

# 10º CONGRESO INTERNACIONAL

## INNOVACION TECNOLOGICA EDIFICACION

INTERNATIONAL CONFERENCE ON TECHNOLOGICAL INNOVATION IN BUILDING

DEPARTAMENTO DE TECNOLOGÍA DE LA EDIFICACIÓN  
Escuela Técnica Superior de Edificación de Madrid  
Avda. Juan de Herrera Nº 6 28040 Madrid

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# CITE 2026

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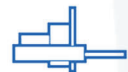


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# CITE

X Congreso Internacional de Innovación  
Tecnológica en Edificación

X International Conference on Technological  
Innovation in Building

## ESCUELA TÉCNICA SUPERIOR DE EDIFICACIÓN

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**Organizador: Departamento de Tecnología de la Edificación**

Universidad Politécnica de Madrid

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## GREETINGS

### **X INTERNATIONAL CONGRESS ON TECHNOLOGICAL INNOVATION IN BUILDING CONSTRUCTION (CITE 2026)**

**18<sup>th</sup> to 20<sup>th</sup> March 2026**

CITE was launched in 2016 with the aim of promoting the transfer of knowledge on learning, innovation and competitiveness between the productive and educational sectors, as well as disseminating best practices related to innovation in training and learning within the building sector. Since its creation, the congress has also served as a meeting point for different social and professional agents linked to education and construction, fostering cooperation among participants and encouraging collaboration in areas related to learning, innovation and competitiveness in the sector.

We hope that this new edition of the International Congress on Technological Innovation in Building Construction (CITE 2026) will once again be a success in terms of the quality and number of communications presented, generating valuable and enriching results in the field of technological innovation in building construction that will contribute to the continuous improvement of future editions of the congress.

As in previous editions, the CITE 2026 programme includes all its activities —oral communications and poster presentations— in a virtual format, accessible through the congress website. The congress is structured around several thematic areas, including building environment, building technology, domotics and smart cities, innovation in building and civil works, materials and construction systems, rehabilitation, pathology and building maintenance, installations, general issues, and gender perspective in construction.

In this tenth edition, it is important to highlight the quality and commitment of all participants, which has resulted in the presentation of more than ninety scientific contributions and has brought together over 221 national and international participants.

Finally, we would like to express our sincere gratitude for the valuable collaboration and support of the companies, Trimble, Íscar, Proiescon and Saint-Gobain, whose sponsorship has made the organization of this congress possible.

The Organizing Committee



# X Congreso Internacional de Innovación Tecnológica en Edificación

## X Conference on Technological Innovation in Building

### MIÉRCOLES 18

| Sala de Juntas |  |
|----------------|--|
| Hora           | Sala de Juntas   |
| 9:30 - 14:30   | <b>REGISTRO / RECEPCIÓN DE DOCUMENTACIÓN</b><br>Lugar: Vestíbulo de entrada de la escuela  |
| 10:15 - 11:00  | <b>APERTURA: AMPARO VERDÚ VAZQUEZ</b><br><i>Directora del Departamento de Tecnología de la Edificación</i><br><b>SESIÓN INAUGURAL: ENRIQUE GÓMEZ DE LA PEÑA</b><br><i>Responsable de prescripción zona centro, Grupo Saint-Gobain</i><br><i>Profesor Asociado, Universidad Alcalá de Henares</i>               |
| 11:00 - 12:15  | <b>COFFEE BREAK &amp; POSTER SESSION</b>   |
| Sala de Juntas |  |
| Hora           | TOPIC<br>Nº Ponencia   |
| 12:20-12:40    | 02<br><b>ADAPTATION OF A TOURIST-ENERGY LOCK INSPIRED BY STRASBOURG TO THE CANAL DE CASTILLA: PROPOSAL FOR HERITAGE VALORIZATION AND ECOSYSTEM SERVICES</b><br><i>Antonio García Chica; Julio Jose Caparros Mancera; Angel Mariano Rodríguez Pérez; Lucía Olmo Rodríguez; César Antonio Rodríguez González</i> |
| 12:40-13:00    | 34<br><b>STRUCTURAL INTERVENTIONS IN THE SCHOOL OF STO DOMINGO IN ORIHUELA BETWEEN 1940-1974</b><br><i>Arianna Guardiola-Villora; Agustín Pérez-García</i>   |
| 13:00-13:20    | 54<br><b>INITIAL STUDY AND MODELLING OF RADON EXHALATION IN HERITAGE WALLS</b><br><i>Isabel Sicilia; Borja Frutos; Carmen Alonso; Jon Fernández; Julen Vázquez; Carlos Sainz; Sofia Aparicio</i>   |
| 13:20-13:40    | 55<br><b>KEY FACTORS FOR SUSTAINABLE REHABILITATION: POLYMER MORTARS</b><br><i>Sonia Navarrete Ocaña</i>   |
| 13:40-14:00    | 62<br><b>ASSIMILATION OF BUILDING PATHOLOGY WORKSHOPS IN CONSTRUCTION METHODS INSTRUMENTAL STUDIES</b><br><i>Igal M. Shohet; Gili Lifshitz Sherzer</i>   |
| 14:00-15:30    | LUNCH TIME   |
| Sala de Juntas |  |
| Hora           | TOPIC<br>Nº Ponencia   |
| 15:30-15:50    | 04<br><b>ASSESSING THE ROLE OF SOLAR SHADING DEVICES IN MITIGATING OVERHEATING IN HIGH SCHOOLS IN MADRID</b><br><i>Juan María Hidalgo-Betanzos; César Escudero-Revilla; Raúl Briones-Llorente; Pablo Hernandez-Cruz; Jon Terés-Zubiaga</i>   |
| 15:50-16:10    | 07<br><b>BIOCHAR AS AN INSULATING AMENDMENT IN GREEN ROOFS: ASSESSING THE POTENTIAL FOR THERMAL IMPROVEMENT</b><br><i>Carlos Rey Mahía</i>   |
| 16:10-16:30    | 10<br><b>EARLY PRESSED-BRICK FAÇADE WALLS IN BOGOTÁ, COLOMBIA: TECHNICAL CHARACTERIZATION AND MATERIAL ANALYSIS</b><br><i>Sandra Rangel Cobos; Javier Pinilla Melo</i>   |
| 16:30-16:50    | 09<br><b>DEVELOPMENT OF A MODULAR PANEL PRINTED IN 3D WITH HIGH ENERGY EFFICIENCY POLYMERS AND INSULATORS FOR ARCHITECTURAL ENCLOSURES</b><br><i>Gissell Alejandra Gamboa Espinoza; Manuel Álvarez Dorado</i>  |

### JUEVES 19

| Sala de Juntas |  |   |
|----------------|--|---|
| Hora           | TOPIC<br>Nº Ponencia   | General Issues<br>Modera: Alejandro Martínez Gordon   |
| 9:40-10:00     | 00   | <b>PONENCIA GRUPO ARPADA</b><br><i>Celia Esteban Herranz</i>  |
| 10:00-10:20    | 39   | <b>THERMAL PERFORMANCE OF A REFURBISHED GREEN ROOF IN A PUBLIC BUILDING UNDER MEDITERRANEAN CLIMATIC CONDITIONS</b><br><i>Julia Corra Arpon</i>   |
| 10:20-10:40    | 47   | <b>INNOVATIVE SUBSTRATES FOR GREEN ROOFS FOLLOWING CIRCULARITY CRITERIA</b><br><i>Gabriel Pérez Luque</i>   |
| 10:40-11:00    | 30   | <b>PROBABILITY FUNCTIONS FOR EXTREME PRECIPITATION IN THE GUADALQUIVIR BASIN FOR CIVIL ENGINEERING DESIGN</b><br><i>Raúl Montes Pajuelo; Ángel Mariano Rodríguez Pérez; Julio Jose Caparros Mancera; Antonio García Chica; César Antonio Rodríguez González</i> |
| 11:00 - 12:15  | <b>COFFEE BREAK &amp; POSTER SESSION</b>   |   |
| Sala de Juntas |  |   |
| Hora           | TOPIC<br>Nº Ponencia   |   |
| 12:20-14:00    |  | <b>PONENCIA ÍSCAR SOFTWARE</b><br><br><i>Ponente: Juan Ibárguen</i>   |
| 14:00-15:30    |  | <b>CATA DE VINO</b><br><i>Lugar: Sala Trimble</i>   |
| 14:00-15:30    | LUNCH TIME   |   |
| Sala de Juntas |  |   |
| Hora           | TOPIC<br>Nº Ponencia   | Materials and construction systems<br>Modera: Paula de Andrés Anaya   |
| 15:30-15:50    | 14   | <b>FACTORS INFLUENCING STUDENTS TO CHOOSE BUILDING ENGINEERING. A PRELIMINARY STUDY WITH A GENDER PERSPECTIVE</b><br><i>Elena Navarro Astor; MARGARITA INFANTE PEREA</i>  |
| 15:50-16:10    | 16   | <b>FUZZY-LOGIC ASSESSMENT OF VERTICAL PV SHADING RETROFITS</b><br><i>Julio Jose Caparros Mancera; Antonio García Chica; Ángel Mariano Rodríguez Pérez; César Antonio Rodríguez González</i>   |
| 16:10-16:30    | 22   | <b>MULTI-CRITERIA FRAMEWORK FOR PCM SELECTION IN ENERGY-EFFICIENT BUILDINGS ACROSS CLIMATE ZONES</b><br><i>Javier Martínez Gómez; Juan Francisco Nicolalde</i>  |
| 16:30-16:50    | 40   | <b>VERIFICATION OF INDOOR ENVIRONMENTAL TOXICITY AT THE WHOLE-BUILDING SCALE: INTEGRATING REFERENCE MEASUREMENTS AND SENSOR-BASED MONITORING</b><br><i>BELÉN REY-ÁLVAREZ; Antonio Sánchez Cordero; Antonio García-Martínez; BENITO SÁNCHEZ-MONTAÑÉS</i>         |
| 16:50-17:10    | 43   | <b>TOWARD A HOLISTIC-FRACTAL BIM MODEL: REINTERPRETING THE 8D, 9D, AND 10D DIMENSIONS BEYOND THE LINEAR PARADIGM</b><br><i>Rodrigo Fuentes</i>  |
| 18:00-20:00    | <b>VISITA GUIADA AL MADRID DE LOS AUSTRIAS</b><br><i>Lugar de encuentro: Plaza de la villa</i> |   |
| 21:00          | <b>CENA DE GALA</b>  |   |

### VIERNES 20

| Sala de Juntas |   |  |
|----------------|---|--|
| Hora           | TOPIC<br>Nº Ponencia  | Materials / Innovation in Building<br>Modera: Alejandro Payán de Tejada Alonso   |
| 9:40-10:00     | 24  | <b>ON THE USE OF LARGE-SCALE PRECAST CONCRETE ELEMENTS ON SITE</b><br><i>Luis Carrillo Alonso</i>  |
| 10:00-10:20    | 21  | <b>MODULAR GREEN ROOFS</b><br><i>Laura Herrera Díez</i>  |
| 10:20-10:40    | 60  | <b>GIS-BASED INTEGRATED ASSESSMENT OF SEISMIC VULNERABILITY AND ENERGY EFFICIENCY: A CASE STUDY OF A NEIGHBORHOOD IN ARMILLA, GRANADA (SPAIN)</b><br><i>Antonio Martín-Cara; José-Lázaro Amaro-Mellado</i>             |
| 10:40-11:00    | 64  | <b>ENVIRONMENTAL MITIGATION STRATEGIES THROUGH GREEN WALL DESIGN: A PROJECT PROPOSAL FOR THE ENERGY RETROFITTING OF THE FISCIANO CAMPUS (UNISA)</b><br><i>Emanuela D'Andria; Giacomo Viccione; Pierfrancesco Fiore</i> |
| 11:00 - 12:15  | <b>COFFEE BREAK &amp; POSTER SESSION</b>  |  |
| Sala de Juntas |   |  |
| Hora           | Sala de Juntas  |  |
| 12:30 - 12:45  | <b>RESUMEN DEL EVENTO Y CIERRE: AMPARO VERDÚ VÁZQUEZ</b><br><i>Directora del Departamento de Tecnología de la Edificación</i> |  |

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# STRATEGIES FOR REDUCING GWP EMISSIONS ON A MACRO SCALE IN BUILDINGS. INDUSTRIAL TRANSFORMATION OF MINERAL WOOL PRODUCTION.

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**Keywords:** Stone Wool, Electric, Furnace, Carbon footprint. GWP.

## Abstract

Buildings account for 35% of global energy use and 38% of CO<sub>2</sub> emissions [1]. Due to this situation, together with climate change, the European Union has established climate neutrality for buildings by 2050, with the consequent establishment of intermediate milestones by member countries [2,3]. This study establishes the influence of low-carbon Mineral Stone Wool on GWP (Global Warming Potential) emissions in the PNIEC (Plan Nacional Integrado de Energía y Clima) [3] to see the potential of this solutions to reduce the embedded carbon footprint of buildings. To this end, two similar materials manufactured for use with ETICS (External Thermal Insulation Construction System) have been compared, based on a comparable solution manufactured using current furnaces operated with coke as the main fuel and a future material manufactured using electric furnace supplied with electricity from renewable sources. The properties of both materials, obtained from the EPD of Mineral Stone Wool [4] and the extrapolation based on the LCA of Electric Mineral Stone Wool, can be seen in Table 1. The verified EPD for the material produced in the electric furnace will be published once the facility is operational, scheduled for 2027.

TABLE I  
FUNCTIONAL UNITS OF MINERAL WOOL INSULATION UNDER STUDY

| Functional Unity   | Units                | Mineral Wool | Electric Mineral Wool |
|--------------------|----------------------|--------------|-----------------------|
| Mineral wool type  |                      | Stone Wool   | Stone Wool            |
| Density            | Kg/m <sup>3</sup>    | 100,00       | 100,00                |
| Thermal Resistance | m <sup>2</sup> K/W   | 1,00         | 1,00                  |
| Conductivity       | W / mK               | 0,034        | 0,034                 |
| Size               | m <sup>2</sup>       | 1,00         | 1,00                  |
| Thickness          | mm                   | 34,00        | 34,00                 |
| Climate change     | KgCO <sub>2</sub> eq | 4,89         | -52%                  |

Table 2 shows the characteristics of the insulation panels established for the study of the carbon footprint impact obtained from the average extrapolation of the thicknesses established in the supporting document for compliance with DB-HE [5], adopting a thickness of 80 mm as it is the commercial thickness closest to the average values established with the conductivity of the material studied.

TABLE II  
CHARACTERISTICS OF THE INSULATION PANELS STUDIED

| Climate change of panels | Units                     | Mineral Wool | Electric Mineral Wool |
|--------------------------|---------------------------|--------------|-----------------------|
| Thickness of insulation  | mm                        | 80,00        | 80,00                 |
| Climate change / mm      | KgCO <sub>2</sub> eq / mm | 0,14         | 0,07                  |

|  |                 |              |             |
|--|-----------------|--------------|-------------|
| <b>Insulation panel Climate change</b> | <b>KgCO2 eq</b> | <b>11,51</b> | <b>-52%</b> |
|--|-----------------|--------------|-------------|

Table 3 shows the embedded carbon footprint corresponding to the insulation panels studied, applied as an ETICS insulation solution for the renovation of the total number of homes established in the PNIEC objective.

TABLE III  
EMBEDDED CARBON FROM THE TARGET OF HOUSING TO BE RENOVATED USING THE INSULATION PANELS STUDIED

| Climate change of panels                 | Units     | Stone Wool | Electric Stone Wool | Reduction |
|--|-----------|------------|---------------------|-----------|
| <b>Embodied Carbon of rehabilitation</b> | KTnCO2 eq | 1660,41    | 797,00              | 863,41    |

Table 4 shows the GWP values emitted by residential buildings in Spain in 2024 [5] and the emissions target for these buildings in 2030 [6,7], and establishes the reduction in GWP emissions if the low-carbon solution studied had been used for the renovation of all homes. To this end, the emissions target has been established as the sum of operational carbon emissions plus the embedded carbon emissions from the materials used for such refurbishment, equating it with the current solution of stone wool insulation manufactured in a coke furnace. The façade area was established as the average area obtained by dividing the number of single-family dwellings by the number of dwellings in multi-family buildings [8] using an area of 200 m<sup>2</sup> for a single-family dwellings and 60 m<sup>2</sup> for a dwellings in multi-family buildings.

TABLE IV

| REDUCTION OF EMBEDDED CARBON IN THE HOUSING RENOVATION TARGET SET OUT IN THE PNIEC | Units     | GWP     | Electric stone wool |
|--|-----------|---------|---------------------|
| <b>Residence Buildings Spain 2024</b>  | KTnCO2 eq | 23300   | 23300               |
| <b>2030 Spain Target Residence Buildings</b>                                       | KTnCO2 eq | 14100   | 13236               |
| <b>Target number of rehabilitated homes</b>  | Units     | 1377000 | -                   |
| <b>Facade surface</b>  | m2        | 104,80  | -                   |
| <b>Reduction</b>   | KTnCO2 eq | 9200    | 10063               |
| <b>Total</b>   | %         |         | <b>-6,12</b>        |

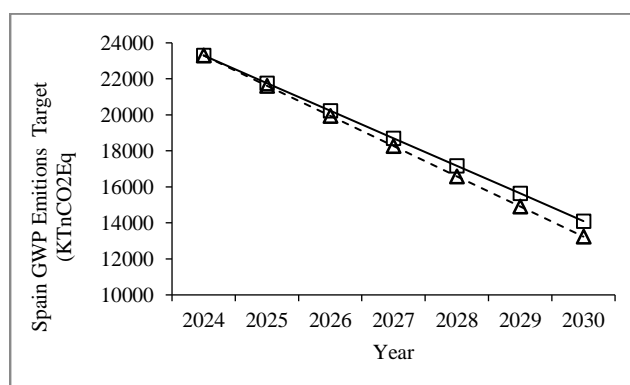


Fig. 1. Comparison of Spain GWP emissions target per year renovating buildings with standard Stone Wool and Electric Low Carbon Stone wool.

Meeting decarbonization objectives will require the deployment of solutions that can be implemented at industrial scale, such as the one studied. Stone wool produced in an electric furnace powered by renewable electricity helps to reduce the embedded carbon footprint, cutting emissions by more than 10,000 kTnCO2 eq in the case studied, achieving improvements in greenhouse gas reduction targets.

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## References

- GlobalABC. UNEP, Global Status Report for Buildings and Construction: towards a Zero-Emissions, Efficient and Resilient Buildings and Construction Sector, 2020. <https://wedocs.unep.org/20.500.11822/34572>.
- Long-term decarbonisation strategy for a modern, competitive and climate-neutral Spanish economy in 2050. MITECO. [https://ec.europa.eu/clima/sites/lts/lts\\_es\\_es.pdf](https://ec.europa.eu/clima/sites/lts/lts_es_es.pdf). 2020.
- Plan Nacional Integrado de Energía y Clima PNIEC. [https://www.miteco.gob.es/content/dam/miteco/es/energia/files-1/pniec-2023-2030/PNIEC\\_2024\\_240924.pdf](https://www.miteco.gob.es/content/dam/miteco/es/energia/files-1/pniec-2023-2030/PNIEC_2024_240924.pdf). 2024.
- EPD Acustialaine 100. Registro Environdec EPD-IES-0028983:001. 2026.
- Guía de Aplicación DB-HE 2019. Documento Básico de Ahorro Energético. DB-HE. [https://www.codigotecnico.org/pdf/GuiasyOtros/Guia\\_aplicacion\\_DBHE2019.pdf](https://www.codigotecnico.org/pdf/GuiasyOtros/Guia_aplicacion_DBHE2019.pdf). 2022.
- Inventario Nacional de Emisiones a la Atmósfera. Serie 1990-2023. Ministerio para la Transición Ecológica y el Reto Demográfico. <https://www.miteco.gob.es/content/dam/miteco/es/calidad-y-evaluacion-ambiental/temas/sistema-espanol-de-inventario-sei-/resumen-Inventario-GEI-2025.pdf>. 2024.
- Avance de emisiones de gases de efecto invernadero correspondientes al año 2024. Ministerio para la Transición Ecológica y el Reto Demográfico. <https://www.miteco.gob.es/content/dam/miteco/es/calidad-y-evaluacion-ambiental/temas/sistema-espanol-de-inventario-sei-/Avance-GEI-2024.pdf>. 2025.

# EARLY PRESSED-BRICK FAÇADE WALLS IN BOGOTÁ, COLOMBIA: TECHNICAL CHARACTERIZATION AND MATERIAL ANALYSIS

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**Keywords:** *pressed brick; brick façade; late 19<sup>th</sup> century; running bond; Calvo bricks.*

## Abstract

In brick masonry, the onset of large-scale industrial pressed brick production not only represented the introduction of a material with enhanced physical and mechanical properties but also the beginning of a significant change in the solid face-brick wall construction techniques. Important examples of this technical shift are the ‘fábrica refrentada’ in Spain (Camino, 2001), the ‘Backstein-Rohbau’ in German-speaking countries (Potgeter, 2021), and the ‘face and running bond’ solutions in the United States (Rangel et al., 2023).

In Bogotá, this material and technological transformation of the face-brick wall began with the mass production of pressed bricks at the ‘Fábrica de Ladrillos Calvo’. Initially, these bricks were used to finish the external face of solid ordinary-brick façade walls built with traditional regular bonds, such as the English or Flemish bonds. However, this method was eventually replaced by a technique that allowed the pressed bricks of the front to be laid in running bond—which minimized the use of these costly bricks—while the ordinary bricks in the backing were arranged in a regular strong bond.

Around 100 buildings in Bogotá’s historic center preserve this last type of pressed-brick wall façade, which now requires maintenance and restoration. Despite this, there is virtually no comprehensive knowledge of their construction technique and the physical-mechanical properties of the pressed bricks used in them. This study is divided into two sections to address these knowledge gaps. First, it identifies the primary characteristics of press-brick façade walls built in Bogotá during the late 19th and early 20th centuries through a systematic examination of existing and demolished buildings, and subsequently compares the findings with construction techniques documented in foreign technical literature of the period to highlight both similarities and differences. Second, it characterizes 35 Calvo pressed bricks through physical (dimensions, colorimetry), hygric (absorption, porosity, density), and mechanical (compressive strength) tests, as well as chemical (XRF) and petro-mineralogical (XRD, mercury intrusion porosimetry) analyses.

Results show that in the construction of the first pressed brick façade walls in Bogotá was employed a technique derived from the American ‘running bond’ solution. Additionally, that Calvo-pressed bricks comprised extruded pieces that were repressed in a semi-dry state before being fired in closed kilns at temperatures above 1100°C.

