments of the existing cladding or base substrate are considered, as the system's installation by means of point mechanical fastenings makes this unnecessary.

5. ADAPTATION OF THE CALCULATION METHODOLOGY

Finally, this section details the changes made to the calculation methodology in order to adapt it to the specific needs of refurbishment construction solutions.

5.1. OBTAINMENT OF ECONOMIC DATA

Just as in new building work, the source used to obtain the **prices of the materials** making up the construction solutions, whenever possible and with a view to homogenising prices, is the *Construction Prices Generator by CYPE Ingenieros S.A.* [xi]. In cases where this database does not have the required data, the *BEDEC Bank by ITeC* [xii] or *the Construction Database by IVE* [xiii] is used.

The price databases that the tool uses consider different costs for refurbishment and new building work projects, mainly owing to the uncertainty involved in working, in refurbishment, on an existing building work. This variation will be greater or lesser, depending on the characteristics of each project and materialises in a rise in labour costs as a result of higher materials installation outputs.

As to date, for the development of the tool, all prices of the construction solutions components in relation to new building work had been broken down, and, in view of future upgrades, in order not to expressly perform a data search for refurbishment, it was decided to use new building work prices with a certain % increase for labour costs.

To establish this percentage, a small study was performed in which the price increase was analysed (taking the CYPE Ingenieros, S.A., construction prices database as reference) for the same material in refurbishment compared to that in new building work projects. The assessment of the results was used to obtain the price increase to be applied, these values being used in the tool to calculate the costs of the components making up the refurbishment construction solutions.

Life cycle

Just as in new building work, in refurbishment, a functional unit equivalent to a surface area of 1 m^2 construction solution in a timeline of 50 years in a geographic and technological context of Spain was considered.

In new building work, the different stages making up the life cycle were taken from the model set out in the Sustainability in Construction standards[5]. This model was followed for refurbishment, incorporating, however, an initial end-of-life stage designated "Ci".

[5] UNE-EN 15978:2012 *Sustainability of construction works - Assessment of environmental performance of buildings - Calculation method* and UNE-EN 15804:2012 *Sustainability of construction works - Environmental product declarations - Core rules for the product category of construction products*.

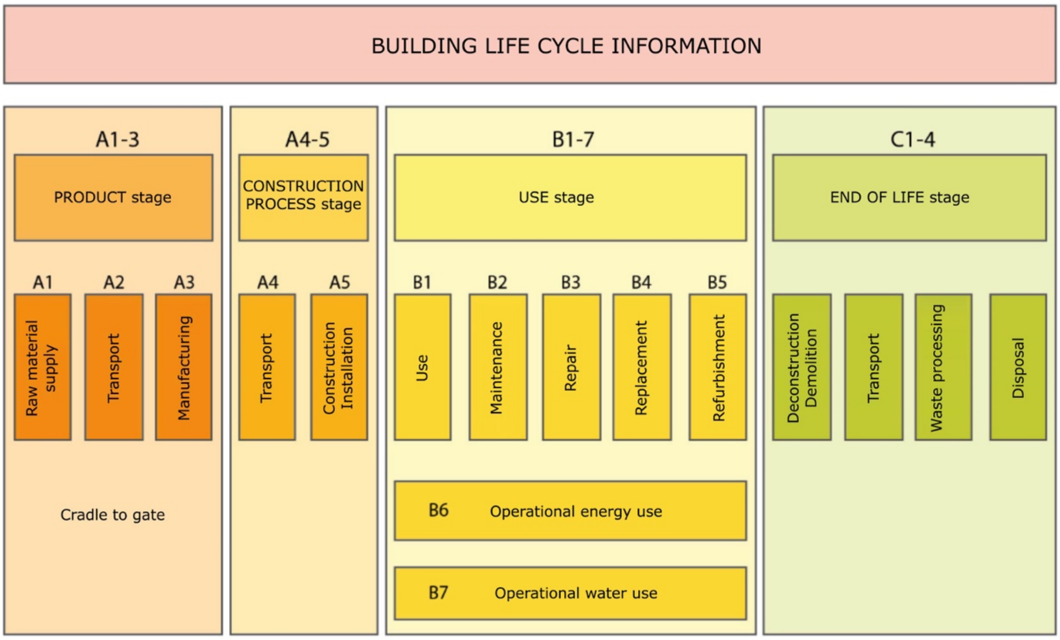

***Figure 4**. Life cycle stages*

This new stage considers all the actions required to replace the existing cladding material and the layers deemed to be needed for proper installation of the new material. This initial end-of-life stage of the existing elements (Ci) envisages the following actions:

- Deconstruction and demolition or preparation of the existing elements (C1i)
- Transport of the waste generated in C1i (C2i)
- Reuse and recycling (C3i)
- Disposal (C4i)

In this tool, both for assessment of construction solutions in new building work and in refurbishment, the A1–A3 modules are considered jointly. In addition, the B5 Refurbishment module, which consists of the programmed replacement of the element is deemed equivalent to B4 Replacement. Similarly, the modules Operational use of energy and water (B6 and B7) are not applicable.