## References

- Camino Olea, M. S (2001). *Construcción y ornamentación de las fachadas de ladrillo prensado, al descubierto, en la ciudad de Valladolid* [PhD Thesis, Universidad de Valladolid]. <https://www.cervantesvirtual.com/obra/construccion-y-ornamentacion-de-las-fachadas-de-ladrillo-prensado-al-descubierto-en-la-ciudad-de-valladolid--0/>
- Potgeter, W. (2021). *Backstein-Rohbau im Zeitalter der Industrialisierung* [PhD Thesis, ETH Zurich]. <https://www.research-collection.ethz.ch/entities/publication/e3105bf2-d0df-425a-8ef0-7ad29b581002>
- Rangel Cobos, C., Lasheras, F., Pinilla-Melo, J. (2023). Disregarded bonds: The running bond and face bond in the construction of solid face-brick walls – a historical review of American and English technical texts published up to the 1930s. *Construction History*, 38 (2), 131-156.

# PHYSICAL-MECHANICAL EVALUATION AND VIABILITY OF LIGHTWEIGHT PLASTER COMPOSITES REINFORCED WITH COCONUT FIBRE FOR APPLICATIONS IN PREFABRICATED ELEMENTS

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**Keywords:** Coir fibre, Lightweight plaster composites, Fibre reinforcement, Circular economy, Raw material replacement

## Abstract

The construction sector requires strategies to reduce resource consumption and associated emissions, driving the need to use materials with low environmental impact, such as gypsum (United Nations, 2024). Although this material is favourable due to its low embodied energy, it has intrinsic limitations in terms of strength and hardness (Al-Ridha *et al.*, 2021). To address these shortcomings, the incorporation of coconut fibre, a highly available agricultural by-product, was explored as a reinforcing material (Wolfgang *et al.*, 2023). The main objective of this research was to evaluate the physical-mechanical properties of the resulting lightweight gypsum composites to establish their viability for the manufacture of prefabricated panels for building construction.

E-35 type gypsum composites were prepared with a water/binder ratio of 0.7. Coconut fibre, processed to an average length of 2.45 cm, was incorporated by progressive volumetric replacement, with percentages ranging from 2.50% to 17.50%. The 4×4×16 cm prismatic test specimens were cured for seven days under laboratory conditions before characterisation (UNE-EN 13279-1:2009). The bulk density, surface hardness (UNE 102042:2023), flexural strength, and compressive strength were determined in accordance with UNE-EN 13279-2:2014.

The inclusion of coconut fibre reduced density, consistent with another study on natural reinforcements in plaster (Braiek *et al.*, 2017). All compounds were classified within the medium density category. The compound with the highest fibre content (17.50%) showed a 9.46% reduction compared to the control. Flexural strength reached 4.35 MPa in the mixture with 15.00% fibre, representing an increase of 20.50% compared to the reference (3.61 MPa). This trend is consistent with other studies on natural fibre reinforcements (Arawit *et al.*, 2023). All specimens exceeded the minimum of 1 MPa required by the standard (UNE-EN 13279-2:2014). Compressive strength increased progressively, in line with other research (Alcaraz *et al.*, 2019), reaching a maximum of 8.77 MPa in sample P0.7-12.5CF; however, excessive fibre content (17.50%) led to decreases attributable to increased porosity and lower matrix cohesion. Shore C surface hardness also improved and exceeded the minimum requirement of 45 units in all cases (UNE 102042:2023).

The results confirm that the incorporation of coconut fibre optimizes the physical-mechanical performance of gypsum, supporting its viability for the manufacture of lightweight prefabricated panels. This approach constitutes a strategy aligned with the principles of the circular economy by valorising agricultural waste and reducing its environmental impact. However, it is recommended to evaluate the long-term durability, fire behaviour, and acoustic properties to complete the industrial validation of the material.



Fig. 1 Coconut fibre composites.

TABLE I  
BULK DENSITY OF PLASTER COMPOSITES WITH COCONUT FIBRE.

| Sample      | Bulk Density (kg/m <sup>3</sup> ) | Variation (%) | Density Class (UNE 102042:2023) |
|-------------|-----------------------------------|---------------|---------------------------------|
| P0.7-REF    | 1094.01                           | -             | Media                           |
| P0.7-2.5CF  | 1055.03                           | ↓3.30         | Media                           |
| P0.7-5.0CF  | 1044.64                           | ↓4.25         | Media                           |
| P0.7-7.5CF  | 1041.18                           | ↓4.57         | Media                           |
| P0.7-10.0CF | 1038.26                           | ↓4.83         | Media                           |
| P0.7-12.5CF | 1037.85                           | ↓4.87         | Media                           |
| P0.7-15.0CF | 1036.91                           | ↓4.86         | Media                           |
| P0.7-17.5CF | 987.83                            | ↓9.46         | Media                           |

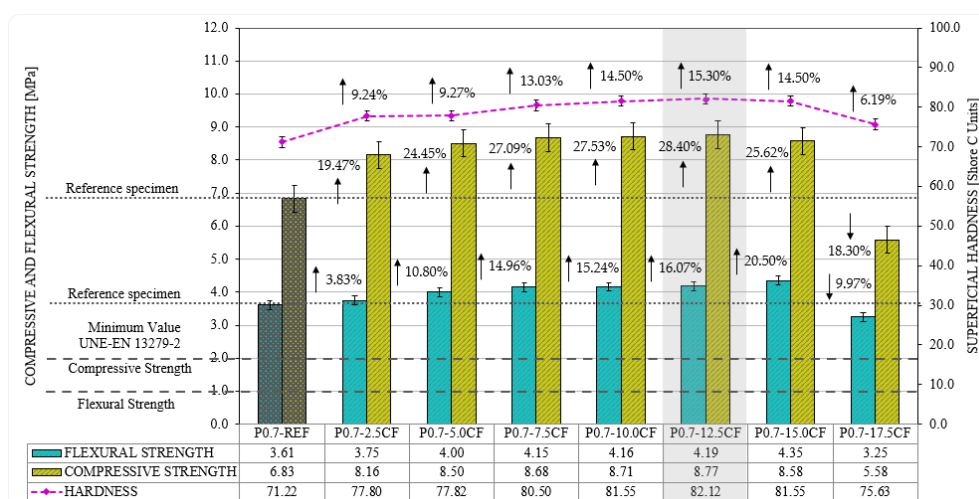


Fig. 2. Resistance to bending, compression, and surface hardness.

## References

- Alcaraz, J. S., Belda, I. M., Sanchis, E. J., & Gadea Borrell, J. M. (2019). Mechanical properties of plaster reinforced with yute fabrics. *Composites Part B: Engineering*, 178. <https://doi.org/10.1016/j.compositesb.2019.107390>
- Al-Ridha, A. S. D., Abboud, A. A., Hussein, F. M., Dheyab, L. S., Abdullah, E. L. N., Ali, E. H. Z., Mohialdeen, E. M. S., & Abdulhussein, E. A. A. (2021). Effect of Chopped Sisal fiber (CSF) on enhancing the compressive strength of Local Plaster of Paris (LPOP). *Materials Today: Proceedings*, 47, 2575–2579. <https://doi.org/10.1016/j.matpr.2021.05.063>
- Aramwit, P., Daniel Chin Vui Sheng, D., Krishna Moorthy, G., Guna, V., & Reddy, N. (2023). Rice husk and coir fibers as sustainable and green reinforcements for high performance gypsum composites. *Construction and Building Materials*, 393. <https://doi.org/10.1016/j.conbuildmat.2023.132065>
- Braiek, A., Karkri, M., Adili, A., Ibos, L., & ben Nasrallah, S. (2017). Estimation of the thermophysical properties of date palm fibers/gypsum composite for use as insulating materials in building. *Energy and Buildings*, 140, 268–279. <https://doi.org/10.1016/j.enbuild.2017.02.001>
- UNE-EN 13279-1:2009; Gypsum Binders and Gypsum Plasters—Part 1: Definitions and Requirements. Asociación Española de Normalización: Madrid, Spain, 2009.
- UNE 102042:2023; Gypsum Plasters. Other Test Methods. Spanish Association for Standardization: Madrid, Spain, 2023.
- UNE-EN 13279-2:2014; Gypsum Binders and Gypsum Plasters—Part 2: Test Methods. Asociación Española de Estandarización: Madrid, Spain, 2014.
- United Nations. 2023 Global Status Report for Buildings and Construction: Beyond foundations - Mainstreaming sustainable solutions to cut emissions from the buildings sector. (2024). United Nations Environment Programme. <https://doi.org/10.59117/20.500.11822/45095>
- Wolfgang, S.; Narendra, R.; Soren, B.; Anand, R. Coir from Coconut Processing Waste as a Raw Material for Applications Beyond Traditional Uses. *BioResources* 2023, 18, 2187–2212.

# PASSIVHAUS AS A DECARBONIZATION DRIVER: FROM LUXURY PRODUCT TO ACCESSIBLE AND PROFITABLE SOLUTION

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**Keywords:** *Passive House, Housing Accessibility, Middle-Income Households, Energy Efficiency, Decarbonization.*

## Abstract

The construction sector is undergoing a transformation driven by the need to meet European decarbonization targets and the requirement to achieve nearly zero-energy or zero-emission buildings, leaving behind its more traditional past.

Under these conditions lies the Passivhaus standard, a construction standard with one of the most rigorous methodologies to guarantee maximum energy efficiency, excellent indoor comfort, and a drastic reduction in the environmental impact of both the existing building stock and future developments (Schneider et al., 2015). Despite its benefits, the belief or perception persists that construction under this standard entails an unaffordable cost, preventing access for middle-income households (García-Lamarca & Kaika, 2016) and hindering its scalability in the real estate market.

This technical-economic study addresses the gap between the technical excellence of the Passivhaus standard and its market penetration. The research targets the Community of Madrid, a key market due to high housing demand and high prices, with the main objective of determining the economic viability and accessibility of Passivhaus housing for households classified as Middle Net Income Households.

The methodology employed combines an analysis of the building market and construction costs with the development of a detailed financial-economic model. This model simulates the lifespan of a Passivhaus dwelling compared to an equivalent home built under current building regulations. Critical variables have been evaluated, such as the differential construction cost, access to specific financing products like green mortgages, and—with special emphasis—the accumulated energy savings that these homes generate over time.

The results demonstrate how the initial extra cost associated with a Passivhaus home has experienced a notable reduction in recent years, becoming increasingly competitive. The analysis reveals that, for Middle-Income Households in Madrid, the initial investment can be offset and even exceeded in the short to medium term. Factors such as reduced interest rates on green mortgages and the elimination of virtually all heating and cooling costs act as key drivers in improving the long-term financial return for the homeowner.

Furthermore, non-economic benefits are outlined, such as significant improvements in indoor air quality and thermal-acoustic comfort, which have a direct and positive impact on the occupants' health (Xiao et al., 2022). In conclusion, Passivhaus housing should not be considered a luxury product, but rather a viable and accessible solution for Middle-Income Households in Madrid. The study confirms that the correct combination of initial investment management with long-term financial benefits and subsequent advantages in terms of habitability transforms the acquisition of an efficient home into a sustainable, profitable, and necessary decision to drive the energy transition of Spain's existing building stock.:

## References

- Schneider, J., Feist, W., & Rongen, L. (2015). Passive Houses for different climate zones. *Energy and Buildings*, 105, 71–87.
- García-Lamarca, M., & Kaika, M. (2016). 'Mortgaged lives': the biopolitics of debt and housing financialisation. *Transactions of the Institute of British Geographers*, 41(3), 313–327.
- Xiao, J., Zhao, J., Luo, Z., Liu, F., & Greenwood, D. (2022). The impact of built environment on mental health: A COVID-19 lockdown perspective. *Health & Place*, 77, 102889.

# INTERPRETATION OF RAFAEL GUASTAVINO'S US PATENT 947,177 THROUGH AI-ASSISTED GRAPHIC RECONSTRUCTION

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**Keywords:** *Rafael Guastavino, Architectural patents, Historical construction systems, AI-assisted graphic reconstruction, Ceramic vaulting*

## Abstract

Throughout the twentieth century, patents played a fundamental role as legal and economic instruments of technological progress. Beyond protecting innovation, they documented inventions through both textual descriptions and graphic representations, preserving technical knowledge that remains relevant today. In addition to their legal function, patents constitute a primary source for the study of construction history, as they reflect technical processes, design decisions, and regulatory constraints specific to their time (Christensen, 2024). However, patent texts often contain omissions or deliberately ambiguous formulations, either to safeguard technical content until formal grant or to protect certain aspects of a system, method, or technique until its commercialization phase. These shortcomings should not be understood as flaws, but rather as part of a technical and legal strategy that conditions their interpretation.

In the twenty-first century, artificial intelligence has emerged as a key tool in a comparable process, acting as an instrument for the interpretation, generation, and transmission of knowledge across multiple fields. In this context, the application of AI to historical documents offers new opportunities to revisit and reassess technical foundations developed in earlier periods (Spina, 2023; Ziran *et al.*, 2025).

The patent *Masonry Structure* (US Patent 947,177), granted to Rafael Guastavino in 1910, represents a milestone in the development of vaulting systems constructed with steel-reinforced ceramic elements (Gustavino, 2019). It provides an especially suitable case for exploring the potential of AI as a tool for analysis and for identifying textual gaps and ambiguities within historical technical documentation. Guastavino's work is distinguished by its ability to combine traditional ceramic vaulting techniques with structural innovations such as metallic reinforcement, anticipating construction methods that would later be systematized in modern practice.

From this perspective, the AI-assisted interpretation of historical documents—such as the patent examined in this study—allows two distinct historical moments to be connected, using contemporary technology to reexamine the constructive principles that shaped past developments.

The methodology adopted is based on an iterative graphic reconstruction process derived primarily from the patent's descriptive text. AI-assisted generation tools are employed to translate written information into controlled graphic representations. The original patent drawings are not used as a direct modeling basis, but rather as a subsequent reference to verify and refine the proposed reconstructions.

The images generated through this process demonstrate that a literal reading of the text alone does not directly yield the graphic solutions proposed in the patent. Explicit reformulations are required in order to arrive at an interpretation consistent with the technical description. This confirms that artificial intelligence does not operate as an autonomous interpretative agent, but rather as a graphic support tool, subordinated to technical criteria defined by the author.

This study highlights the potential of AI-assisted graphic reconstruction as a methodological approach for the rigorous analysis of historical technical documents. By enabling a comparison between historical designs and contemporary digital interpretations, the proposed methodology offers valuable insights for engineers, architects, and conservation specialists interested in the recovery, analysis, and teaching of historical construction systems, contributing both academic and practical value (Toth *et al.*, 2025).

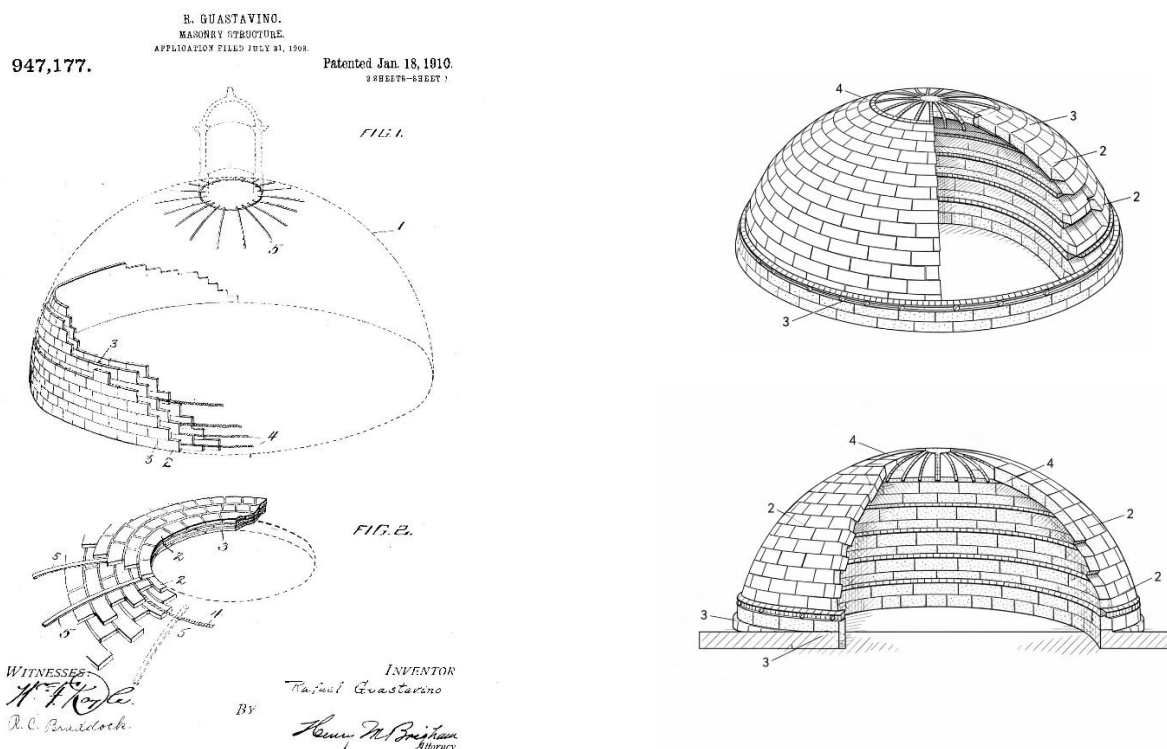


Fig. 1. Left: Original drawing from Rafael Guastavino's *Masonry Structure* patent (US 947,177, 1910) [4]. Right: AI-assisted graphic reconstruction generated exclusively from the patent's descriptive text.

## References

- Christensen, P.H. (2024). *Prior Art: Patents and the Nature of Invention in Architecture*. The MIT Press. <https://doi.org/10.7551/mitpress/15067.001.0001>
- Guastavino, R. (1910) *Masonry Structure*. U.S. Patent No. 947,177. <https://patents.google.com/patent/US947177A/en>
- Spina, S. (2023). *Artificial intelligence in archival and historical scholarship workflow: HTS and ChatGPT*. arXiv:2308.02044. <https://doi.org/10.48550/arXiv.2308.02044>
- Toth, G.M., Albrecht, R. & Pruski, C. (2025). Explainable AI, LLM, and digitized archival cultural heritage: a case study of the Grand Ducal Archive of the Medici. *AI & Soc*, 40, 4561–4573. <https://doi.org/10.1007/s00146-025-02238-5>
- Ziran, Z., Mecella, M. & Marinai, S. (2025). AI-driven enhancement of historical documents. *International Journal on Digital Libraries*, 26, 22. <https://doi.org/10.1007/s00799-025-00430-y>

# VERIFICATION OF INDOOR ENVIRONMENTAL TOXICITY AT THE WHOLE-BUILDING SCALE: INTEGRATING REFERENCE MEASUREMENTS AND SENSOR-BASED MONITORING

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**Keywords:** *Indoor air quality (IAQ), Human toxicity, Low-cost sensors, Exposure monitoring, Life Cycle Assessment*

## Abstract

Indoor air quality assessment in buildings has traditionally prioritised thermal comfort and ventilation proxies (temperature, relative humidity, CO<sub>2</sub>), while the toxicological dimension of indoor air remains weakly operationalized (Logue et al., 2011; Martins et al., 2025). This constitutes a structural limitation for research lines seeking to integrate human toxicity into building sustainability assessment, because material-based inventories describe potential hazards, yet they do not directly represent the effective exposure that ultimately drives health-relevant outcomes. As buildings become more airtight and systems more complex, the pertinent question shifts from what an individual product may emit, to what exposure profile the building, as a coupled system of assemblies, ventilation and use conditions, actually generates.

This communication positions indoor toxicity as a whole-building performance dimension that requires verification, not only modelling. In real dwellings, emission sources are multiple and interacting, including composite products and finishes, furnishings and occupant-related activities, as well as outdoor infiltration. Under these conditions, robust source attribution to a specific material is rarely feasible through monitoring alone (Morawska et al., 2020). Rather than treating this as a drawback, we argue it is an epistemic feature of indoor exposure that justifies assessing toxicity at the scale at which exposure occurs, the building and its zones.

To support this argument, a monitoring strategy combining continuous sensing and reference measurements was implemented in a dwelling, deploying low-cost sensors across four functionally distinct zones (living room, master bedroom, basement and corridor). The sensor network captured time series of indoor environmental parameters, enabling the observation of temporal variability, episodic behaviour and spatial heterogeneity. In parallel, reference and laboratory measurements were conducted during the deployment period as a data-quality prerequisite, providing an external anchor to interpret and constrain low-cost sensor outputs. Importantly, reference testing is not framed as the contribution of the work, but as the minimum validity condition for using continuous monitoring in health-oriented discussions.

The analytical focus is twofold. First, we delineate what low-cost sensing can and cannot support when the objective is to discuss toxic pollutants, distinguishing indicative screening (trend detection, spatial gradients, episode identification) from compliance-grade quantification (Ródenas García et al., 2022). Second, we demonstrate why whole-building interpretation is necessary: while monitoring cannot reliably identify single sources, it can characterise the aggregated effect of construction solutions, ventilation performance and operational conditions, which is precisely the level at which risk management and corrective action are implemented.

The expected contribution is therefore conceptual and methodological within a framework on toxicity integration: the communication provides an evidence-based rationale for moving from material-centred toxicity narratives toward exposure-centred building verification and proposes a replicable approach to

incorporate monitoring into decision-making protocols without overstating the capabilities of low-cost sensors. Ultimately, this work supports the broader thesis claim that toxicity should be measured and discussed alongside energy and comfort as a building performance criterion, enabling health-oriented evaluation in design, handover and operation.

## References

- Logue, J. M., Mckone, T. E., Sherman, M. H., & Singer, B. C. (2011). Hazard assessment of chemical air contaminants measured in residences. *Indoor Air*, 21(2), 92–109. <https://doi.org/10.1111/J.1600-0668.2010.00683.X>
- Martins, C., Teófilo, V., Clemente, M., Corda, M., Feroso, J., Aguado, A., Rodriguez, S., Moshammer, H., Kristian, A., Ferri, M., Costa-Ruiz, B., Pérez, L., Hanke, W., Badyda, A., Kepa, P., Affek, K., Doscocz, N., Martín-Torrijos, L., Mulayim, M. O., ... Viegas, S. (2025). Sources, levels, and determinants of indoor air pollutants in Europe: A systematic review. *Science of The Total Environment*, 964, 178574. <https://doi.org/10.1016/J.SCITOTENV.2025.178574>
- Morawska, L., Tang, J. W., Bahnfleth, W., Bluysen, P. M., Boerstra, A., Buonanno, G., Cao, J., Dancer, S., Floto, A., Franchimon, F., Haworth, C., Hogeling, J., Isaxon, C., Jimenez, J. L., Kurnitski, J., Li, Y., Loomans, M., Marks, G., Marr, L. C., ... Yao, M. (2020). How can airborne transmission of COVID-19 indoors be minimised? *Environment International*, 142, 105832. <https://doi.org/10.1016/J.ENVINT.2020.105832>
- Ródenas García, M., Spinazzé, A., Branco, P. T. B. S., Borghi, F., Villena, G., Cattaneo, A., Di Gilio, A., Mihucz, V. G., Gómez Álvarez, E., Lopes, S. I., Bergmans, B., Orłowski, C., Karatzas, K., Marques, G., Saffell, J., & Sousa, S. I. V. (2022). Review of low-cost sensors for indoor air quality: Features and applications. *Applied Spectroscopy Reviews*, 57(9–10), 747–779. <https://doi.org/10.1080/05704928.2022.2085734>

# CONTRIBUTIONS OF EMERGING TECHNOLOGIES TO THE FUTURE OF THE COMMON DATA ENVIRONMENT (CDE) WITHIN BIM

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**Keywords:** BIM, CDE, Technologies, Emerging, Blockchain.

## Abstract

The great challenge of this digital age is ensuring flexibility in access to information, its security, and its scalability; that is, to manage all digital information efficiently, and for this it is necessary to adopt emerging technologies such as blockchain, Big Data, artificial intelligence, among others. Therefore, the purpose of this document is to establish the connections of these technologies within the BIM ecosystem, and more specifically within Common Data Environments (CDEs), which in our opinion represent the heart of the BIM methodology, which is driving digitization and automation in the management of the different phases in construction projects.

The study focuses on the analysis of the CDEs currently used by public administrations, which are collaborative platforms that centralize and manage project information with the mediation of centralized servers in most cases managed by external providers, contrasting them with their more futuristic alternative oriented towards distributed storage, which is a method of storing data through multiple nodes in a network of interconnected computers, all of this with the aim of identifying the role played by the aforementioned emerging technologies in the development and application of decentralized storage in common data environments within BIM.

The proposed methodological design will consist of first examining the main benefits that data decentralization, established by blockchain technology in different areas, can offer for storing data essential in the development of BIM projects and asset management. Secondly, the drawbacks of current centralized data storage systems (CDS) will be identified, given the growing concern surrounding data privacy and security. Finally, a comparison will be drawn between traditional centralized storage systems and decentralized storage systems, analyzing the impact that emerging technologies such as artificial intelligence and big data can have on the development of decentralized CDS.

The study determined that the decentralization of the CDE within BIM can be achieved through technologies such as blockchain, as it can provide information traceability, security, scalability, integrity, and transparency in the data, guaranteeing an immutable record of changes in the models without the need for a central authority or intermediary. On the other hand, Big Data would allow the management and validation of large volumes of information generated throughout the life cycles of different BIM projects. This validated data can be analyzed through the integration of algorithms provided by artificial intelligence, so that it can be transformed into intelligent and automated actions to improve decision-making in projects.

## References

- González Márquez, R. J. (2014). Introducción a la metodología BIM. The Spanish Journal of BIM.
- Coloma, E. (2010). Definir BIM, Model, Representació i Vista. s.l. Escuela Técnica Superior de Arquitectura de Barcelona.
- Observatorio de Licitaciones BIM de la CIBIM. (2025, 27 de octubre). Informes trimestrales del observatorio. Ministerio de Transportes y Movilidad Sostenible. <https://cibim.transportes.gob.es/observatorio/informes-trimestrales-del-observatorio>.
- Turk, Ž., & Klinc, R. (2017). Potentials of blockchain technology for construction management. *Procedia engineering*, UNE-CEN/TR 18093:2024. Framework and Implementation of Common Data Environment solutions and workflow, in accordance with EN ISO 19650. AENOR, Asociación Española de Normalización.

# VÊTURES FOR ARCHITECTURE: A PROPOSAL FOR TRADITION AND INNOVATION

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**Keywords:** *Vêtire systems; external wall insulation; lime-based mortars; prefabricated façades; European regulatory framework.*

## Abstract

Traditional architecture in Madrid is characterised by the richness of its façade finishes, such as revoco a la madrileña and sgraffito, whose texture and colour play a key role in defining the identity of the urban landscape (Rodríguez, 1992; Rodríguez, 1999). However, the contemporary reproduction of these craft-based techniques has become increasingly complex due to high costs and the progressive scarcity of specialised labour. In this context, the present research examines the feasibility of industrialising such finishes through prefabricated façade systems known as Vêtures, with the aim of reproducing the aesthetic qualities of traditional finishes while meeting current construction efficiency requirements.

Vêtire systems are defined as prefabricated external wall insulation units that integrate a thermal insulation product and a factory-applied outer skin, configured as non-load-bearing elements mechanically fixed, bonded, or combined to the substrate (Kubečková et al., 2024). Their technical assessment and market placement within the European framework are governed by the European Assessment Document (EAD) 040914-01-0404, which establishes the scope of application, system structure, fixing typologies and methods for verifying essential performance characteristics (EAD 040914-00-0404, 2018). The experimental development of this study has been carried out in accordance with this regulatory framework, incorporating technical criteria derived from the author's participation in the editing and drafting processes of the EAD.

The main objective of the research is to demonstrate the technical and aesthetic viability of an industrialised insulating panel system combining aerial and hydraulic lime mortars, and to verify their compatibility with expanded polystyrene (EPS) substrates. To this end, an experimental methodology structured around three main lines of work was developed: analysis of case studies through field surveys, prototype fabrication, and laboratory testing. Site visits to historic buildings in Madrid enabled the identification of representative examples and a better understanding of real application conditions. The experimental phase included additive and subtractive fabrication of panels with brick-pattern and sgraffito-type designs, assessing their behaviour in terms of adhesion and water absorption (Rodríguez, 1992; Rodríguez, 1999).

The results indicate a satisfactory compatibility of lime-based mortars with the Vêtire system, achieving adhesion and hygric performance values in accordance with the requirements established in the EAD (EAD 040914-00-0404, 2018). Furthermore, resistance to wind suction exceeded the minimum values required for buildings over fifteen metres in height, confirming the technical feasibility of the system, in line with previous research on ETICS and EPS-based façade systems (McLaggan et al., 2018; Zhou et al., 2020).

The study concludes that the industrialisation of traditional façade finishes through Vêtire systems constitutes a valid strategy for preserving Madrid's architectural identity, while simultaneously providing an efficient, sustainable and regulation-compliant technical solution aligned with contemporary construction demands.

## References

- EAD 040914-00-0404. (2018). VETURE KITS – PREFABRICATED UNITS FOR EXTERNAL WALL INSULATION AND THEIR FIXING DEVICES. EOTA <https://www.eota.eu/eads?search=040914-00-0404&product=all&published=all#eads-results>
- Kubečková, D., Kubenková, K., Afsoosbiria, H., Musenda, O. K., & Mohamed, K. (2024). External Thermal Insulation Composite Systems— Past and Future in a Sustainable Urban Environment. *Sustainability*, 16(19), 8500. <https://doi.org/10.3390/su16198500>
- McLaggan, M., Flecknoe-Brown, K. W., Dragsted, A., & Van Hees, P. (2018). Heat release and flame spread assessment of insulation in External Thermal Insulation Composite System (ETICS) façades. *Journal Of Physics Conference Series*, 1107, 032021. <https://doi.org/10.1088/1742-6596/1107/3/032021>
- Rodríguez, C. B. (1992). Revestimientos continuos en la arquitectura tradicional española.
- Rodríguez, C. B. (1999). Técnicas para revestir fachadas.
- Zhou, B., Yoshioka, H., Noguchi, T., & Wang, K. (2020). Experimental study of time-averaged upward fire propagation speed of expanded polystyrene external thermal insulation composite systems masonry façade. *Fire And Materials*, 45(2), 193-204. <https://doi.org/10.1002/fam.2923>

# ASSESSING THE ROLE OF SOLAR SHADING DEVICES IN MITIGATING OVERHEATING IN HIGH SCHOOLS IN MADRID

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**Keywords:** Solar shading; Overheating; Thermal comfort; Educational buildings; Energy simulation

## Abstract

Educational buildings require careful design and operation, especially in warm and sunny locations. Current decarbonisation strategies and Zero Emissions Buildings (ZEB) design (Ministerio de Vivienda y Agenda Urbana, 2025) mainly focus on reducing winter heating demand and deploying high-efficiency systems and renewable energy sources. However, classrooms pose a particular challenge, as they combine high internal gains, significant glazing areas and intermittent occupancy, normally without active cooling systems. As a result, maintaining acceptable indoor conditions during warm periods strongly depends on the effective use of passive strategies, especially solar shading and ventilation.

On top of that, Climate Change is widening the summer duration and providing more frequent heat waves, and so the traditional educational building designs are struggling to keep indoor environments good enough for students. While the summer break traditionally avoided the hottest period of summer, in recent decades, thermal discomfort has become more frequent, even during spring and fall. Literature has explored this in Mediterranean areas and largely exposed buildings (Perez-Carraminana, 2024; M. T. Aguilar-Carrasco, 2025), the first to perceive these issues and urgently need solutions. Nevertheless, few studies examined schools located in central Spain.

This study focuses on secondary schools in Madrid, classified as D3 according to the Spanish Technical Building Code (CTE) and between BSk and Csa under the Köppen–Geiger classification for the 1990–2020 period data. This intermediate climate makes Madrid a relevant case to analyse overheating risks and the effectiveness of passive mitigation strategies. A parametric simulation-based assessment is conducted in a representative classroom to evaluate the impact of different solar shading solutions on indoor thermal comfort.

Sixteen scenarios are analysed, combining two construction periods (new buildings with CTE 2019 and existing schools built in the 1980s), two orientations (south and east), and four solar shading configurations: no shading, internal roller blinds, external roller shutters and external venetian blinds. The tests are conducted with EnergyPlus (through CypeTherm HE Plus), and the model incorporates realistic assumptions regarding occupancy, internal gains, ventilation strategies, and shading operation. Reflecting typical secondary school use.

The results show a clear improvement in indoor conditions when solar shading devices are implemented in all cases. The main benefits are a 36% reduction in the cooling degree hours (CDH26), a 47% reduction in cooling needs, and approximately 2 °C lower peak indoor temperatures during June and September. There are consistent improvements in all cases with solar shading, both interior and exterior.

The study concludes that shading devices, together with proper use of mechanical or natural ventilation, significantly improve indoor comfort and reduce the risk of overheating during warm periods. On the other hand, achieving adequate thermal comfort without active cooling remains challenging in certain scenarios. Further studies including more locations, improved control strategies to operate shadings, deeper assessments

of thermal comfort, monitoring data, and future weather or heat island effects, would support better design and renovation strategies for educational buildings. The calculations described in this paper are part of a larger investigation carried out for the Spanish Solar-Shading Organisation (AESSO).

## References

- Ministerio de Vivienda y Agenda Urbana, 2025, Real Decreto por el que se modifica el Código Técnico de la Edificación, aprobado por Real Decreto 314/2006, de 17 de marzo, Borrador para audiencia e información pública. Noviembre 2025, [https://www.mivau.gob.es/recursos\\_mfom/audienciainfopublica/recursos/proyecto\\_rd\\_modificacion\\_cte\\_audiencia\\_publica\\_nov\\_25.pdf](https://www.mivau.gob.es/recursos_mfom/audienciainfopublica/recursos/proyecto_rd_modificacion_cte_audiencia_publica_nov_25.pdf)
- M.T. Aguilar-Carrasco, C. María Calama-González, R. Escandón, G. Maria Mauro, and Rafael Suárez, Thermal comfort assessment of secondary school building stock in southern Spain using parametric numerical models and applying different climatic and ventilation scenarios, *Journal of Building Engineering*, Volume 111, 2025, 113343, ISSN 2352-7102, <https://doi.org/10.1016/j.jobe.2025.113343>
- C. Pérez-Carramiñana, A.B. González-Avilés, N. Castilla, A. Galiano-Garrigós. Influence of Sun Shading Devices on Energy Efficiency, Thermal Comfort and Lighting Comfort in a Warm Semi-Arid Dry Mediterranean Climate. *Buildings*, 2024, 14, 556. <https://doi.org/10.3390/buildings14020556>

# FATIGUE BEHAVIOR OF CONCRETE REINFORCED WITH STEEL AND POLYOLEFIN FIBRES

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**Keywords:** fatigue, flexure, cyclic loads, fibres reinforced concrete, steel fibres, polyolefin fibres

## Abstract

Fibre reinforcement in concrete improves its post-cracking tensile residual behaviour due to the ability of fibres to bridge the faces of the formed cracks (Carlesso et al., 2021). According to various structural codes and design standards ((Ministerio de Transportes y Movilidad Sostenible, 2021), (fib - International Federation for Structural Concrete, 2023)), under certain conditions, the structural contribution of fibres may be considered on the structural design, thereby allowing a reduction in conventional steel reinforcement or even its complete elimination.

The information available in the literature on the fatigue behaviour of fibre-reinforced concrete subjected to cyclic flexural loading is limited, particularly regarding concrete reinforced with combinations of fibres. This work presents the results of an experimental campaign to analyse the flexural fatigue behaviour of concrete reinforced with a combination of steel and polyolefin fibres. The study focuses on the characterisation of the behaviour induced by cyclic loading using previously pre-cracked specimens.

The results obtained indicate that, after the application of the loading cycles, no accumulated damage is observed in the specimens reinforced with the fibre combination. This suggests that the presence of fibres enhances the structural performance of concrete under flexural fatigue. Therefore, the post-cracking behaviour of fibre-reinforced concrete is significantly superior to that of conventional concrete, exhibiting higher residual mechanical capacity and improved resistance to crack propagation.

It should be noted that the hybrid combination of steel and polyolefin fibres allows optimisation of the material response over different crack opening ranges: steel fibres are more effective at small crack openings, whereas polyolefin fibres govern the behaviour in the large crack opening regime of the load–crack opening displacement curve. This work contributes to broadening the knowledge of the fatigue behaviour of concrete reinforced with hybrid fibre combinations.

## References

- Carlesso, D. M., Cavalaro, S., & de la Fuente, A. (2021). Flexural fatigue of pre-cracked plastic fibre reinforced concrete: Experimental study and numerical modeling. *Cement and Concrete Composites*, 115, 103850. <https://doi.org/10.1016/J.CEMCONCOMP.2020.103850>
- fib - International Federation for Structural Concrete. (2023). fib Model Code for Concrete Structures 2020. International Federation for Structural Concrete (fib). <https://www.fib-international.org/news/509-fib-model-code-2021.html>
- Ministerio de Transportes y Movilidad Sostenible. (2021). Código Estructural. <https://www.transportes.gob.es/ministerio/normativa-y-estudios-tecnicos/reglamentacion-vigente-sobre-seguridad-estructural/codigo-estructural>

# MODULAR GREEN ROOFS

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**Keywords:** green roofs, modular construction systems, modern methods of construction, industrialization, nature-based solutions

## Abstract

The architecture and construction industries are undergoing rapid transformation, driven by the pursuit of efficiency, sustainability, and technological advancement. Construction 4.0 refers to the integration of digitalization and industrialization within the building sector, which has traditionally been perceived as inefficient, unproductive, and resistant to technological innovation (Forcael et al., 2020).

Several strategies have emerged to achieve this dual objective. On the digitalization side, technologies such as the Internet of Things (IoT), Building Information Modelling (BIM), big data, artificial intelligence (AI), and virtual reality (VR) play a key role. From the industrialization perspective, efforts focus on developing new sustainable materials and promoting modularity. Modern Methods of Construction (MMC) encompass a range of techniques that depart from traditional on-site practices, most of which involve off-site construction (OSC). These approaches shift a significant portion of work to manufacturing facilities, followed by on-site assembly. (Sánchez-Garrido et al., 2023).

As one of the most exposed elements of the building envelope, roofs represent approximately 20–25% of the total urban surface. This makes the implementation of green roofs a significant opportunity to transform nearly a quarter of urban areas into green spaces (Castleton et al., 2010).

The construction system of a green roof involves multiple layers, from structural components to vegetation, combining elements from both gardening and building disciplines. To ensure long-term performance and the delivery of ecosystem services, the system must be designed as an integrated package. However, limited knowledge in this area often results in unclear responsibilities during execution, construction errors, and challenges in future maintenance and monitoring.

To remain competitive, the green roof industry must embrace Modern Methods of Construction (MMC). A modular green roof system could be an effective solution for extensive green roof applications. Modular systems offer several benefits, including streamlined installation, improved sustainability, standardized dimensions, easier maintenance and monitoring, and cost efficiency. However, challenges persist, such as limited design flexibility, internal composition issues, regulatory constraints, market immaturity, and social stigma-factors largely linked to the sector's recent and underdeveloped nature (Kamali & Hewage, 2016).

## References

- Forcael, E., Ferrari, I., Opazo-Vega, A., & Pulido-Arcas, J. A. (2020). Construction 4.0: A literature review. *Sustainability*, 12(22), 9755. <https://doi.org/10.3390/su12229755>
- Sánchez-Garrido, A. J., Navarro, I. J., García, J., & Yepes, V. (2023). A systematic literature review on modern methods of construction in building: An integrated approach using machine learning. *Journal of Building Engineering*, 72, 106725. <https://doi.org/10.1016/j.jobbe.2023.106725>
- Castleton, H. F., Stovin, V., Beck, S. B. M., & Davison, J. B. (2010). Green roofs: Building energy savings and the potential for retrofit. *Energy and Buildings*, 42(10), 1582–1591. <https://doi.org/10.1016/j.enbuild.2010.05.004>
- Kamali, M., & Hewage, K. (2016). Life cycle performance of modular buildings: A critical review. *Renewable and Sustainable Energy Reviews*, 62, 1171–1183. <https://doi.org/10.1016/j.rser.2016.05.031>

# PROBABILITY FUNCTIONS FOR EXTREME PRECIPITATION IN THE GUADALQUIVIR BASIN FOR CIVIL ENGINEERING DESIGN

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**Keywords:** modelling; hydrological engineering; precipitation distribution functions; drainage in urban areas; basin.

## Abstract

Hydrometeorological calculation models are required for the design of hydraulic works, both in urban areas, including sewerage works, and in civil engineering, including dams and their spillways. These models use design storms, which are developed from meteorological data on extreme precipitation, and appropriate probability distribution functions. There are different options within the distribution functions. This paper conducts a comparative analysis between the SQRT-ET max, log-Pearson III, Gumbel, and three-parameter log-normal functions. The study area is the Guadalquivir basin in the region of Andalusia, southern Spain, where eight weather stations have been selected with data on maximum annual precipitation over 24 hours between 1972 and 2024. These are the weather stations in Seville, Córdoba, Jaén, Granada, Puebla del Maestre, Jerez de la Frontera, Beas de Segura, and Guádix. Figure 1 shows the geographical location of these stations, with the Guadalquivir basin (located almost entirely in the Andalusian community) marked in dark green.

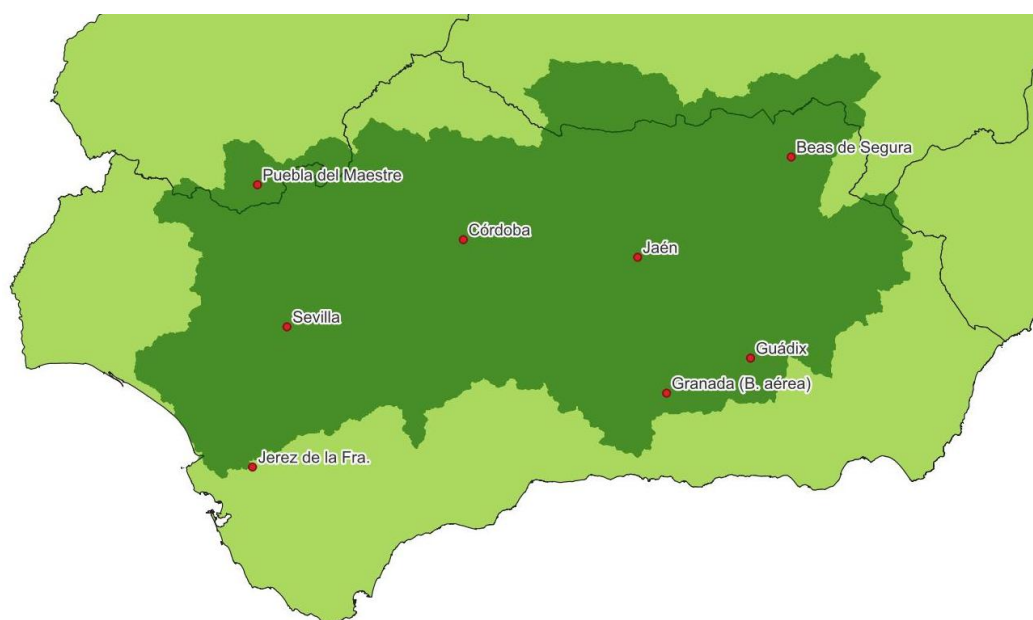


Fig. 1. Geographical location of weather stations.

The number of weather stations has been limited to eight, which are select stations with data on maximum annual precipitation in 24 hours covering at least 50 years in the Guadalquivir basin. Sample homogeneity was first assessed using the von Neumann and Thom tests on data from all weather stations. Samples that did not pass either of the tests were excluded from further analysis due to lack of homogeneity. Subsequently,

distribution parameters were estimated according to the characteristics of each case, using either the maximum likelihood method or the method of moments, with the exception of the SQRT-ET max. function, for which the Ferrer method was applied. Once the parameters were estimated, the goodness of fit of each distribution was evaluated at each weather station using the Kolmogorov–Smirnov and Anderson–Darling tests. Distributions that failed either test at a given station were rejected for that station. Afterwards, a frequency analysis was conducted to relate precipitation depth to the return period  $T$ . In the context of hydraulic infrastructure planning, such as bridges, reservoirs, and dams, maximum annual precipitation is commonly modelled using probability distribution functions. For high return periods (greater than 500 years), preference was given to the distribution yielding the highest estimated precipitation depth. Based on this criterion, the four distribution functions were ranked. In addition, a second ranking of the distribution functions was performed for each weather station using Akaike’s information criterion corrected for small sample sizes (AICc), which accounts for information loss associated with model selection. This analysis provided an alternative classification of the four candidate distribution models for each station. Finally, the entire methodology was repeated using data from the most recent 25-year period to evaluate potential changes in precipitation trends.