6. CONCLUSIONS

The study describes the adaptation to refurbishment of the SOLCONCER tool, and in this procedure:

- The construction solutions of refurbishable horizontal partitions and façades are characterised.
- The systems and materials used in refurbishment, as well as the construction processes considered for proper installation of the new cladding materials, are defined.
- The different scenarios that the tool envisages for customisation and assessment of these construction solutions are presented.
- The changes made to the program's calculation methodology, to adapt it to the new context, are explained.

The introduction of refurbishment construction solutions has enabled the functionality of the program, which to date had focused on construction solutions for new building work, to be extended and improved. The incorporation into the program of refurbishment construction solutions allows the user to assess a great number of different construction solutions, enabling selection from numerous different cladding materials, this all being done in new as well as in refurbishment building work contexts.

7. FUNDING

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8. REFERENCES

[1] Beltrán, A., Celades, I., Corrales, J., Mira, J., Muñoz, A., Rioja, A., Ros, T., Agost, V. (2016). *Solconcer, herramienta de ayuda para la caracterización de soluciones constructivas.* XIV Congreso Mundial de la Calidad del Azulejo y del Pavimento Cerámico. Qualicer 2016. http://www.qualicer.org/recopilatorio/

[2] Beltrán, A., Celades, I., Corrales, J., Mira, J., Muñoz, A., Ros, T., Vilalta, L., Agost, V. (2018). *Solconcer. Caracterización de soluciones constructivas de fachadas.* XV Congreso Mundial de la Calidad del Azulejo y del Pavimento Cerámico. Qualicer 2018.http://www.qualicer.org/recopilatorio/

[3] IVE - Instituto Valenciano de la edificación (2016). *Catálogo de tipología edificatoria residencial*. Generalitat Valenciana. Conselleria de Vivienda, Obras Públicas y Vertebración del Territorio. https://www.five.es/tienda-ive/catalogo-de-tipologia-edificatoria-residencial/

[4] Instituto de Promoción Cerámica (2008). *Aislamientos. Los aislamientos en el nuevo Código Técnico de la Edificación. Protección frente al ruido según DB HR*. Diputación de Castellón. http://www.ipc.org.es/guia_colocacion/info_tec_colocacion/sopor_sup_colocacion/capas_intermedias/aislamientos.html

[5] IVE - Instituto Valenciano de la Edificación (2013). *Catálogo de Soluciones Constructivas de Rehabilitación*. http://www.five.es/tienda-ive/catalogo-de-soluciones-constructivas-de-rehabilitacion/

[6] De Lorenzo, A., Escudero, C., Iribar, E. (2014). *Catálogo de Rehabilitación Energética*. Universidad del País Vasco, Laboratorio de Control de Calidad en la Edificación (Área Térmica). Dirección de Vivienda, del Departamento de Empleo y Políticas Sociales del Gobierno Vasco. https://www.legegunea.euskadi.eus/contenidos/informacion/2649/eu_2179/adjuntos/catalogo_rehabilitacion_rev03.pdf

[7] IDAE - Instituto para la Diversificación y Ahorro de Energía (2011). *Escala de calificación energética para edificios existentes*. Ministerio de Fomento. https://www.idae.es/uploads/documentos/documentos_11261_EscalaCalifEnerg_EdifExistentes_2011_accesible_c762988d.pdf

[8] IVE - Instituto Valenciano de la Edificación (2015). *Estudio del potencial de ahorro energético y reducción de emisiones de CO2 en la Comunidad Valenciana*. Estudio realizado dentro del proyecto europeo EPISCOPE. http://episcope.eu/fileadmin/episcope/public/docs/pilot_actions/ES_EPISCOPE_RegionalCaseStudy_IVE.pdf

[9] Lizundia-Uranga, I. (2015). *La solución de fachada convencional del periodo desarrollista en el caso de Gipuzkoa: declive (y final) de un sistema constructivo*. Informes de la Construcción. Vol. 67, 538, e079.http://informesdelaconstruccion.revistas.csic.es/index.php/informesdelaconstruccion/article/view/4219/4861

[10] CYPE Ingenieros, S.A. Generador de precios de la construcción. España. http://www.generadordeprecios.info/

[11] ITeC – Instituto de Tecnología de la Construcción de Cataluña. Bases de datos con información de productos de la construcción BEDEC. http://metabase.itec.cat/vide/es/bedec

[12] IVE - Instituto Valenciano de la Edificación. Base de Datos de la Construcción. https://www.five.es/productos/herramientas-on-line/visualizador-2018/