## References

- Bakouch,H.S.; Hussain,T.; Chesneau,C.; Jónás,T. A notable bounded probability distribution for environmental and lifetime data. *Earth Science Informatics*202215(3),1607-1620. <https://doi.org/10.1007/s12145-022-00811-w>
- Elsebaie,I.H.; ElAlfy,M.; Kawara,A.Q. Spatio temporal Variability of Intensity–Duration–Frequency(IDF) curves in arid areas: wadi AL-Lith, Saudi Arabia as a case Study. *Hydrology* 20219(1),6. <https://doi.org/10.3390/hydrology9010006>
- Kuo, C. C.; Gan, T. Y. Risk of exceeding extreme design storm events under possible impact of climate change. *Journal of Hydrologic Engineering* 2015, 20(12), 04015038. [https://doi.org/10.1061/\(ASCE\)HE.1943-5584.0001228](https://doi.org/10.1061/(ASCE)HE.1943-5584.0001228)
- Etoh, T., Murota, A., Nakanishi, M. SQRT-exponential type distribution of maximum. In *Hydrologic Frequency Modeling*. Springer: Dordrecht, The Netherlands. 1987, pp. 253-264. [https://doi.org/10.1007/978-94-009-3953-0\\_17](https://doi.org/10.1007/978-94-009-3953-0_17)
- Anderson, T. W. Anderson-Darling Tests of Goodness-of-Fit. *International encyclopedia of statistical science*, 2011, 1, 52-54. <https://doi.org/10.1029/2004WR003204>
- International Commission of Large Dams. Definition of a Large Dam. Available online: [https://www.icold-cigb.org/GB/dams/definition\\_of\\_a\\_large\\_dam.asp](https://www.icold-cigb.org/GB/dams/definition_of_a_large_dam.asp)
- Ministerio de la Presidencia, Relaciones con las Cortes y Memoria Democrática. Gobierno de España. Real Decreto 264/2021, de 13 de abril, por el que se aprueban las normas técnicas de seguridad para las presas y sus embalses. Publicado en: «BOE» núm. 89, de 14 de abril de 2021, páginas 42480 a 42533. <https://www.boe.es/eli/es/rd/2021/04/13/264>
- Maity, R. *Statistical Methods in Hydrology and Hydroclimatology*; Springer: Singapore, 2018, Volume 555. <https://doi.org/10.1007/978-981-16-5517-3>
- Montes-Pajuelo, R., Rodríguez-Pérez, Á. M., López, R., Rodríguez, C. A. Analysis of Probability Distributions for Modelling Extreme Rainfall Events and Detecting Climate Change: Insights from Mathematical and Statistical Methods. *Mathematics*, 2024, 12(7), 1093. <https://doi.org/10.3390/math12071093>
- Watt,E.; Marsalek,J. Critical review of the evolution of the design storm event concept. *Canadian Journal of Civil Engineering* 2013, 40(2),105-113. <https://doi.org/10.1139/cjce-2011-0594>

# THERMAL PERFORMANCE OF A REFURBISHED GREEN ROOF IN A PUBLIC BUILDING UNDER MEDITERRANEAN CLIMATIC CONDITIONS

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**Keywords:** *BIG4LIFE; Green roof; Real-scale monitoring; Thermal performance; Environmental performance*

## Abstract

Rapid urbanisation has intensified pressures on natural resources, energy consumption, and environmental quality, with cities responsible for a large share of global waste generation and pollution [1]. In this context, nature-based solutions (NBS) have emerged as a key strategy to enhance urban resilience and sustainability [2]. Building-Integrated Greenery (BIG) systems integrate vegetation into the building envelope and provide multiple ecosystem services at both the building and city scales. Among them, green roofs are widely recognised as effective NBS for mitigating urban heat island effects, improving building thermal performance, and enhancing urban biodiversity [3–6]. However, many early implementations have underperformed due to inadequate technical design, inappropriate substrate and vegetation selection, and insufficient maintenance strategies. Within this framework, the BIG4LIFE project [7] focuses on the real-scale implementation and monitoring of BIG systems to generate empirical evidence of their environmental, thermal, and ecological performance under Mediterranean and semi-arid climatic conditions. This paper presents the results of a monitored pilot project analysing the functional refurbishment of a green roof in a public educational building in Lleida (Spain), the Ronda la Mercè Nursery School (Figure 1).



Fig. 1. Rooftop of the Ronda la Mercè Nursery School. Left side: original green roof as initially designed (failed implementation); right side: refurbished and fully functional green roof system

The case study is based on a single-storey educational building composed of two geometrically and functionally identical classroom blocks, each with an approximate roof area of 200 m<sup>2</sup>. This configuration results in low building compactness and a high surface-to-volume ratio, amplifying the influence of the roof on overall thermal performance. Both blocks share orientation, construction systems, internal use patterns, and climatic exposure, differing only in roof configuration. The original green roof (Figure 1 left side) progressively failed due to inadequate substrate and plant selection, the use of a highly compacted clay-rich growing medium, and the absence of a structured maintenance strategy, leading to very low vegetation coverage. In contrast, the adjacent block (Figure 1 right side) was retrofitted in April 2024 with a redesigned extensive green roof system incorporating adapted vegetation species and a clearly defined maintenance and management strategy.

A monitoring campaign initiated in May 2024 is evaluating the impact of the refurbished green roof using key performance indicators related to roof thermal behaviour, indoor temperature stability, vegetation coverage, and biodiversity. In addition to comparing the two green roof systems, both configurations were compared against flat roof areas finished with a conventional rounded gravel protection layer.

Results from Figure 2 show that the Old Green Roof reaches very high surface temperatures, frequently exceeding 75 °C, together with large diurnal thermal amplitudes, indicating limited thermal inertia and weak heat regulation capacity. In contrast, the New Green Roof limits surface temperature peaks to approximately 50-55 °C, achieving a reduction of 20-25 °C under comparable climatic conditions. This improved behaviour is also observed at the bottom layer, where lower maximum temperatures, reduced thermal amplitudes, and a clear thermal phase shift indicate enhanced thermal damping and delayed heat transfer through the roof assembly. Compared with the gravel roof, the refurbished green roof demonstrates a greater ability to attenuate and delay heat transfer towards the interior, whereas the gravel configuration exhibits intermediate surface temperatures (60-65 °C) and earlier thermal peaks at the bottom layer.

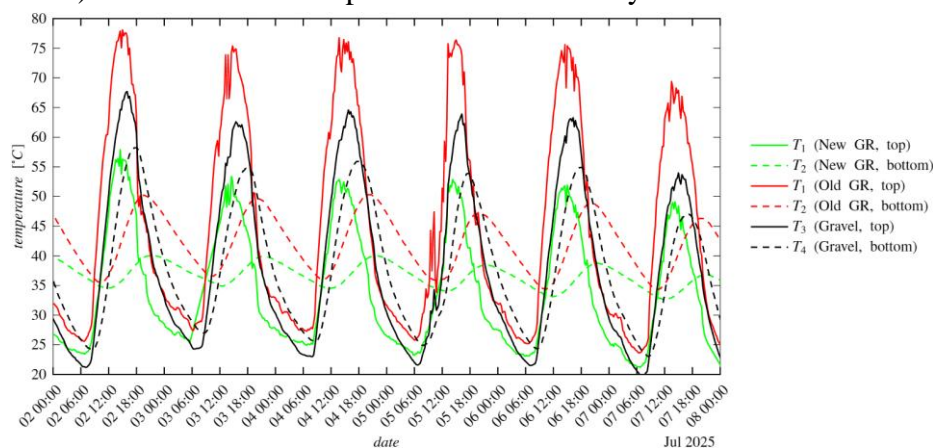


Fig. 2. Evolution of temperature profiles measured at the upper and lower layers of three roof configurations a) new green roof, b) old green roof, and c) gravel reference during a representative summer period (2–8 July 2025)

Overall, the refurbished green roof shows a better improvement in thermal performance, including a reduction of indoor air temperature peaks of up to 1 °C in summer, improved thermal stability of the waterproofing layer across seasons, and a significant decrease in daily thermal fluctuations. These results confirm the effectiveness of properly designed and maintained green roofs as nature-based solutions for enhancing building thermal performance under Mediterranean summer conditions.

## References

- Kapucu, N., Ge, Y., Rott, E., & Isgandar, H. (2024). Urban resilience: Multidimensional perspectives, challenges and prospects for future research. *Urban Governance*, 4(3), 162–179. <https://doi.org/10.1016/j.ugj.2024.09.003>
- Ribeiro, I., Lopes, H. S., Remoaldo, P. C., Ribeiro, V., Alves, J. A., & Silva, L. (2026). Contribution of nature-based solutions (NbS) to resilience: A review of European projects between 2014 and 2023. *Environmental Development*, 57, 101367. <https://doi.org/10.1016/j.envdev.2025.101367>
- Reyes, M., Pérez, G., & Coma, J. (2024). The Role of Building-Integrated Greenery Systems in Building Sustainability Rating Systems. *Land*, 13(8), 1114. <https://doi.org/10.3390/land13081114>
- Pérez, G., Reyes, M., Coma, J., Alva, A., Berigüete, F. E., & Lacasta, A. M. (2024). Methodological framework for impact evaluation of Building-Integrated Greenery (BIG-impact). *MethodsX*, 13, 102961. <https://doi.org/10.1016/j.mex.2024.102961>
- Fabiani, C., Coma, J., Pisello, A. L., Pérez, G., Cotana, F., & Cabeza, L. F. (2018). Thermo-acoustic performance of green roof substrates in dynamic hygrothermal conditions. *Energy and Buildings*, 178, 140–153. <https://doi.org/10.1016/j.enbuild.2018.08.024>
- Pérez, G., Coma, J., Chocarro, C., Juárez, A., Marín, C., Rauter, F., Zupanc, N., Šubic, B., & Majkovič, D. (2025). Rock mineral wool-based green roofs to improve the quality of urban water runoff. *Environmental Science and Pollution Research*, 32(14), 8986–9003. <https://doi.org/10.1007/s11356-025-36232-7>
- European Commission. (2023). BIG4LIFE (LIFE22-ENV-ES-BIG4LIFE/101114024): Building-integrated greenery collaborative xeriscaping based maintenance and monitoring in Mediterranean cities. LIFE Programme. <https://ec.europa.eu/info/funding-tenders/opportunities/portal/screen/opportunities/projects-details/43252405/101114024/LIFE2027>

# ADAPTATION OF A TOURIST-ENERGY LOCK INSPIRED BY STRASBOURG TO THE CANAL DE CASTILLA: PROPOSAL FOR HERITAGE VALORIZATION AND ECOSYSTEM SERVICES

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**Keywords:** *Revitalization, heritage locks, river tourism, micro-hydroelectric plants, sustainable infrastructure.*

## Abstract

This study proposes a model transfer based on benchmarking; adapting the "lock as a tourist experience" approach observed in Strasbourg, where the navigation product explicitly incorporates passage through two locks as a key feature of the route, to Lock 1 of the Canal de Castilla (Barrio de San Vicente, Alar del Rey, Palencia), transforming it into a multifunctional heritage hub with tourism, economic, energy, and water resources benefits. The Canal de Castilla is declared an Asset of Cultural Interest with the category of historical site (BOE, 1991), which requires reversible solutions that respect the landscape and structural integrity. Furthermore, it is a state infrastructure managed by the Duero River Basin Authority, with current priority uses (CHD, 2019a): supplying water to approximately 400,000 inhabitants and irrigation, so the main design constraint is to avoid interfering with hydraulic operation or the availability of the resource (CHD, 2019b).



Fig. 1. Tourism at the Strasbourg lock.

The case study is justified by its high capacity for "territorial narrative," the first lock being located approximately 2 km along the towpath, and the presence of ruins of an old power plant on the site, which allows for an integrated presentation of water, energy, and heritage. The proposed intervention is structured in four modules. (i) Tourism and Culture: a safe route, discreet viewpoints, educational panels, and scheduled demonstrations of the lock cycle, inspired by the experiential approach to the Strasbourg river tourism product. (ii) Operation and Light Digitization: non-intrusive sensors (levels, gate status, cycle recording) geared towards maintenance and traceability, with educational data visualization for visitors. (iii) Energy: self-

consumption micro-hydropower (lighting, sensors, small interpretive classroom), sized and with an explicit restriction on the divertable flow to avoid affecting water supply/irrigation. (iv) Local Economy; Tourist circuits and connections with cycling tourism/hospitality are being considered to increase average stay and spending.



Fig. 2. Rehabilitation project simulation.

The evaluation is based on a multi-criteria analysis (heritage, water, safety, tourism, energy, and cost) with quantifiable indicators: visitors, seasonality, satisfaction, employment, kWh/year, and operational compatibility metrics (incidents, compliance with restrictions). Overall, Lock 1 at San Vicente can evolve from a passive element to an active demonstration model that can be replicated in other locks of the Canal, reinforcing conservation and education without compromising the water supply.

## References

- Boletín Oficial del Estado. (1991). *Decreto 154/1991, de 13 de junio, por el que se declara Bien de Interés Cultural, con categoría de Conjunto Histórico, el Canal de Castilla*. BOE. <https://www.boe.es>
- Confederación Hidrográfica del Duero. (2019a). *Usos del Canal de Castilla: abastecimiento y regadío*. Ministerio para la Transición Ecológica y el Reto Demográfico. <https://www.chduero.es>
- Confederación Hidrográfica del Duero. (2019b). *Normativa y régimen de protección del Canal de Castilla*. Ministerio para la Transición Ecológica y el Reto Demográfico. <https://www.chduero.es>
- Ayuntamiento de Alar del Rey. (s. f.). *Rutas turísticas del Canal de Castilla: Esclusa 1 del Barrio de San Vicente y antigua central eléctrica*. <https://www.alardelrey.es>

# DIGITAL PLATFORM FOR BRIDGE ASSET MANAGEMENT IN SPAIN INTEGRATING GIS RELATIONAL DATABASES AND BIM MODELLING

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**Keywords:** GIS, BIM, relational database, asset management, structural heritage

## Abstract

Bridge management in Spain faces significant challenges due to the limited adoption of BIM in civil engineering, particularly for bridges where homogeneous tools for unified workflows are lacking (Blanco et al., 2019). This fragmentation is further evidenced by non-standardized inspection processes in public heritage that generate dispersed databases (Bazán et al., 2021), and by the lack of interoperability between BIM and GIS platforms seen in complex infrastructures (Cepa et al., 2024).

Consequently, there is an urgent need for digital tools that integrate these technologies to improve data traceability (Lozano-Galant et al., 2025) and support rational lifecycle management (Blanco et al., 2019), aligning with international trends in data-driven decision making (Casas, 2024).

To address these issues, this project introduces a scalable digital environment designed to centralize structural, geographic, and typological bridge data, enabling advanced analysis, interactive visualization, and seamless integration with emerging technologies. A relational database based in Structured Query Language (SQL) was developed to normalize and organize the collected information, which feeds a Microsoft Power BI interface that supports multicriteria queries, geospatial exploration, and dynamic dashboards. As an example of the visualization and management power of the tool, a BIM model of the Peraleda bridge in Toledo was created in Revit and integrated into the database as a central digital asset, linking geometry, materials, typology, and structural attributes.

The results demonstrate substantial improvements in data accessibility, consistency, and interpretability, allowing cross-analyses by region, material, typology, and structural characteristics considering all bridges saved into the Database. The case study further underscores the potential of BIM integration as the backbone of asset management systems, paving the way for future extensions toward digital twins and IoT-based monitoring, serving as a solid base for the application of artificial intelligence capable of managing and interpreting this information. In conclusion, the platform illustrates how a unified digital system can reduce information fragmentation, optimize the management of structural heritage, and establish a foundation for predictive maintenance strategies. Its scalable architecture is ready to incorporate GIS, BIM, and sensor technologies, positioning it as a powerful tool for the modernization of bridge management in Spain.

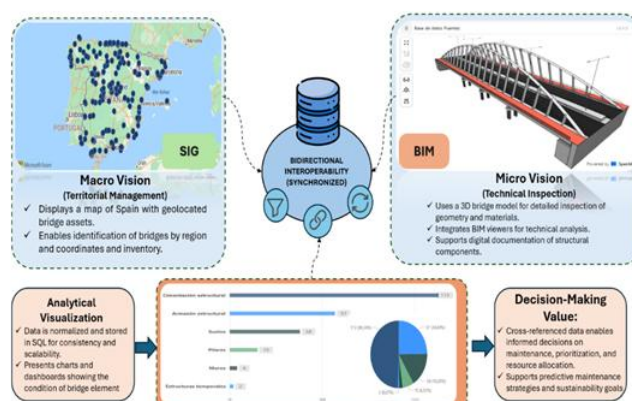


Fig. 1. Interoperability and Bidirectional Data-Flow Scheme

## References

- Bazán, Á. M., Alberti, M. G., Álvarez, A. A. A., Pavón, R. M., & González Barbado, A. (2021). BIM-Based Methodology for the Management of Public Heritage. CASE Study: Algeciras Market Hall. *Applied Sciences*, 11(24), 11899. <https://doi.org/10.3390/app112411899>
- Blanco, R., Martínez, J., Mozas, B., García Alberti, M., & Arcos Álvarez, A. A. (2019). Use of BIM methodology for the remodeling of an existing bridge (p. 2 p.). Editorial Universidad Politecnica de Madrid. <https://doi.org/10.20868/ade.2019.4376>
- Casas, J. R. (2024). Sostenibilidad y digitalización en la gestión de puentes: ¿hasta dónde llegamos? En *Mantenimiento, seguridad, gestión, digitalización y sostenibilidad de puentes* (pp. 13–25). CRC Press. <https://doi.org/10.1201/9781003483755-327>
- Cepa, J. J., Alberti, M. G., Pavón, R. M., & Calvo, J. A. (2024). Integrating BIM and GIS for an Existing Infrastructure. *Applied Sciences*, 14(23), 10962. <https://doi.org/10.3390/app142310962>.
- Lozano-Galant, F., Montalvo, A., Atencio, E., Porras, R., & Lozano-Galant, J. A. (2025). Una aplicación SIG de código abierto para digitalizar inspecciones de puentes y automatizar la integración de modelos BIM. *Ingeniería de Estructuras e Infraestructuras*, 1–12. <https://doi.org/10.1080/15732479.2025.2456979>

# STATISTICAL ANALYSIS OF THE DEPENDENCE BETWEEN THE TYPOLOGIES OF VERNACULAR DWELLINGS AND THE LOCALITIES OF THE MONTESINHO NATURAL PARK

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**Keywords:** *heritage management, statistical dependency, vernacular architecture*

## Abstract

The INHAVIT project investigates vernacular housing as a key component of cultural heritage and territorial identity, aiming to support informed strategies for conservation, rehabilitation, and sustainable development in rural and protected landscapes. Within this framework, Montesinho Natural Park (MNP), Portugal, presents a particularly diverse architectural context shaped by topography, climate, material availability, and settlement history. The systematic documentation of this diversity has been carried out through large-scale, ICT-enhanced field surveys, resulting in a substantial digital dataset that requires robust yet accessible analytical methods capable of handling both quantitative and qualitative attributes of vernacular architecture.

This paper addresses the methodological challenge of statistically assessing whether or not specific vernacular building typologies exhibit dependency relationships with particular localities. Based on the survey, 23 building typologies were identified across 8 localities, generating a 23×8 contingency matrix. Its large size, combined with frequent zero observed counts, produces a high proportion of cells with low expected frequencies. As a result, conventional inferential statistical techniques as the Chi-square ( $\chi^2$ ) and the Fisher's exact test are unsuitable.

To overcome these constraints, the paper proposes the use of Probabilities for a Normal Distribution  $N(0,1)$  as a pragmatic analytical alternative. This approach transforms deviations between observed and expected frequencies into standardised values, allowing the identification of statistically meaningful departures from an initial assumption of independence. The method is presented as a low-barrier computational filter that can be implemented using basic spreadsheet or scripting tools, making it particularly suitable for heritage researchers and practitioners working with limited computational resources.

Critical values that give a probability of less than 5 %, or 0.05 parts per unit, will be considered to indicate that the initial assumption that there is no relationship between building types and localities, is not true. There are more buildings observed than expected for the same typology (Figure 1). These deviations, illustrated through graphical representations, enable the identification of locality-specific architectural concentrations that warrant further investigation.

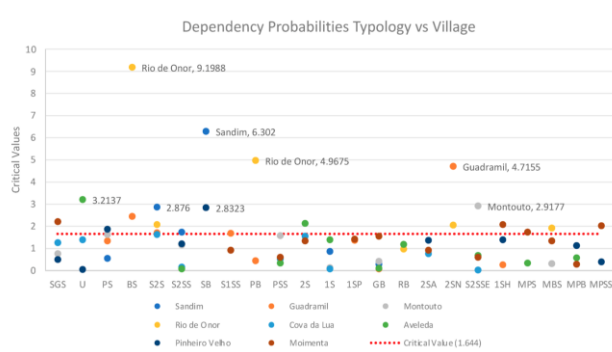


Fig. 1. Dependency chart between typology and village for a Normal Distribution  $N(0,1)$ .

Source: Adapted from (Khei et al., 2024)

The null hypothesis—namely, that building typologies are distributed independently of locality—is intentionally adopted as a starting point, allowing the observed data to determine whether statistically significant dependencies exist. While this paper does not seek to explain the causal mechanisms behind such dependencies, it establishes a rigorous foundation upon which subsequent qualitative, historical, and environmental analyses can be developed.

By integrating ICT-based data collection with an accessible statistical workflow, the proposed method constitutes a valid form of scientific analysis that supports evidence-based decision-making within the objectives of the INHAVIT project. More broadly, it offers a transferable and cost-effective analytical framework for digital heritage studies in regions worldwide where complex vernacular datasets challenge the applicability of standard statistical tools.

## References

- Khei, S., Mateus, R., Ortega, J., & Briones-Llorente, R. (2024). Quantitative Analysis of Vernacular Residential Building Typologies and Bioclimatic Strategies in the Warm-Summer Mediterranean Climate: The Montesinho Natural Park as a Case Study. *Buildings* 2024, Vol. 14, 14(8), 2321. <https://doi.org/10.3390/BUILDINGS14082321>

# NEW CERAMIC MATERIALS INCORPORATING SULFIDIC MINING WASTE: A COMPARATIVE ANALYSIS OF SINTERING. A SUSTAINABLE SOLUTION FOR THE CONSTRUCTION SECTOR

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**Keywords:** Mining waste; Ceramic characterisation; Sintering behaviour; Microstructural analysis; Sustainable construction.

## Abstract

The increasing generation of mining waste constitutes a significant environmental challenge in regions with a high concentration of industrial liabilities, such as the province of Huelva. The valorisation of these residues within circular economy strategies has been identified as an effective pathway to reduce their environmental impact while generating new sustainable products (Matinde et al., 2018). The ceramic industry offers a particularly suitable context for this valorisation, as numerous studies have demonstrated that mining wastes can be successfully incorporated into the manufacture of ceramic materials, contributing to a reduction in the consumption of virgin raw materials (Paiva et al., 2021; Simão et al., 2021).

This study analyses the feasibility of formulating new ceramic materials using mining residues from Huelva sintered at 950°C and 1100°C. The main objective is to evaluate the physical, mechanical and mineralogical behaviour of ceramic materials produced using mining residues from Huelva, examining how the firing temperature influences their performance. In addition, the study aims to determine the viability of these materials as a sustainable alternative for construction products, in line with recent research on the application of mining waste in structural ceramics (Izak et al., 2025).

The mining residues were dried, crushed and sieved prior to their incorporation into the ceramic mixtures. Test specimens were shaped by uniaxial pressing and subsequently sintered at 950°C and 1100°C following standard procedures used in the ceramic industry (Paiva et al., 2021). The samples were then characterised in terms of physical analysis, together with mineralogical analysis by X-ray diffraction (XRD) and microstructural characterisation by scanning electron microscopy (SEM), following methodologies widely accepted in the literature (Simão et al., 2021).

The results indicate that the firing temperature has a decisive influence on the final properties. Samples fired at 950°C exhibit lower mechanical strength, although they maintain dimensional stability. In contrast, specimens sintered at 1100°C display a more compact structure, with higher mechanical strength, in agreement with trends reported in previous studies on the incorporation of mining tailings into ceramics (Paiva et al., 2021; Izak et al., 2025). SEM observations reveal progressive microstructural densification with increasing temperature, while XRD analysis confirms the formation of stable silicate phases. Overall, the results highlight the technical potential of mining residues from Huelva as a ceramic raw material.

To conclude, the study demonstrates the feasibility of using mining residues from Huelva in the manufacture of sustainable ceramic materials for construction. Sintering at 1100°C yields products with physical and mechanical properties suitable for structural applications, whereas a firing temperature of 950°C may be adequate for less demanding uses. The research confirms that the valorisation of mining waste through its incorporation into ceramic matrices contributes to circular economy objectives and to the reduction of environmental impact.

## References

- Izak, P., Sutou, Y., González, M., & Havel, Y. (2025). Utilisation of mining waste for production of ceramic tiles. *Applied Sciences*, 15(7), 3957.
- Matinde, E., Simate, G. S., & Ndlovu, S. (2018). Mining and metallurgical wastes: A review of recycling and re-use practices. *Minerals & Metallurgical Processing*, 35(4), 201–216.
- Paiva, H., Teles, M., Segadães, A. M., & Rocha, F. (2021). Production of ceramic materials using sulfidic mining waste as a raw material. *SN Applied Sciences*, 3(5), 1–12.
- Simão, F. V., Paiva, H., Segadães, A. M., & Rocha, F. (2021). Incorporation of sulphidic mining waste material in ceramic roof tiles and blocks. *Construction and Building Materials*, 266, 121–214.

# INTEGRATING HERITAGE CONSERVATION AND ENERGY PERFORMANCE IN HAUSSMANNIAN URBAN NEIGHBORHOOD

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**Keywords:** *Urban heritage; Sustainable development; Energy performance; Haussmannian architecture; Heritage-led rehabilitation.*

## Abstract

*“Heritage is our legacy from the past, what we live with today, and what we pass on to future generations”* (UNESCO Convention, 1972). This statement captures the dynamic nature of urban heritage as both an inherited asset and a living framework within contemporary cities, shaped by ongoing social, political and environmental transformations. In the current context of climate change, the preservation of historic urban fabrics must be integrated into broader strategies of sustainable development. Nevertheless, heritage conservation and sustainability are often perceived as competing objectives: the former associated with safeguarding the past, and the latter oriented towards future environmental performance. This dichotomy overlooks the adaptive nature of historic urban environments and their capacity for long-term resilience.. Consequently, a holistic reinterpretation of urban heritage is required—one that aligns heritage values with environmental protection, social cohesion and economic viability.

This study focuses on the urban fabric of Paris’s 16th arrondissement, a representative example of Haussmannian urban development, and explores how this architectural and urban paradigm can be leveraged as a driver of sustainable development. The main objective is to identify the strengths and limitations of the inherited Haussmannian fabric when confronted with contemporary environmental, social and functional challenges, with particular emphasis on energy performance. Through the analysis of selected case studies, the research seeks to formulate context-sensitive intervention strategies capable of enhancing sustainability while respecting heritage values.

The methodological framework combines qualitative and quantitative approaches, integrating historical, morphological and diagnostic analyses. Archival research is employed to reconstruct the historical evolution and regulatory framework of the district, while morphological and typological studies enable the characterisation of the built fabric and its architectural constraints. The findings are synthesised through a SWOT analysis assessing the capacity of the Haussmannian fabric to accommodate sustainable interventions. The proposed intervention strategy follows methodologies developed by the French National Association of Cities and Countries of Art and History and the Centre for Technical Studies for Infrastructure, and is organised into successive stages including energy performance assessment, evaluation of existing conditions and the definition of rehabilitation measures.

The analysis identifies significant challenges, such as high energy consumption associated with affluent households and tensions between heritage protection requirements and increasingly stringent energy regulations. At the same time, favourable conditions for intervention are observed, notably high rates of home ownership and strong economic capacity, which facilitate investment in building rehabilitation. The proposed measures focus on improving energy performance through techniques compatible with heritage conservation, including aerogel-based insulating mortars and interior thermal insulation systems incorporating vacuum

insulation panels. These solutions address architectural constraints—particularly façade preservation—while responding to owner priorities, such as minimising the loss of interior space.

Overall, the study demonstrates that heritage conservation and sustainability can be mutually reinforcing when addressed through integrated and context-sensitive approaches. The Haussmannian urban fabric of Paris's 16th arrondissement is shown to possess the potential to act as a catalyst for sustainable urban development when interventions are carefully tailored to its architectural, social and economic specificities.

## References

UNESCO. (1972). *Convention concerning the protection of the world cultural and natural heritage*. Paris, France: United Nations Educational, Scientific and Cultural Organization.

# EVALUATING MOISTURE IN GYPSUM WITH A CONTACT HYGROMETER: CORRELATION WITH ACTUAL MOISTURE AND MECHANICAL PERFORMANCE

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**Keywords:** Gypsum, Moisture content, Non-destructive testing (NDT), Contact hygrometers, Conservation assessment

## Abstract

Gypsum is a highly versatile construction material whose main properties—rapid setting, whiteness and low density—make it suitable for a wide range of applications, particularly smooth surface coatings for walls and ceilings. However, its performance is strongly affected by moisture due to the slight solubility of the hardened calcium sulphate dihydrate ( $\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$ ), which is approximately  $2.3 \text{ g L}^{-1}$  at  $20 \text{ }^\circ\text{C}$  (Innorta et al., 1980), and the consequent reduction in mechanical properties when water is present within its capillary network (Coquard & Boistelle, 1994; Reynaud et al., 2006; Wirsching, 1985). Although moisture-induced deterioration is often considered reversible, its reversibility depends on both the moisture content and the duration of exposure; prolonged wet conditions may lead to partial dissolution of the crystal structure and irreversible structural changes.

Moisture in gypsum elements may arise from hygroscopic adsorption from ambient air, capillary absorption from the building structure, direct absorption of liquid water in exposed elements, or surface condensation. Therefore, the in situ detection of moisture in gypsum coatings and prefabricated elements using non-destructive testing (NDT) techniques is essential for inspection and conservation assessment. Portable contact hygrometers are commonly used for this purpose; these devices provide indirect moisture measurements based on variations in the surface electrical resistance of the material, yielding qualitative or semi-quantitative moisture indications.

This study investigates the correlation between moisture readings obtained using a portable contact hygrometer and the actual moisture content determined by gravimetric laboratory methods. Six types of test specimens were prepared using two commercially available gypsum plasters commonly used in building construction (B1 and A2) with water-to-plaster ratios of 0.6, 0.7 and 0.8. The results reveal significant discrepancies between both measurement methods, with deviations strongly dependent on plaster type and water-to-plaster ratio, indicating the need for regression-based calibration equations to convert hygrometer readings into real moisture content (Fig.1).

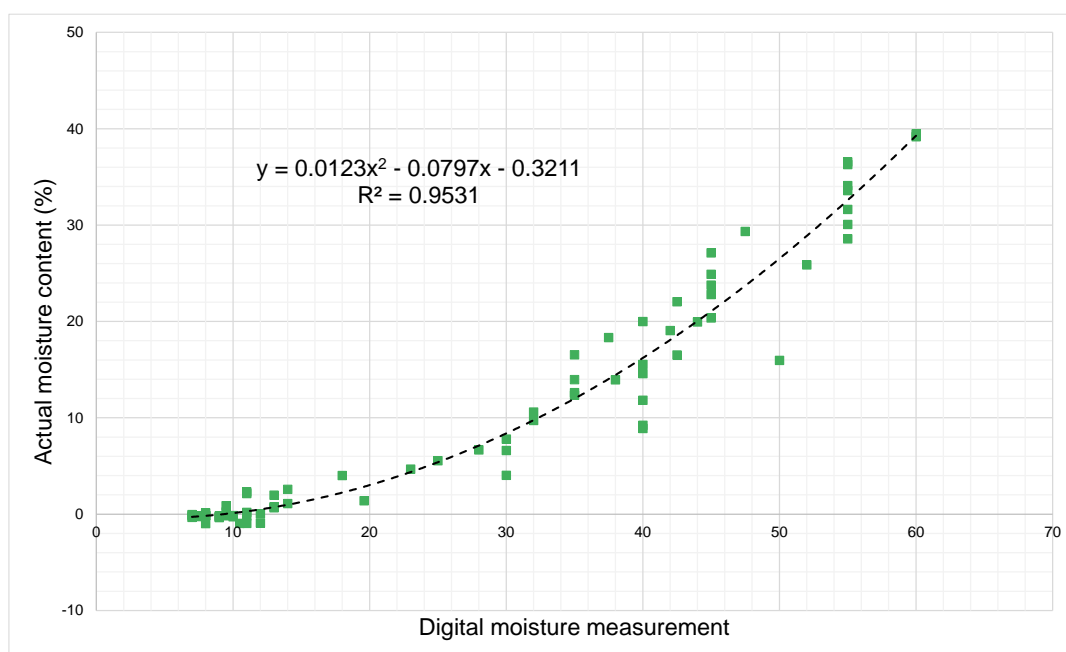


Fig. 1. Correlation between hygrometer moisture and actual moisture (%) for plaster

The findings highlight the limitations of uncalibrated portable contact hygrometers for conservation assessment. Finally, considering the pronounced sensitivity of gypsum to even low moisture contents, the suitability of the lower detection limits of these devices for reliably assessing the conservation state of gypsum-based elements is critically discussed.

## References

- Coquard, P., & Boistelle, R. (1994). Water and solvent effects on the strength of set plaster. *International Journal of Rock Mechanics and Mining Sciences and*, 31(5), 517-524. [https://doi.org/10.1016/0148-9062\(94\)90153-8](https://doi.org/10.1016/0148-9062(94)90153-8)
- Innorta, G., Rabbi, E., & Tomadin, L. (1980). The gypsum-anhydrite equilibrium by solubility measurements. *Geochimica et Cosmochimica Acta*, 44(12), 1931-1936.
- Reynaud, P., Saâdaoui, M., Meille, S., & Fantozzi, G. (2006). Water effect on internal friction of set plaster. *Materials Science and Engineering: A*, 442(1-2 SPEC. ISS.), 500-503. <https://doi.org/10.1016/j.msea.2006.01.152>
- Wirsching, F. (1985). Calcium Sulfate. En *Ullmann's Encyclopedia Industrial Chemistry* (pp. 555-584). Weinheim: Wiley-VCH Verlag GmbH & Co. KGaA. <https://doi.org/10.1002/14356007.a04>

# STRUCTURAL INTERVENTIONS IN THE SCHOOL OF STO DOMINGO IN ORIHUELA BETWEEN 1940-1974

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**Keywords:** *Santo Domingo (Orihuela), restoration, reconstruction, archival research*

## Abstract

The Santo Domingo Convent School in Orihuela, built between 1553 and 1739 (Sánchez Portas, 2003), was declared a National Historic-Artistic Monument in 1931 (Ministerio de Instrucción Pública y Bellas Artes, 1931) and a Site of Cultural Interest in 1985 (Jefatura del estado, 1985). The complex underwent a series of interventions between 1940 and 1974, under the supervision of Alejandro Ferrant Vázquez, the architect responsible for the Conservation of Monuments in the Fourth Zone (Catalonia, Valencia, and the Balearic Islands).

The role of monument conservation architect was created with the aim of supervising and inspecting all restoration projects to be carried out on listed buildings. These architects were not assigned to any particular heritage construction, but reported to the Board of Trustees for the Protection, Conservation, and Enhancement of the National Artistic Treasure (Pérez Martín, 2017).

The works carried out during this period are characterized by being emergency interventions on historical heritage within a context of very limited resources and under the precepts of the Law of May 13, 1933, (Ministerio de Instrucción Pública y Bellas Artes, 1933) on the protection of the treasure (in force until 1985) which ‘prohibited any attempt to reconstruct monuments, seeking by all technical means to conserve and consolidate them, limiting restoration to what was absolutely essential.’

In this context, the interventions planned by Alejandro Ferrant had a very small budget, which was allocated annually and was used each time in small portions of roofs, terraces and vaults that require urgent intervention due to the risk of collapse (Ferrant Vázquez, 1941; Ferrant Vázquez, 1946). The study of the projects shows how the interventions become larger in scale, more invasive, and with a higher budget available.

This analysis makes it possible to identify and map the interventions carried out, such as repairs, replacements, demolitions, reconstructions and shoring. From the first interventions, in which some of the roof trusses of the church were repaired with wood, to the construction of the new floors of the terraces of the university cloister with reinforced concrete beams and hollow brick vaults. It is also important to note that some of the proposals carried out to address damp in walls and floors had to be reversed in future interventions, already in the democratic period, as they are proving to be counterproductive and harmful.

This research has been made possible thanks to the donation of the architect's personal archive to the ‘Biblioteca Valenciana Nicolau Primitiu’ Library, allowing scholars and researchers to access it.

## References

- Ferrant Vázquez, A., 1941. “Proyecto de obras de reparación en la iglesia del convento de Santo Domingo” Accessed May 2024. Arxiu Antonio Ferrant Vázquez. Reference AAFV 378 Archivo Biblioteca Valenciana Nicolau Primitiu (BVNP), Valencia, Spain
- Ferrant Vázquez, A., 1946. “Obras de reconstrucción de bóvedas, cubiertas y terrazas del Convento” Accessed May 2024. Arxiu Antonio Ferrant Vázquez. Reference AAFV 379 Archivo Biblioteca Valenciana Nicolau Primitiu (BVNP), Valencia, Spain
- Jefatura del Estado. Ley 16/1985, de 25 de junio, del Patrimonio Histórico Español. BOE núm. 155, de 29/06/1985 <https://www.boe.es/eli/es/l/1985/06/25/16/con>
- Ministerio de Instrucción Pública y Bellas Artes, 1931. “Declaración de Monumentos histórico-artísticos pertenecientes al Tesoro Artístico Nacional” BOE, Gaceta 4 de junio de 1931. N° 155. <https://www.boe.es/datos/pdfs/BOE//1931/155/A01181-01185.pdf>
- Ministerio de Instrucción Pública y Bellas Artes, 1933, “Ley del 13 de mayo relativa al Patrimonio Artístico Nacional”. BOE, Gaceta de Madrid número 145 de 25 de mayo de 1933. <https://www.boe.es/datos/pdfs/BOE//1933/145/A01393-01399.pdf>
- Pérez Martínez, J.L., Rodríguez Sánchez, A., Arbaiza Blanco-Soler, S., 2017. Los arquitectos conservadores de zona. Anales de Edificación. Vol.3, nº3, 41-54 (2017) DOI: 10.20868/ade.2017.3677
- Sánchez Portas, J. (2003). “El Patriarca Loazes y el Colegio Santo Domingo de Orihuela”. Caja Rural Central. ISBN 84-930977-1-3, 191 p. <https://rua.ua.es/dspace/handle/10045/110067>

# ASSESSMENT OF THE METHODOLOGY TO EVALUATE THE INDOOR AIR QUALITY AT SCHOOLS: LIME4HEALTH PROJECT

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**Keywords:** Sustainability, IAQ, Schools, Methodology, Health

## Abstract

Air quality is one of the most concerning issues in the European Union. According to the European Environment Agency (EEA) over 182,000 deaths were attributable to exposure to air pollution in UE in 2023 (EEA, 2025). Since, 95% of the European cities are exposed to limits over the WHO levels, air quality has clear consequences that go far beyond deaths and involve a succession of different types of diseases or even labour absenteeism among others. Then, air quality defines the population health but also economic development of the countries, their social wellbeing and cultural preservation. In spite of the advanced performed in the last decades in terms of reduction of the air pollution, it is necessary to move forward more quickly given the devastating effects that this issue has on society as a whole.

Among the different groups of population, children under twelve years old is one of the most vulnerable. Their un-developed respiratory system and their physical constitution makes them specially susceptible of suffering diseases that could be preserved along their whole life (Pérez-Moneo et al, 2025, p.2). In spite of its incidence, there is scarce information about the levels of pollutants at which the children are exposed.

On the other hand, the complexity of the issue related to the air quality mandatorily requires an interdisciplinary and holistic approach. From this point of view, it is important that, at least, urbanist, architects, physicians, chemist, statistics, biologist, aerobiologist, epidemiologist and doctors, all together, work for its global comprehension. At the same time, solutions must be based on analysis and researches that discard or recommend them and not by trial and error that many time is applied.

Based on this, in this paper, a new methodology developed by the Lime4Health project (PID2021-123023OA-I00) is presented. In this project, the combination of different disciplines together with the combination of qualitative and quantitative techniques had been started-up in four primary schools located in Madrid region. A preliminary evaluation of the state of the art of the schools was performed followed by two types of interventions: modification of the indoor paintings as well as user's habits. Both of them had been evaluated from the reduction of the biological and abiotic pollutants and by the health perception of the users. Findings show the high potential on reduction of pollutants and improvement of children health if a global action is considered.

## References

- EEA (2025). Harm to human health from air pollution in Europe: burden of disease status, 2025. Available at: <https://www.eea.europa.eu/en/analysis/publications/harm-to-human-health-from-air-pollution-burden-of-disease-status-2025?activeTab=44013774-f1e9-4e76-8819-7a9184bbe4a>
- Pérez-Moneo, B.; Aparicio Rodrigo, M.; Redondas Marrero, M.D.; Sabariego Moreno, K.; Barbero-Barrera, M.M. (2025). Descripción de la calidad del aire y características ambientales en aulas de primaria de la Comunidad de Madrid. *Anales de Pediatría*: 503792.

# INTEGRATION OF GEOGRAPHICAL INFORMATION SYSTEMS (GIS) FOR THE SAFEGUARDING OF CULTURAL HERITAGE: ‘DINAMAPP’, AN INNOVATIVE TOOL FOR DYNAMIC PROTECTION AGAINST EMERGING THREATS

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**Keywords:** *Historic city centres; Historic Urban Landscape; Overtourism; Touristification; Seville*

## Abstract

This paper presents one of the primary outcomes of the DINAMO Project, which aims to design an innovative protocol for the formulation and revision of Special Protection Plans (SPP) in historic city centres, underpinned by the Recommendation on the Historic Urban Landscape (HUL) (UNESCO, 2011). The methodology is based on integrating the local community into heritage valuation and identifying current and emerging threats, while accounting for the contemporary economic, environmental, and cultural needs of society.

DINAMO is situated within two evolving processes affecting both society and cultural heritage. Firstly, the concept of heritage is a shifting cultural construct requiring continuous redefinition and the inclusion of new actors in its identification—a notion that now stands substantially apart from the theoretical frameworks that shaped existing tutelary tools. Secondly, current socio-economic and environmental realities present a set of threats to cultural heritage that are unprecedented in either nature or scale. Exponential gentrification is leading to the abandonment of historic centres by their inhabitants (Díaz-Parra & Jover-Báez, 2022). Overtourism exacerbates and accelerates this phenomenon to socially and physically dramatic levels (Sánchez-Montañés et al., 2023). Furthermore, urban climate change, characterized by increasingly hostile scenarios and rising pollution, challenges the viability of the liveable city, while architectural obsolescence hinders the settlement of diverse family units. This landscape reveals outdated protection tools, the exclusion of the community from decision-making, and a lack of a comprehensive vision. Historic city heritage is frequently managed as a collection of static objects rather than a complex urban reality inhabited by a changing society and threatened by highly dynamic phenomena.

These conditions are prevalent in our historic centres, which currently serve as the primary attraction for urban tourism (Herruzo-Domínguez et al. 2023). A salient example is the city of Seville, one of Spain’s most visited cities due to its heritage significance. This status, coupled with municipal policies focused on tourism promotion, has led to a state of overtourism (Romero-Ojeda et al., 2025). Consequently, there is a paradoxical reduction in both liveability and the destination’s own appeal, reflected in impacts on architecture, urban planning, and heritage, alongside socio-economic phenomena such as the loss of the resident population (Romero-Ojeda & Sánchez-Montañés, 2023).

In response to this scenario, DINAMO incorporates a mechanism for the permanent updating of heritage threats: ‘DinaMAPP’. This dynamic, georeferenced tool, powered by Geographical Information Systems (GIS), represents a substantial innovation compared to traditional instruments. By focusing on emerging areas of opportunity or those at high risk, it enables sustainable, inclusive, and up-to-date heritage management

based on the mapping of attributes and values, the identification of new impacts, and the integration of demographic, creative-cultural, and economic vectors.

## References

- Díaz-Parra, I., & Jover-Báez, J. (2022). Who is the city for? Overtourism, lifestyle migration and social sustainability. *Tourism Geographies*, 24(1), 9–32. <https://doi.org/10.1080/14616688.2020.1713878>
- Herruzo-Domínguez, G., Aladro-Prieto, J. M., & Rey-Pérez, J. (2023). Analysis of touristification processes in historic town centers: The city of Seville. *Architecture*, 4(1), 24–34. <https://doi.org/10.3390/architecture4010003>
- Romero-Ojeda, J. M., & Sánchez-Montañés Macías, B. (2025). 'Grafitización' vs 'turistificación': ¿Signos informales de apropiación de la ciudad o desprotección del área histórica no turística? *Pasos: Revista de Turismo y Patrimonio Cultural*, 23, 259–270. <https://doi.org/10.25145/j.pasos.2025.23.017>
- Romero-Ojeda, J. M., & Sánchez-Montañés Macías, B. (2025). 'TourGISitized': A tool for assessing the physical impacts of overtourism on heritage areas. Its application to Seville. *Journal of Cultural Heritage*, 72, 91–103. <https://doi.org/10.1016/j.culher.2024.12.021>
- Sánchez-Montañés Macías, B., Romero-Ojeda, J. M., & Castilla, M. V. (2023). The impact of overtourism on architecture and urban space in historic cities: An understudied phenomenon. *Journal of Tourism Analysis: Revista de Análisis Turístico*, 30(1). <https://doi.org/10.53596/jta.v30i1.439>
- UNESCO. (2011). Recommendation on the historic urban landscape. <https://whc.unesco.org/en/hul/>

# ON THE USE OF LARGE-SCALE PRECAST CONCRETE ELEMENTS ON SITE

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**Keywords:** *Precast, concrete, prestress, pier cap, slab*

## Abstract

Currently, given the easy availability of high-capacity auxiliary equipment, such as big mobile cranes, construction processes can be planned in which certain large concrete elements can be prefabricated on site, thereby facilitating both the quality and ease of execution of these elements.

The main requirement, in addition to the availability of high-capacity lifting equipment, is having enough space on site both for assembling the crane and for the execution of the prefabricated piece on ground.

In these cases, the design of the elements (AENOR, 2013), (AASHTO, 2024), (FIB, 2017), (Freyermouth, 1997) must focus enabling this construction process compatible by means of a very detailed and specific design of the join elements.

This presentation will show two unique cases of this methodology applied to civil engineering projects.

The first consists of the prefabrication of the pier caps of the Matadero Viaduct in Tijuana, which were constructed on site, with a total weight around 120 t, and assembled in position at a height of 40 m using cranes.

The solutions adopted for the pier caps involved the construction of a concrete shell that served as formwork on top of the pier and avoided the need for complex and very high falsework.

The second case corresponds to the bridge over the Arcelor Canal in Sagunto, where the use of falsework over the channel should be avoided and the solution had to comply with a very strict depth slab requirement due to vertical alignment of rail wail line that pass over it. Thereby, the use of conventional factory-prefabricated beams was not possible, and the decks were prefabricated entirely on site and then placed by means of the use of cranes. The total weight of the slabs was over 130 t.

The bridge is formed by three independent isostatic decks, each one for each of the three rail tracks. The deck is a prestress concrete slab of only 0.80 depth and a span length of 16.0 m.

Given the depth slab requirement, the track itself was embedded in the deck, being in consequence very important to have a very accurate geometry and to reduce execution tolerances in order for the sucess of the solution.



Fig. 1. Precast pier caps of the Matadero Viaduct in Tijuana (México).



Fig. 2. Precast slab of the Arcelor Canal Bridge in Sagunto (Spain).

## References

- AENOR “UNE EN-1992-2. Proyecto de estructuras de hormigón. Parte 2: Puentes de hormigón. Cálculo y disposiciones constructivas” (abril 2013).
- AASHTO “LFRD bridge design specification, 10th edition” (2024)
- FIB bulletin n° 82 “Precast segmental bridges. Guide to good practice” (august 2017)
- Freyermuth, Clifford L. PCI Journal “AASHTO-PCI-ASBI segmental box girder standards: a new product for grade separations and interchanges bridges” (1997)

# MECHANICAL RECOVERY OF DAMAGED CONCRETE COLUMNS THROUGH BIDIRECTIONAL CARBON FIBER CONFINEMENT

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**Keywords:** CFRP, bidirectional carbon fibers, concrete confinement, structural rehabilitation, post-failure strengthening

## Abstract

The rehabilitation of damaged concrete structures represents a major challenge in contemporary structural engineering. Among the most widely used strengthening techniques are confinement systems based on carbon fiber reinforced polymers (CFRP). However, the mechanical behavior of concrete elements strengthened after experiencing structural failure remains insufficiently studied. (Alhassan, M. A. 2019); (Xu, Y., 2019)

This research investigates the effectiveness of bidirectional carbon fiber fabrics for the mechanical recovery of concrete specimens previously subjected to compressive failure. The experimental program consisted of 48 cylindrical concrete specimens (100 × 200 mm) initially tested in compression until failure and classified according to their initial compressive strength into two groups: Type I stresses (>15 N/mm<sup>2</sup>) and Type II stresses (<15 N/mm<sup>2</sup>), the latter being below the minimum value recommended by manufacturers. Additionally, half of the specimens incorporated 3 kg/m<sup>3</sup> of polypropylene fibers in order to evaluate their influence on post-reinforcement behavior. (Gómez Prieto, T. 2020)

After the initial failure tests, the specimens were confined using high-strength carbon fiber fabrics with bidirectional morphology (BI-230 and BI-360) and, for comparison purposes, unidirectional fabrics. The reinforced specimens were subsequently tested again under compression to evaluate their mechanical response. (Gómez Prieto, T. 2020)

The results indicate that CFRP confinement is a highly effective strengthening technique, achieving strength increases of up to 250% in low-strength specimens. Furthermore, increasing the fiber grammage produced additional improvements in compressive strength between 12% and 17%. In terms of ductility, bidirectional reinforcement significantly increased the strain energy density, reaching values up to 30 times higher than those of the original specimens. (Gómez Prieto, T. 2020)

Finally, the combination of external CFRP confinement and internal polypropylene fibers improved the cohesion of the concrete core, transforming the failure mode from explosive to progressive and more ductile. These findings confirm that bidirectional carbon fiber reinforcement provides a technically viable solution for the rehabilitation of deteriorated concrete structures, even when the residual compressive strength is below 15 N/mm<sup>2</sup>.(Gómez Prieto, T. 2020)

## References

- Alhassan, M. A., Al Rousan, R. Z., & Al Shuqari, E. A. (2019). Bond–slip behavior between fiber reinforced concrete and CFRP composites. *Ain Shams Engineering Journal*, 10(2), 359–367. <https://doi.org/10.1016/j.asej.2019.03.001>
- Kabir, M. I., Subhani, M., Shrestha, R., & Samali, B. (2018). Experimental and theoretical analysis of severely damaged concrete beams strengthened with CFRP. *Construction and Building Materials*, 178, 161–174. <https://doi.org/10.1016/j.conbuildmat.2018.05.038>
- Xu, Y., Liu, C. Y., Chai, L., & Luo, C. C. (2019). The effect of defect size on the integrity of CFRP-confined concrete columns. *Construction and Building Materials*, 200, 521–529. <https://doi.org/10.1016/j.conbuildmat.2018.12.087>
- CNR. (2013). *CNR-DT 200 R1/2013 – Guide for the Design and Construction of Externally Bonded FRP Systems for Strengthening Existing Structures*. National Research Council, Italy.
- European Committee for Standardization. (2009). *UNE-EN 12390-3: Testing hardened concrete – Part 3: Compressive strength of test specimens*.
- European Committee for Standardization. (2006). *EN 14889-2: Fibres for concrete – Part 2: Polymer fibres – Definitions, specifications and conformity*.
- Gómez Prieto, T. (2020). *Comportamiento mecánico de estructuras de hormigón reforzadas con fibra de carbono tras el fallo estructural*. Universidad Politécnica de Madrid.

# BIOCHAR AS AN INSULATING AMENDMENT IN GREEN ROOFS: ASSESSING THE POTENTIAL FOR THERMAL IMPROVEMENT

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**Keywords:** Biochar, blue-green infrastructure (BGI), Sustainable Urban Drainage Systems (SUDS), thermal efficiency

## Abstract

Green roofs have become a widely adopted nature-based solution to mitigate urban overheating and reduce building energy demand. However, their thermal performance is strongly governed by substrate properties—particularly thermal conductivity and its dependence on moisture content (Coma et al., 2017; Lunt, 2023). In this context, this study investigates the potential of biochar (a carbon-rich material produced by biomass pyrolysis) as a substrate amendment to enhance the thermal behaviour of green roofs, with special emphasis on insulating capacity and the attenuation of thermal signals through the roof system. Beyond thermal aspects, biochar is increasingly reported to improve key substrate functions such as water retention and density reduction, which may indirectly influence hydrothermal performance (Lee et al., 2024).

The research follows an experimental approach combining material characterization with heat-transfer testing. Substrate mixtures are prepared with increasing biochar dosages, from 0% up to 50% in 5% increments, to identify trends and establish optimal addition ranges. For each mixture, a set of physico-chemical and functional properties that condition both thermal performance and practical applicability on roofs is determined: bulk density, pH, electrical conductivity, and cation exchange capacity, along with particle-size distribution, water absorption, and drying behaviour associated with evapotranspiration.

Thermal improvement is quantified through thermal conductivity measurements under steady-state and transient regimes using a TCi-type instrument, comparing dry and wet conditions as well as intermediate moisture states to capture the effect of water content. Moisture is expected to increase substrate thermal conductivity substantially, as reported for green roof media and artificial soils (Coma et al., 2017; Lunt, 2023). In parallel, laboratory thermal attenuation tests record temperature profiles and heat flux across system layers under controlled boundary conditions, enabling assessment of the amended substrate's ability to dampen temperature peaks and delay heat propagation. Complementary rainfall simulation and filtration tests are incorporated to interpret coupled water–energy dynamics, and germination assays are used to constrain biochar dosages compatible with plant establishment. This broader perspective aligns with recent green-roof-focused studies emphasizing the need to evaluate biochar effects on both substrate performance and vegetation (Nguyen et al., 2024).

Preliminary results indicate an almost linear decrease in bulk density with increasing biochar content and a clear reduction in thermal conductivity as biochar proportion rises—consistent with prior evidence that biochar can lower thermal conductivity by decreasing bulk density and increasing porosity (Zhang et al., 2013; Khaledi et al., 2023). The full experimental campaign is expected to deliver dosage recommendations aimed at maximizing thermal benefits in green roofs while preserving substrate functionality for vegetation.

## References

- Coma, J., de Gracia, A., Chàfer, M., Pérez, G., & Cabeza, L. F. (2017). Thermal characterization of different substrates under dried conditions for extensive green roofs. *Energy and Buildings*, *144*, 175–180. <https://doi.org/10.1016/j.enbuild.2017.03.031>
- Lunt, P. H., Fuller, K., Fox, M., Goodhew, S., & Murphy, T. R. (2023). Comparing the thermal conductivity of three artificial soils under differing moisture and density conditions for use in green infrastructure. *Soil Use and Management*, *39*(1), 260–269. <https://doi.org/10.1111/sum.12841>
- Nguyen, C. N., Chau, H.-W., & Muttill, N. (2024). Addition of biochar to green roof substrate to enhance plant performance: A long-term field study. *Buildings*, *14*(9), 2775. <https://doi.org/10.3390/buildings14092775>
- Nguyen, C. N., Chau, H.-W., Kumar, A., Chakraborty, A., & Muttill, N. (2024). Biochar amendment in green roof substrate: A comprehensive review of the benefits, performance, and challenges. *Applied Sciences*, *14*(16), 7421. <https://doi.org/10.3390/app14167421>
- Usowicz, B., Lipiec, J., Łukowski, M., Marczewski, W., & Usowicz, J. (2016). The effect of biochar application on thermal properties and albedo of loess soil under grassland and fallow. *Soil and Tillage Research*, *164*, 45–51. <https://doi.org/10.1016/j.still.2016.03.009>
- Zhang, Q., Wang, Y., Wu, Y., Wang, X., Du, Z., Liu, X., & Song, J. (2013). Effects of biochar amendment on soil thermal conductivity, reflectance, and temperature. *Soil Science Society of America Journal*, *77*(5), 1478–1487. <https://doi.org/10.2136/sssaj2012.0180>

# DEVELOPMENT OF A MODULAR PANEL PRINTED IN 3D WITH HIGH ENERGY EFFICIENCY POLYMERS AND INSULATORS FOR ARCHITECTURAL ENCLOSURES.

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**Keywords:** Panel; Thermal efficiency; Cotton textile fiber; Rice husk; 3D printing; Thermoplastic.

## Abstract

This research develops a constructive panel system for architectural envelope applications, using recyclable thermoplastics manufactured through 3D printing and integrating bio-based thermal insulation materials. The primary objective was to design, fabricate, and evaluate the thermal and mechanical performance of prototype panels composed of PLA, PETG, PCTG, and PETG FP (a PETG variant containing halogen- and red phosphorus-based flame-retardant additives), combined with recycled insulators such as cotton textile fiber and loose rice husk.

The panel design incorporates an internal structure based on hyperbolic paraboloid geometries, enabling efficient mechanical load distribution and passive thermal flow control. The additive manufacturing process allowed for the creation of monolithic panels without metallic elements or external connectors, thus eliminating thermal bridges and facilitating the integration of the insulation within a modular, airtight, and demountable system.

Mechanical performance was assessed through three-point bending tests according to the UNE-EN ISO 178 standard. Thermal conductivity tests were conducted following UNE-EN 12667, using a steady-state heat flow method within a sealed and controlled chamber. Additionally, numerical simulations were performed: thermal simulations were carried out using the SimScale platform, while mechanical simulations were conducted in ANSYS Mechanical, allowing the design to be validated under simulated operating conditions. The thermal tests demonstrated that both bio-insulators offer good thermal resistance, with rice husk showing superior performance (minimum  $\lambda$  of 0.032 W/m·K and maximum R of 2.27 m<sup>2</sup>·K/W). Cotton textile fiber also performed consistently ( $\lambda$  between 0.037 and 0.069 W/m·K), presenting a viable alternative particularly when reduced panel weight is desired.

In terms of structural behavior, PLA achieved the highest flexural strength (1.62 kN), followed by PETG and PCTG. PETG FP exhibited the lowest resistance (0.47 kN), which may be attributed to the influence of flame-retardant additives on the base polymer's stiffness. Thermal simulations confirmed a highly uniform temperature distribution, with differences below 0.01 °C between the interior and exterior surfaces of the panel, validating the design's effectiveness in minimizing thermal bridging.

Overall, the results confirm that the proposed panel system is technically and thermally feasible. The synergy between additive manufacturing, structurally optimized geometries, and the use of recycled bio-based materials contributes to the development of lightweight, modular, and environmentally responsible construction components for sustainable building envelopes.

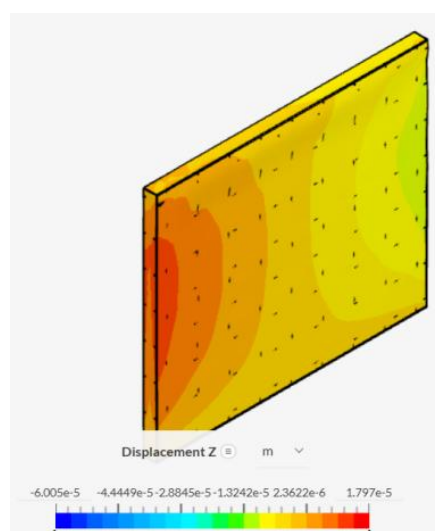


Fig. 1. Panel subjected to displacement in Z analyzed by Sim Scale and interpreted by Para View for mechanical analysis in digital twins.

TABLE I  
RESULTS OBTAINED FROM DIGITAL ANALYSIS AND IN LABORATORIES.

| PROTOTIPES         | Thermal testing |           | Mechanical testing |                | Mechanical testing- Compression |  |                       | Thermal testing                  |
|--------------------|-----------------|-----------|--------------------|----------------|---------------------------------|--|-----------------------|----------------------------------|
|                    | U               | $\lambda$ | Strength [kN]      | Panel mass [g] | Displacement total [m]          | Von Mises' effort [Pa (N/m <sup>2</sup> )] | Total deformation [m] | Thermal difference in panel [°C] |
| <b>PLA-TE-1</b>    | 0.633           | 0.069     |                    |                |                                 |  |                       |                                  |
| <b>PLA-TE-2</b>    | 0.569           | 0.049     |                    |                |                                 |  |                       |                                  |
| <b>PLA-TE-3</b>    | 0.561           | 0.037     | 1.62               | 457.9          | $1,6 \times 10^{-4}$            | $4,3 \times 10^6$                          | $1,1 \times 10^{-3}$  | 0,01°                            |
| <b>PLA-CA-1</b>    | 0.44            | 0.032     |                    |                |                                 |  |                       |                                  |
| <b>PLA-CA-2</b>    | 0.547           | 0.048     |                    |                |                                 |  |                       |                                  |
| <b>PLA-CA-3</b>    | 0.475           | 0.038     |                    |                |                                 |  |                       |                                  |
| <b>PETG-TE-3</b>   |                 |           | 1.09               | 418.5          |                                 |  |                       |                                  |
| <b>PETGFP-TE-3</b> |                 |           | 0.47               | 428.4          |                                 |  |                       |                                  |
| <b>PCTG-TE-3</b>   |                 |           | 0.97               | 431.1          |                                 |  |                       |                                  |

EVALUATING MOISTURE IN GYPSUM WITH A CONTACT

# FACTORS INFLUENCING STUDENTS TO CHOOSE BUILDING ENGINEERING. A PRELIMINARY STUDY WITH A GENDER PERSPECTIVE

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**Keywords:** *Building Engineering, Career choice, Gender perspective, Students.*

## Abstract

According to the General Council of the Building Engineering professional body, the percentage of female members increased from 6.58% in 1990 to 20.8% in 2018. After several years of consistent female participation, this figure reached 21% in 2024. Furthermore, of the 55 presidencies in Spain, four were held by women in 2018, increasing to eight in 2025. These figures show a positive trend in the representation of women in technical roles and their increased access to a historically male-dominated profession. In addition, their presence in building engineering schools has grown significantly in recent decades, representing on average almost 50% of the student body in Spain in 2024. Hence, an increasing number of women are becoming interested in and qualified to work in the sector.

One of the most difficult and important decisions a person makes in life is choosing a university degree, as it can have a significant impact on the personal and professional development, as well as requiring great effort and dedication during these formative years. This decision involves taking into account numerous factors that influence the choice. However, at present there is a gap in the literature regarding the formal and informal reasons that motivate young people to choose the Building Engineering Bachelor Degree.

Understanding what influences students to choose this degree could help universities and the construction industry design more effective strategies to attract and retain young people. Following a review of international literature focusing on reasons for choosing university degrees, a questionnaire has been designed to gather information on new students' socio-economic profiles, academic determinants, satisfaction with chosen studies and factors that influenced their choice. In order to validate this questionnaire, an initial pilot study has been carried out in the schools of Seville and Valencia. A total of 101 new enrolled students in the first year have completed the online survey (57,4% women and 42,6% men). The data collected will be processed and analyzed using the SPSS software tool with the aim of answering to the main research question: What are the gender differences in the factors influencing their choice of studying Building Engineering?

# FUZZY-LOGIC ASSESSMENT OF VERTICAL PV SHADING RETROFITS

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**Keywords:** building-integrated technology; photovoltaics; building retrofit; fuzzy logic

## Abstract

Window openings on exterior walls often rely on shading elements such as louvers, blinds, brise-soleil, or semi-opaque screens to balance daylight admission, glare control, and solar protection. Replacing these passive components with vertical, semi-transparent photovoltaic (PV) shading elements adds an additional function: electricity generation in envelope areas that typically do not contribute to on-site production. In practice, such systems combine PV cells with a translucent backing or inter-cell spacing so that part of the light is transmitted while useful shading is still provided. This dual role is attractive for retrofit projects (Ardente et al., 2011) where roof space is limited or reserved for other services, and where vertical exterior walls offer large, architecturally accessible surfaces. Figure 1 shows examples of vertical semi-transparent PV shading elements installed at a window opening, illustrating how the module geometry can simultaneously provide partial shading and allow controlled daylight passage (Mancera et. al, 2022; Rengel Gálvez et. al, 2025). The main limitation is performance uncertainty. Vertical PV rarely operates at the optimum tilt for annual energy yield, and the final outcome depends strongly on orientation constraints imposed by the building, local shading patterns, and practical maintenance conditions. For this reason, early-stage decision support is needed to screen feasibility before committing to detailed design, simulation, and procurement.



Fig. 1. Vertical PV integrated for building integration. INTA and University of Huelva.

This contribution proposes a compact fuzzy-logic decision model that translates three practical parameters into a single suitability index for vertical PV shading elements. The model is intentionally lightweight so it can be used during preliminary design and retrofit appraisal, when only partial information is available and trade-offs must be handled transparently. The fuzzy system is defined with three inputs: (i) installation height, (ii) orientation of the PV, and (iii) cost level. Height is introduced as a proxy for robustness factors that affect

long-term performance and operability, including exposure to accidental impacts, vulnerability to splash water or minor flooding at ground level, likelihood of partial obstruction, and the tendency to accumulate localized dirt. Orientation represents the unavoidable geometric constraint of the building: south-facing walls are typically preferred, while deviations progressively reduce direct irradiance availability, especially in seasons with low solar altitude. Cost aggregates both investment and expected maintenance burden, capturing differences among PV technologies, mounting complexity, access requirements, and replacement strategy.

A Mamdani-type inference structure is implemented. The rule base reflects a conservative retrofit rationale: high suitability is assigned when orientation is favorable and height supports durability, while cost penalizes solutions whose operational complexity is likely to offset expected gains. This aligns with recent developments on PV-integrated shading devices on building exterior walls and with the broader use of fuzzy decision frameworks to handle multi-criteria PV choices under uncertainty (García-Chica et al.). Figure 2 summarizes the fuzzy-logic architecture.

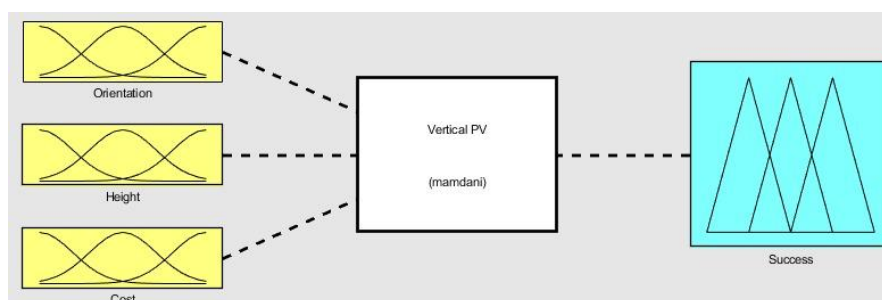


Fig. 2. Fuzzy-logic system designed.

## References

- Ardente, F., Beccali, M., Cellura, M., & Mistretta, M. (2011). Energy and environmental benefits in public buildings as a result of retrofit actions. *Renewable and Sustainable Energy Reviews*, 15(1), 460-470.
- García-Chica, A., Chica, R. M., Caparros-Mancera, J. J., Giménez-Fernández, A., & Torres-Moreno, J. L. (2025). Future of smart greenhouses in Almería: Farmers' perspectives and fuzzy logic-based evaluation. *Smart Agricultural Technology*, 12, 101515.
- Mancera, J. J. C., Saenz, J. L., López, E., Andújar, J. M., Manzano, F. S., Vivas, F. J., & Isorna, F. (2022). Experimental analysis of the effects of supercapacitor banks in a renewable DC microgrid. *Applied Energy*, 308, 118355.
- Rengel Gálvez, R. M., Caparrós Mancera, J. J., López González, E., Tejada Guzmán, D., & Sancho Peñate, J. M. (2025). Application of Electric Energy Storage Technologies for Small and Medium Prosumers in Smart Grids. *Processes*, 13(9), 2756.

# GRAPHIC SURVEY OF BUILDINGS. TECHNOLOGICAL EVOLUTION. VOT CHAPEL OF A CORUÑA

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**Keywords:** Topographic Survey, Total Station, Laser Scanner, GNSS

## Abstract

Topographic instrumentation has evolved by integrating into a single machine the total station, the GNSS station, and the point and image scanner, allowing the acquisition of topographic surveys with great precision and a three-dimensional visualization of the built environment. The main objective will be to compare the traditional work methodology with the possibilities offered by this technology with integrated GNSS and scanner. Starting from a building: The Vot Chapel of A Coruña (PERNAS, 2025), the positions of a total station are planned and aiming targets are placed on the facade as prominent points. Positioning is carried out with the GNSS and the facade is scanned. The topographic surveys conducted with both machines are initially compared at the highlighted points marked with aiming targets. Carrying out routes inside the building with georeferenced positions will show the interior survey of the building.

The analysis of the results obtained with both techniques will allow for determining the comparative accuracy, as well as proposing surveying methodologies using the new surveying technology available on the market. The new equipment available on the market is being used in public works for tunnel surveying due to its still very high acquisition cost. The lack of knowledge about the great advancement of this equipment among construction professionals is the biggest obstacle preventing its widespread use in large construction projects.

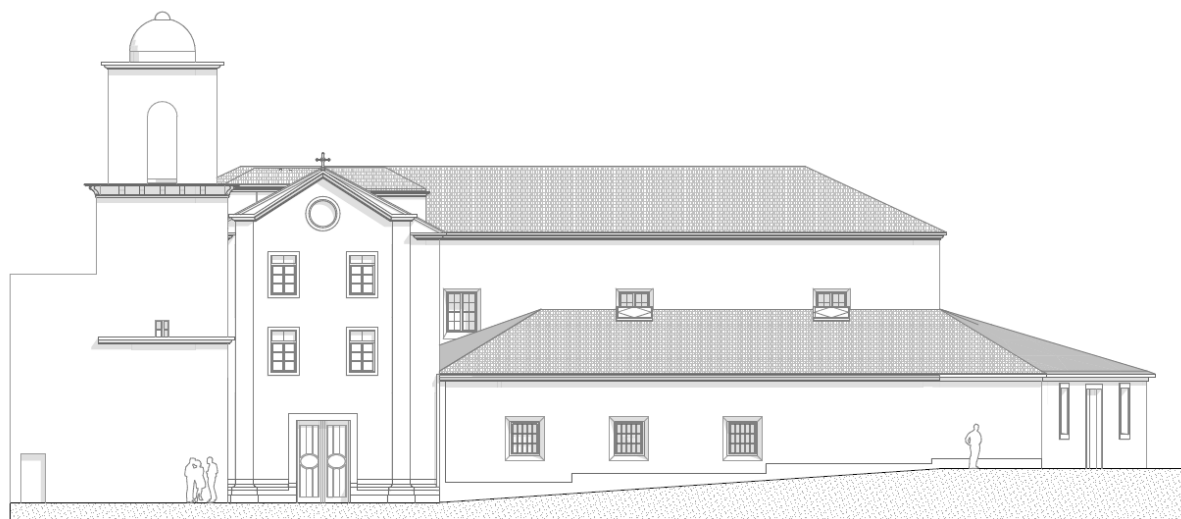


Fig. 1. Restoration of the roof of the Chapel of La Vot in A Coruña. West elevation. Author: Antonio Pernas

## References

- [1] PERNAS, 2025 Proyecto Básico y de Ejecución. Restauración de la Cubierta de la Capilla de La Vot de A Coruña; Plaza de Carlos I, A Coruña.Doc nº2 Planos. Alzado Oeste

# MULTI-CRITERIA FRAMEWORK FOR PCM SELECTION IN ENERGY-EFFICIENT BUILDINGS ACROSS CLIMATE ZONES

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**Keywords:** energy efficiency, thermal comfort, phase change materials, multi-criteria decision-making, sustainable building design

## Abstract

The building sector accounts for approximately 40% of total energy consumption and 36% of CO<sub>2</sub> emissions in the European Union, making it a critical area for achieving sustainability targets [1]. Passive strategies that enhance thermal comfort and reduce energy demand are essential to meet these goals. Among these strategies, Phase Change Materials (PCMs) stand out for their ability to store and release thermal energy during phase transitions, helping stabilize indoor temperatures and reduce HVAC loads [2, 3].

This paper introduces an innovative climate-responsive methodology for PCM selection, based on Multi-Criteria Decision-Making (MCDM) techniques [4, 5]. The framework combines the Analytic Hierarchy Process (AHP) for weighting key thermophysical properties—melting point, latent heat of fusion, volumetric latent heat, thermal conductivity, specific heat capacity, and density—with five MCDM methods: COPRAS, VIKOR, TOPSIS, MOORA, and PROMETHEE II. Sixteen PCM alternatives were evaluated for different representative climates zones.

Results demonstrate strong convergence across methods (Spearman  $\rho > 0.99$ ), confirming the robustness of the approach. For temperate and subtropical climates, n-Heptadecane (C17) consistently ranked as the most suitable PCM, while n-Octadecane (C18) and hydrated salts such as CaCl<sub>2</sub>·6H<sub>2</sub>O and Na<sub>2</sub>CO<sub>3</sub>·10H<sub>2</sub>O were optimal for tropical zones due to their high volumetric energy storage (up to 381 MJ·m<sup>-3</sup>) and latent heat (up to 254 kJ·kg<sup>-1</sup>). These materials enable significant reductions in HVAC energy demand and improve indoor thermal stability, supporting EU and DOE targets for 40–50% reductions in building energy use.

The proposed framework introduces three key innovations:

1. Explicit mapping of PCM melting points to climate-specific comfort bands, based on EN 16798-1 and ASHRAE 55 standards.
2. Integration of volumetric latent heat as a decisive criterion for building applications.
3. Cross-method validation and sensitivity analysis, ensuring ranking stability under weight perturbations.

This methodology provides architects, engineers, and designers with a practical, adaptable tool for PCM selection in both new and retrofit projects. Beyond building envelopes, the approach can be extended to other climate-sensitive applications such as district thermal storage and renewable energy systems. By enabling

informed material selection, the framework contributes to the development of sustainable, resilient buildings aligned with global decarbonization goals.

## References

- Mehling, H. (2023). Review and analysis of existing approaches to investigate property degradation of phase change materials and development of a new systematic approach. *Applied Sciences*, 13(15), 8682. <https://doi.org/10.3390/app13158682>
- Parameshwaran, R., Harikrishnan, S., & Kalaiselvam, S. (2010). Energy efficient PCM-based variable air volume air conditioning system for modern buildings. *Energy and Buildings*, 42(9), 1353–1360. <https://doi.org/10.1016/j.enbuild.2010.03.004>
- Sun, X., Zhang, Q., Medina, M. A., & Lee, K. O. (2014). Energy and economic analysis of a building enclosure outfitted with a phase change material board (PCMB). *Energy Conversion and Management*, 83, 73–78. <https://doi.org/10.1016/j.enconman.2014.03.035>
- Kumar, A., & Singh, R. (2022). A hybrid decision-making method for the selection of a phase change material based on experimental data. *ASME Journal of Thermal Science and Engineering Applications*, 12(4), 041020. <https://doi.org/10.1115/1.4054495>
- Taherdoost, H., & Madanchian, M. (2023). Multi-criteria decision making (MCDM) methods and concepts. *Encyclopedia*, 3(1), 77–87. <https://doi.org/10.3390/encyclopedia3010006>

# SUSTAINABILITY CALCULATION SOFTWARE FOR BIM MODELS POWERED BY ARTIFICIAL INTELLIGENCE

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**Keywords:** *Sustainability, Artificial Intelligence (AI), Digital Twin (DTw), Industry Foundation Classes (IFC), Building Information Modelling (BIM), Large Language Model (LLM), web platform*

## Abstract

In recent years the carbon footprint has been growing by leaps and bounds and the Architecture, Engineering, Construction, and Operations (AECO) sector remains one of the largest contributors (1) (2) being the construction sector, according to the Global Alliance for Buildings and Construction, the responsible of 34 per cent of total emissions and the same percentage of global energy demand (3). Thus, alternatives have been sought to respond to this problem. Building Information Modeling (BIM) methodology is expected to be one driver that can gradually help reducing the impact in terms of sustainability (4) (5) (6). However, the software used in various aspects of this methodology lacks of interoperability (7). This is where the Industry Foundation Classes (IFC) format comes in, allowing different software programs to export a common file type (8). Although IFC is known for this interoperability, it does present certain problems. The final information when a file is exported to IFC from one software program to another, may not be the same, creating important interoperability issues.

With the aim of unifying sustainability concepts in the quest to reduce interoperability challenges, it is proposed an study stems from the need for a tool that simplifies the calculation of the Structure Contributions Sustainability Index in the Spanish Structural Concrete Code 2023 (ICES) (9), from an IFC file, as well as the 3D visualization of the IFC on the platform with open-source libraries, which eliminates dependence on commercial companies. Because of the aforementioned interoperability problem, several algorithms were implemented into the platform. Thanks to them, the information in the IFC files can be extracted according to the data requirements for calculating the ICES. Additionally, a system for classifying structural according to ICES necessities has been developed by using Artificial Intelligence (AI), based on the implementation of a Large Language Model (LLM) in the platform's Backend, which is proposed to perform this classification based on user queries. The development of this software, based on databases, Frontend, Backend and AI, provide a Digital Twin (DTw) (10) for sustainability management. The coding is based on open standards, providing freedom and no dependency on specific software. This DTW opens the door to the development of new applications on it (11), such as Digital Product Passport (DPP) (12), for tracking the carbon footprint of the use of structural materials.

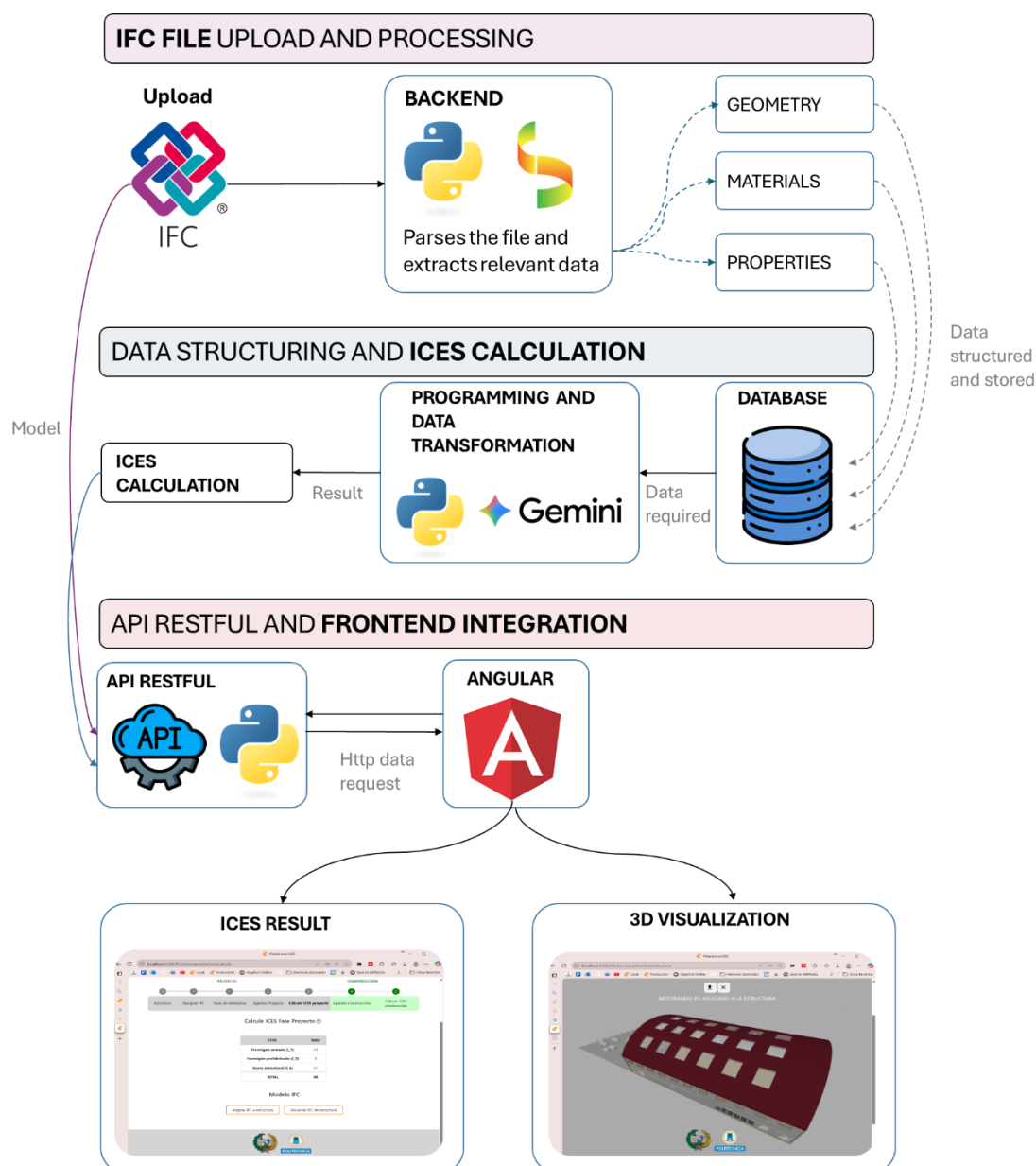


Figure 1. Results to obtain ICES calculation and 3D visualization from an IFC file.

## References

- Amudjie J, Chan APC, Darko A, Debrah C, Agyekum K. CircularBIM: Future needs at the convergence of building information modelling and the circular economy. *Automation in Construction*. 2025; 176: 106250.
- Haghighat S, Sadeh H. Parametric design of an automated kinetic building façade using BIM: A case study perspective. *Journal of Building Engineering*. 2023; 73: 106800.
- GlobalABC. *Global Status Report for Buildings and Construction 2024/25.*; 2025.
- V D, Chowdary BH, Sunny K, Gupta K, Kumar VRP. Integrating A BIM-Based Approach to the Planning, Analysis, and Sustainable Design for a Modern Hospital Building. *Procedia Structural Integrity*. 2025; 70: 493-500.
- Soust-Verdaguer B, Gutiérrez Moreno JA, Cagigas D, Hoxha E, Llatas C. Supporting sustainability assessment of building element materials using a BIM-plugin for multi-criteria decision-making. *Journal of Building Engineering*. 2024; 97: 110818.
- Yuan H, Huang B, Wang M, Tang Y, Mao J, Xiong L. BIM-enabled lifecycle carbon emission management integrating multi-physical field steady-state methods during operation. *Automation in Construction*. 2026; 181: 106683.
- Sandhu HK, Ashe W, Crowder N, Gupta A, Han K, Bodda SS. Automation in digital analysis solutions for nuclear design-construction integration using BIM-FEM interoperability. *International Journal of Pressure Vessels and Piping*. 2026; 219: 105661.
- buildingSMART S. IFC. 2024 April 18..
- BOE BOE. Real Decreto 470/2021, de 29 de junio, por el que se aprueba el Código Estructural. 2021 June 29..
- Aragón A, Arquier M, Tokdemir OB, Enfedaque A, Alberti MG, Lieval F, et al. Seeking a Definition of Digital Twins for Construction and Infrastructure Management. *Applied Sciences*. 2025; 15: 1557.
- Pavón RM, Galao O, Pardo MA, Alberti MG. Digital Twin development and implementation for the management of irrigation networks. *Expert Systems with Applications*. 2026; 297: 129330.
- Aragón A, Alberti MG. Limitations of machine-interpretability of digital EPDs used for a BIM-based sustainability assessment of construction assets. *Journal of Building Engineering*. 2024; 96: 110418.

# PHOTOCATALYTIC PAINTS AS A SUSTAINABLE SOLUTION FOR TEMPORARY CONSTRUCTION ELEMENTS: EXPERIMENTAL STUDY ON RASCHEL MESH

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**Keywords:** *Paints; photocatalytic; sustainability; raschel mesh.*

## Abstract

Exterior photocatalytic paints constitute a type of advanced functional coatings whose development is framed within current strategies aimed at sustainability, improvement of air quality, and reduction of maintenance costs in urban environments. These systems incorporate photocatalytic materials, primarily titanium dioxide (TiO<sub>2</sub>), capable of activating chemical oxidation reactions when exposed to ultraviolet radiation present in sunlight, enabling passive, continuous operation without additional energy consumption.

The operating principle of these paints is based on the phenomenon of photocatalysis. Under the action of UV radiation, TiO<sub>2</sub> becomes energetically activated and generates highly reactive species, such as hydroxyl radicals and superoxides. These species induce oxidation reactions that lead to the degradation of atmospheric pollutants, such as nitrogen oxides (NO<sub>x</sub>) and volatile organic compounds (VOCs), as well as the elimination of microorganisms, algae, and organic dirt deposited on surfaces. In addition, these coatings confer a hydrophilic character to the substrates, promoting a self-cleaning effect through the action of rainwater, which facilitates the removal of degraded residues and reduces the adhesion of new contaminant particles.

Thanks to these properties, photocatalytic paints offer a wide range of applications in outdoor spaces, notably their use on building façades and enclosures, sidewalks and urban pavements, and urban furniture such as benches, pergolas, or parasols. In all these cases, their use simultaneously contributes to improving urban air quality, maintaining the aesthetic appearance of surfaces, and extending the service life of materials.

In this context, the company Arpada decided to assess the feasibility of applying photocatalytic paints to construction fences made of Raschel-type polyethylene (PE) mesh, an element widely used in construction environments and particularly exposed to dirt and environmental degradation. To this end, an experimental plan was designed with the aim of comparing the performance of two commercial photocatalytic paints, previously selected based on their market availability and their declared effectiveness. The study included the evaluation of parameters such as adhesion to the textile substrate, self-cleaning capacity, durability under freeze–thaw cycles, capillary absorption, and fire behavior.

After the laboratory testing phase, the paint that showed the best overall performance was selected and applied in situ to the construction mesh, both in one and two coats. The results obtained confirm that the application of photocatalytic paints helps keep the mesh cleaner over time, with the two-coat application being particularly effective, and that it significantly contributes to improving the durability of the material. These findings highlight the potential of photocatalytic paints as an innovative, sustainable, and functional solution for integration into both temporary and permanent elements of the urban environment.

# SMART GLASS IN ARCHITECTURE: FUTURE PERSPECTIVES AND INNOVATION PATHWAYS

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**Keywords:** smart glass, energy efficiency, sustainable architecture, building automation, internet of things (IoT)

**Abstract** – Smart glass, with its capacity to dynamically modify optical and thermal properties in response to environmental stimuli, represents one of the most significant technological advancements shaping contemporary architectural practice. As buildings increasingly demand solutions that balance energy performance, occupant well-being, and sustainability criteria, smart glass technologies emerge as critical components capable of transforming the interaction between built environments and natural elements. By regulating the transmission of light and heat, smart glass enables architects and engineers to minimize unnecessary energy consumption while simultaneously enhancing the indoor environmental quality for occupants. These qualities position smart glass as a central innovation in future-oriented architectural design.

The primary objective of this paper is to review the current state of smart glass development, assess its performance characteristics, and analyze its potential contributions to sustainable and energy-efficient architecture. Through a theoretical and analytical examination, the study categorizes and compares different types of smart glass, including electrochromic, thermochromic, photochromic, and suspended particle devices, highlighting how each technology functions and where it can be most effectively applied. The review further demonstrates that smart glass can significantly reduce energy demands associated with heating, cooling, and artificial lighting by allowing buildings to respond adaptively to environmental variations throughout the day and across seasons. Additionally, improvements in thermal comfort, daylight management, and visual well-being for occupants are identified as consistent benefits of integrating smart glass into façade systems.

Despite these advantages, several practical challenges continue to restrict large-scale implementation. Economic constraints, such as high initial costs and variable maintenance requirements, remain barriers for many building projects. Technological limitations, including durability, switching speed, color rendering, and long-term performance, also influence adoption rates. Moreover, architectural design considerations—such as integration with existing building systems, façade compositions, and user-control strategies—require careful evaluation to ensure that smart glass functions as intended within diverse operational contexts.

Looking toward the future, the paper investigates emerging innovation pathways that hold the potential to expand the role of smart glass in next-generation architectural design. These include integration with advanced building automation systems and the Internet of Things (IoT), enabling dynamic façade operation synchronized with real-time environmental data. The incorporation of artificial intelligence and machine learning algorithms further supports automated adjustment of transparency, shading, and thermal response. Additionally, developments in materials science, nanotechnology, and intelligent architecture frameworks signal new directions for research and application. Collectively, these innovations position smart glass as a transformative element in creating responsive, energy-efficient, and sustainable buildings of the future.

# THE INTERVIEW AS A KEY INSTRUMENT FOR PSYCHOSOCIAL RISK ASSESSMENT: QUESTIONNAIRE VALIDATION AND EXPECTATION DETECTION IN THE CONSTRUCTION SECTOR

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**Keywords:** Interview, psychosocial risks, construction sector, risk management.

## Abstract

The management of psychosocial risks is a key area for improving occupational health in the construction sector, which has traditionally focused on physical and safety risks. This paper presents the results of a comprehensive psychosocial risk assessment process carried out at the company Arpada, in which the interview is given a central role as a qualitative tool to validate the results of the MentallyPro questionnaire and, above all, to give workers a voice, allowing them to express their experiences, perceptions, and expectations.

The methodology combined the administration of the MentallyPro questionnaire with semi-structured interviews conducted with different professional groups from both office and site operations. This mixed-methods approach made it possible to compare and validate the quantitative results obtained from the survey, as well as to delve deeper into the identified risk factors, revealing nuances and differences between groups that are not always visible through questionnaires alone. The interviews proved to be a key element in understanding the organization's psychosocial reality, strengthening workers' trust in the assessment process, and reinforcing the perception of a company that listens and places people at the center of its strategy.

The results show a high level of agreement between the risk factors identified through MentallyPro and those highlighted in the interviews, particularly regarding working time and pace, work-life balance, and mental workload, which were considered the most recurrent risks in both office settings and site teams. However, the qualitative analysis made it possible to contextualize these results, highlighting the influence of workload peaks, lack of planning, and dependence on external agents, as well as generational differences in the perception of work-life balance and the ability to disconnect. In this way, the interviews provided a deeper understanding of how these factors affect workers' daily lives and how they evolve over time.

In addition, the interviews facilitated the identification of other moderate-intensity risk factors, such as job content, social reward, information and transparency, and leadership style, as well as the assessment of good practices already in place. Measures such as remote work, flexible site work arrangements, intensive work schedules, training in personal competencies, and access to psychological support were widely valued, although workers expressed expectations for improvement in terms of their scope, planning, and adaptation to different professional profiles. The opportunity to express these expectations directly made it possible to identify emerging needs, such as mentoring support for younger profiles, enhanced professional recognition, and improved internal communication.

In conclusion, interviews are consolidated as an essential instrument for validating and complementing the results of the MentallyPro questionnaire, providing depth, context, and legitimacy to the psychosocial risk assessment process. The integration of quantitative and qualitative methodologies, framed within a PDCA-type continuous improvement cycle, enables not only a more accurate diagnosis but also greater worker involvement and better alignment of preventive measures. In this way, psychosocial management ceases to

be a mere formal requirement and becomes a strategic tool for well-being, sustainability, and productivity in the construction sector.

# THE NEW APPROACH FOR THE SLS CRACKING CHECK OF EC2 (2a Gen.). COMPARATIVE STUDY

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**Keywords:** *Eurocode, concrete, cracking check, steel fiber reinforced concrete*

## Abstract

The drafting of the second generation of Eurocodes is currently at a very advanced stage, with implementation planned for the end of 2027 or the beginning of 2028. On that date, both the first edition of the Eurocodes and the current Código Estructural 2021 will be cancelled, as will probably be the case for a large part of the Código Técnico de la Edificación.

As part of this revision of the Eurocodes, subcommittee SC2 has proposed a new edition of the EN1992 documents, which include all the regulations relating to the calculation and design of concrete structures.

This new document incorporates all the technical aspects that are considered that improve the previous version of the code. Specifically, new aspects of the calculation in relation to the ELU for shear, torsion and also the ELS for cracking has been adopted. This study has been focused on the new ELS crack check approach. Thereby, a comparative study has been carried out in order to know what the main difference for the designs are based on previous EC2 and in the new EC2.

The following study shows comparative results of calculations of the ELS cracking check for beam or slab sections, as well as elements subjected to direct tension such as reinforced concrete tie rods.

Special emphasis is also placed on the use of steel fibres as additional reinforcement, which contributes to reducing the characteristic crack width, an aspect that was not explicitly included in the previous document.

## References

“UNE EN-1992-1. Proyecto de estructuras de hormigón. Parte 1: Reglas generales y para la edificación”. (AENOR, abril 2013).

“EN-1992-1. Design of concrete structures. Part 1.1 General rules for buildings, bridges and civil engineering structures”. European Standrad, (November 2023)

# COMPARATIVE STRUCTURAL ANALYSIS OF REINFORCED CONCRETE FRAMES WITH RECYCLED AGGREGATE CONCRETE ACCORDING TO INTERNATIONAL DESIGN CODES

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**Keywords:** *Recycled aggregate concrete; reinforced concrete frames; structural stiffness; international design codes; seismic design.*

## Abstract

The use of recycled aggregate concrete (RAC) has emerged as a sustainable alternative to reduce the consumption of natural aggregates in structural applications. However, RAC typically presents modified mechanical properties, such as reduced elastic modulus and increased deformability, that may influence the global response and stiffness of reinforced concrete (RC) structures. While existing research has explored the behavior of individual RAC elements, comprehensive studies on full RC frame structures designed under different international codes remain limited.

This study analyzes the structural performance of a six-story four-span reinforced concrete frame designed using both conventional concrete and RAC. For RAC, mechanical properties, compressive strength, elastic modulus, and density, were adopted from established experimental studies (González-Fonteboa & Martínez-Abella, 2008; Rahal, 2007; Xiao et al., 2005). The frame was evaluated under three structural design standards: The Spanish Código Estructural (CE 2001), the Chilean NCh 430/NCh 433, and ACI 318. The methodology includes geometric definition, application of gravitational and seismic actions according to each code and structural modeling using CYPE 3D.

The comparative analysis examines differences in fundamental period, seismic demand, lateral drift and required reinforcement when RAC is used instead of conventional concrete. The results highlight the influence of RAC mechanical properties on the structural response and how each design standard addresses the variations. This work contributes to the development of criteria for the safe and efficient use of recycled materials in reinforced concrete structures.

## References

- [2] González-Fonteboa, B., & Martínez-Abella, F. (2008). Concretes with aggregates from demolition waste and silica fume. Materials and mechanical properties. *Building and Environment*, 43(4), 429-437. <https://doi.org/10.1016/j.buildenv.2007.01.008>
- [3] Rahal, K. (2007). Mechanical properties of concrete with recycled coarse aggregate. *Building and Environment*, 42(1), 407-415. <https://doi.org/10.1016/j.buildenv.2005.07.033>
- [4] Xiao, J., Li, J., & Zhang, Ch. (2005). Mechanical properties of recycled aggregate concrete under uniaxial loading. *Cement and Concrete Research*, 35(6), 1187-1194. <https://doi.org/10.1016/j.cemconres.2004.09.020>

# TOWARD A HOLISTIC–FRACTAL BIM MODEL: REINTERPRETING THE 8D, 9D, AND 10D DIMENSIONS BEYOND THE LINEAR PARADIGM

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**Keywords:** *Fractal BIM, BIM 8D-10D Reinterpretation, Construction Metaverse, Blockchain & Web3, Quantum Simulation.*

## Abstract

In the Architecture, Engineering, and Construction (AECO) domain, the “new dimensions” of Building Information Modeling (BIM)—8D, 9D, and 10D—are increasingly framed as Safety, Lean Construction, and Industrialization, respectively (Ershadi y otros, 2021). This sequential, deterministic approach treats them as layers added onto the BIM model, reinforcing a linear view of how project information evolves (Herrera y otros, 2017). This paper challenges that interpretation: forcing a linear hierarchy onto these dimensions constitutes a conceptual regression—metaphorically akin to insisting the Earth is flat and the Sun revolves around it—and instead proposes a holistic-fractal paradigm aligned with how nature organizes growth and, by extension, how the universe operates.

Drawing on historical, philosophical, scientific, and technological evidence, the paper dismantles the notion that 8D–10D should be understood as a simple linear progression. In this new view, Safety, Lean, and Industrialization are not “added dimensions” far from the origin, but intrinsic qualities that must be integrated from the earliest stages (1D–7D) of any BIM project (Espiniza & Eloisa, 2019). Accordingly, an interconnected multidimensional framework for 1D–7D is proposed, and the leap to higher dimensions is redefined: 8D represents a shift toward new digital realities (Web3, metaverse, blockchain) that expand the construction experience beyond the five physical senses, enabling traceability, distributed trust, and new forms of interaction with the project (Bucher y otros, 2024); 9D incorporates quantum computing to simulate “possible universes” within construction processes (Saros, 2025), radically expanding cognition and creativity by exploring scenarios that a classical approach cannot model with the same depth (Aguilera Zavaleta, 2025); and 10D is conceived as a transcendental horizon, attainable through the conscious and integrated mastery of the previous nine dimensions, understood as a convergence of awareness, decision, and material reality beyond our usual sensory reading.

The document clearly establishes that the linear-deterministic model and the holistic-fractal approach proposed here cannot coexist; they are mutually exclusive paradigms. To support this new understanding, the paper provides a formal structure including visual comparisons, theoretical discussion, and bibliographic support. Philosophical and scientific sources are integrated to connect this perspective with universal patterns such as sacred geometry (the seed and flower of life) and the golden ratio, recognizing ordered growth logics—closer to Fibonacci—applicable to the operational design of construction (Camarda, 2021).

The paper also critiques the reductionism of the industry’s linear, fragmented lens—which simplifies a complex system into isolated parts—and argues for evolving toward a holistic, fractal, and “cosmic” awareness (in the sense of interconnection). Finally, the paper critiques industry reductionism and argues for evolving toward holistic, fractal, and “cosmic” awareness (as interconnection). It explains how this vision enhances Sustainability, Productivity, Innovation, and Profitability in building projects, bridging Newtonian

stability with quantum probability (Planck, Heisenberg, Schrödinger) to model nonlinear behaviors—reviving, with modern precision, the geometric and proportional inquiry pursued by Pythagoras, Kepler, Leibniz, and Einstein.

## REFERENCES

- Aguilera Zavaleta, J. (2025). Fusion de BIM e Inteligencia Artificial mediante el uso de Computadores Cuánticos. *Preprints*.
- Bucher, D., Hunhevicz, J., Soman, R., Pauwels, P., & Hall, D. (2024). De BIM a Web3: Una síntesis interpretativa crítica de los enfoques actuales y emergentes de gestión de datos en informática de la construcción. *Elsevier, Advanced Engineering Informatics*.
- Camarda, M. (2021). La Secuencia de Fibonacci y los mecanismos de eficiencia energética: Hacia un uso racional y eficiente de la energía a nivel macroscópico. *Investigacion Operativa*(50).
- Ershadi, M., Jefferies, M., Davis, P., & Mojtahedi, M. (2021). Implementacion del Modelado de Informacion de la Construcción (BIM) en proyectos de construcción de infraestructura: un estudio de dimensiones y estrategias. *Revista Internacional de sistemas de Informacion y gestion de proyectos*, 9(4).
- Espiniza, L., & Eloisa, D.-K. (2019). Relacion entre seguridad y productividad en contexto BIM: Una revision sistematica de la literatura. *Simposio Brasileiro de Tecnologia de Informacion y Comunicacion en Construccion*.
- Herrera, R., Muñoz, F., & Vargas, C. (2017). Usos e Impacto de los Modelos nD con Herramientas para la dirección de proyectos en la industria de la arquitectura, ingeniería y construcción. *Informacion Tecnologica*, 28(4).
- Saros, D. (7 de enero de 2025). *Alpha Infinity*. [www.alphainfinity.com](http://www.alphainfinity.com): <https://www.alphainfinity.com/post/quantum-leap-for-vdc-how-quantum-computing-will-revolutionize-building-design-and-construction>

# MECHANICAL BEHAVIOR OF CONCRETE WITH RECYCLED COARSE AGGREGATES

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**Keywords:** Concrete, recycled aggregates, RCA, compression, flexure

## Abstract

The accelerated growth of cities and global industrial development have significantly increased waste generation, particularly that originating from the construction sector, posing major environmental challenges related to its management, recycling, and final disposal. This situation directly contributes to environmental pollution, becoming one of the most pressing issues to be addressed in the transition toward sustainability. In this context, waste reduction through reuse, recycling, and valorization emerges as a key strategy to minimize environmental impacts and promote more efficient use of natural resources (Adazabra et al., 2020).

The building and construction sector plays a significant role in global CO<sub>2</sub> emissions, both due to energy consumption during building operation and the production of construction materials such as concrete, steel, aluminum, glass, and bricks. In 2022, emissions associated with the operational energy use of buildings accounted for approximately 27% of global emissions, while an additional 7% to 9% was attributed to material production, raising the sector's total contribution to nearly 37%. Nevertheless, in the same year, a reduction in direct CO<sub>2</sub> emissions from building operations was recorded, reaching approximately 3 Gt (United Nations, 2025).

This study evaluates the mechanical behavior of concrete produced with partial replacement of natural coarse aggregate by recycled concrete aggregate (RCA) at substitution rates of 20% and 40%, with the aim of identifying configurations that optimize and enhance the structural performance of the material.

Different concrete mix designs with partial replacement of natural aggregates by construction and demolition waste (RCD) were analyzed, assessing their behavior in both fresh and hardened states. In the fresh state, workability was evaluated, while in the hardened state, compressive strength, indirect tensile strength, flexural strength, deformation, and absorbed energy were investigated. For this purpose, 27 cylindrical specimens were manufactured for compression and indirect tensile tests, along with 20 prismatic beams for flexural testing.

The results show a significant reduction in specimen weight as a function of the RCD content, with decreases of 8.94% for 20% RCD and 21.65% for 40% RCD compared to the reference matrix.

Regarding compressive strength, mixtures with 20% RCD exhibited an increase of 25.96%, while those with 40% RCD achieved an improvement of 28.80%. As show in figure 1.

Conversely, indirect tensile strength showed a reduction of 31.11% for the 20% RCD mixture, whereas the 40% RCD mixture presented a slight decrease of 1.33% compared to the reference matrix.

Finally, flexural tests revealed notable increases in load-bearing capacity, with improvements of 73.45% for beams containing 20% RCD and 25.14% for those with a 40% replacement of recycled aggregates.

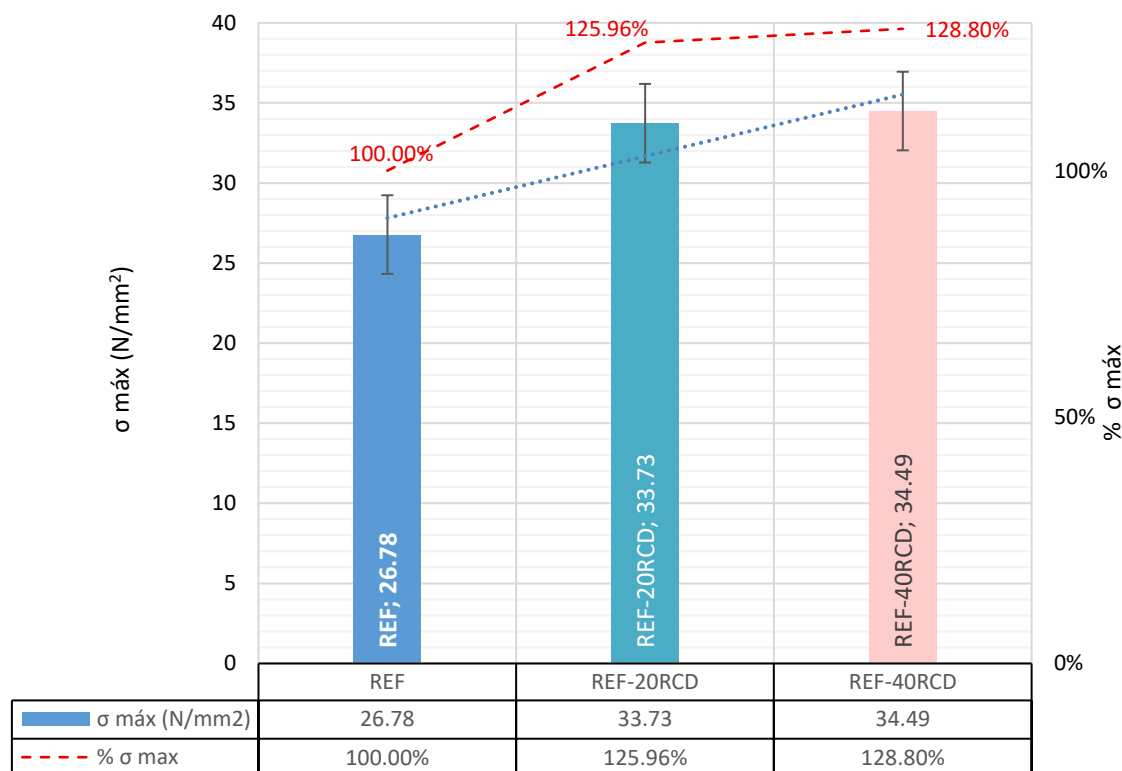


Figure 1. Comparative graph of maximum compressive stresses in reference concrete and concretes with 20% and 40% RCD.

## References

- A. N. Adazabra, G. Viruthagiri, S. A. Sulemana, y J. Yirijor, «Valorising cassava pomace biosolid in fired clay bricks production: Physical, mechanical and thermal evaluation», *Mater Chem Phys*, vol. 309, p. 128402, nov. 2023, doi: 10.1016/J.MATCHEMPHYS.2023.128402.
- United Nations, «The Sustainable Development Goals Report», 2024. Accedido: 1 de abril de 2025. [En línea]. Actualiza Disponible en: <chrome-extension://efaidnbmninnibpcajpcglclefindmkaj/https://unstats.un.org/sdgs/report/2024/The-Sustainable-Development-Goals-Report-2024.pdf>
- UN environment programme, «Informe sobre la situación mundial de los edificios y la construcción en 2022», 2022. [En línea]. Disponible en: <http://www.un.org/Depts/Cartographic/>

# THERMO-OPTICAL CHARACTERISTICS OF OPAQUE COMMERCIAL MATERIALS FOR BUILDING FACADES

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**Keywords:** Thermo-optical features, urban envelope.

## Abstract

Urban areas are increasingly affected by elevated surface and air temperatures driven by climate change, urban densification, and material-driven heat accumulation, intensifying the Urban Heat Island (UHI) effect and increasing building cooling demand. In this context, building facades are evolving from passive enclosures into climate-responsive systems capable of modulating radiative exchanges and contributing to urban heat mitigation. The thermo-optical performance of facade materials—particularly solar reflectance and thermal emissivity—plays a critical role in controlling surface temperatures and reducing heat storage at both building and urban scales. This study evaluates the thermo-optical behavior of more than **300 commercially available facade cladding materials** commonly used in architectural envelopes, with the aim of quantifying their potential contribution to UHI mitigation strategies. Samples were collected from the available materials in the Spanish market and were classified into four categories according to their base composition: **ceramic-based, organic-based, cement-based, and lime-based**, enabling a systematic comparison across material typologies.

The experimental characterization focused on **solar reflectance (SR)**, **thermal emissivity ( $\epsilon$ )**, and *CIE Lab chromatic coordinates ( $L^*$ ,  $a^*$ ,  $b^*$ )*, allowing an integrated analysis of radiative performance and surface color attributes. The results reveal wide performance ranges and significant intra- and inter-category variability, demonstrating that material composition, color, and surface characteristics jointly influence thermo-optical behavior. (Alchapar, N., & Correa, E. 2015). High-reflectance and high-emissivity combinations were identified as particularly relevant for limiting facade surface temperatures and reducing radiative heat gains in urban environments. To assess statistically significant differences in **visible reflectance, solar reflectance, and high-temperature emissivity (HTE)** across material type, color, and texture, the **Kruskal–Wallis non-parametric test** was applied. This approach was selected due to the lack of normality and the presence of asymmetric distributions and potential outliers, ensuring robust and reliable group comparisons. The statistical analysis confirms that material category and surface attributes have a significant influence on thermo-optical performance.

Overall, the findings support the role of facade material selection as an effective passive strategy for climate-responsive building design. By providing quantitative evidence on the thermo-optical variability of commercially available materials, this study contributes to informed decision-making aimed at reducing facade and urban surface temperatures, mitigating UHI intensity, and improving the environmental performance of urban envelopes (Doulos, L., Santamouris, M., & Livada, I. 2004).

## References

- (Alchapar, N., & Correa, E. 2015). Reflectancia solar de las envolventes opacas de la ciudad y su efecto sobre las temperaturas urbanas. Informes de La Construcción, 67(540). <https://doi.org/10.3989/ic.14.131>
- (Doulos, L., Santamouris, M., & Livada, I. 2004). Passive cooling of outdoor urban spaces. The role of materials. Solar Energy, 77(2), 231–249. <https://doi.org/10.1016/j.solener.2004.04.005>

# MECHANICAL AND THERMAL RESPONSE OF DIFFERENT COMMERCIAL GYPSUMS INCORPORATING LOW-DOSAGE GRAPHENE

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**Keywords:** *gypsum, graphene nanoparticles, hydration kinetics, thermal conductivity, microstructure.*

## Abstract

Graphene-modified gypsum performance often varies through the intrinsic chemistry, fineness, and hydration kinetics of the chosen commercial binder. This study compares two commercial gypsums (YG/L and Iberyola) incorporating 0,5% wt. of graphene nanoparticles, in order to clarify matrix-dependent responses. From a visual standpoint, graphene addition produces a systematic darkening of both materials, shifting YG/L toward a light grey tone and Iberyola toward a medium-dark grey appearance. Mechanical testing reveals a contrasting response: YG/L benefits from graphene incorporation, with flexural strength increasing from 2.30 to 2.61 MPa, whereas Iberyola exhibits a reduction from 5.23 to 4.28 MPa. In contrast, thermal conductivity decreases markedly in both systems (YG/L: 0.341 to 0.200 W/m·K; Iberyola: 0.30 to 0.185 W/m·K), indicating that graphene consistently promotes phonon scattering and microstructural disruption irrespective of the base matrix. XRD and SEM analyses suggest that YG/L, despite its lower purity (~80%), maintains effective hydration, allowing graphene to act as heterogeneous nucleation sites and enhance crystal interlocking. Conversely, the finer and more reactive Iberyola shows traces of unhydrated hemihydrate and accelerated setting, indicating that graphene may interfere with hydration in strictly pure gypsum and generate weak phases that penalize mechanical performance.

## References

- Dogan, G. M., Arbag, H., & Eslek Koyuncu, D. D. (2022). Effect of graphene-based additives on mechanical strength and microstructure of gypsum plaster. *Materials Today Communications*, 33, 104555. <https://doi.org/10.1016/j.mtcomm.2022.104555>.
- Zhou, Y., Liu, C., Gao, J., Chen, X., Luo, X., Zhang, G., Gu, T., Zhang, L., & Liu, L. (2024). Effect of graphene oxide on hydration and performance of phosphogypsum-based self-leveling materials used for floor heating backfill. *Construction and Building Materials*, 449, 138367. <https://doi.org/10.1016/j.conbuildmat.2024.138367>.
- Martinez Gordon, A., Prieto Barrio, M. I., & Cobo Escamilla, A. (2024). Unveiling the performance of graphene nanofiber additives in gypsum plasters: A solid vs liquid perspective. *Journal of Building Engineering*, 87, 109061. <https://doi.org/10.1016/j.job.2024.109061>.

# INNOVATIVE SUBSTRATES FOR GREEN ROOFS FOLLOWING CIRCULARITY CRITERIA

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**Keywords:** *Building-integrated greenery systems; green roofs; substrates; circularity; biochar*

## Abstract

Building-integrated greenery systems, such as green roofs and green facades, are nowadays a fundamental strategy for the achievement of sustainable and resilient cities. These construction systems, are perfectly resolved from a technical point of view, and multiple companies and technical solutions can be found on the market. This allows us to address the design and execution of living architecture projects, and multiple successful projects can already be observed (greenroofs.com, 2026) (Figure 1).



**Figure 1. Example of extensive green roof in Lleida. Agrobiotech Park (Lleida, Catalonia, Spain)**

However, these construction solutions are still based on conventional materials that should be redefined under circular economy criteria. This is evident, for example, in waterproofing membranes or filter and protection geotextile sheets.

One of the most important layers of green roofs is the substrate. This layer acts as a physical support and a reservoir of water and nutrients for the plants. Current commercial substrates are designed to meet the requirements established by the few existing standards that regulate them, such as the German FLL, and generally meet all the requirements to guarantee good plant development.

However, it is still necessary to explore substrate compositions to improve not only their performance in terms of the ecosystem services provided (thermal and acoustic insulation, rain runoff control, among others), but also their circularity, by considering more sustainable materials, for example from recycling (Farah G. et al. 2024).

In this context, the TOPSEC research project proposes the use of biochar from the recycling of organic waste from urban metabolism in the Metropolitan Area of Barcelona to improve the composition of substrates for green roofs (Kapetas L., 2025).

In a first phase of this project, 15 different compositions have been proposed, and their potential as a growing medium has been studied through a germination test, using the species “*Linum usitatissimum*” (Golden flax).

The experiment took place at the University of Lleida, in a greenhouse, under controlled environmental conditions, using plug germination trays. A commercial substrate for extensive green roofs was used as a reference. The experimental design consisted of four plugs per substrate, five seeds per plug, and three replications (Figure 1).



Figure 2. Example of one of the new substrate compositions. Golden flax in germination trays and processing of the plants in the laboratory for measuring the length and weight of the aerial and root parts of the plants

Preliminary results, corresponding to the number of germinated seeds, allow us to advance that the incorporation of biochar, whether from organic waste or gardening debris, can contribute positively to the germination of plants.

The conclusions from these previous studies will allow us to select the most suitable compositions to be used in the next phase of the project in which the hydraulic behaviour of the TOPSEC extensive green roof solution will also be studied in terms of plant survival, water saving, and run-off control, in an experimental plant.

## References

- Farah G., Pérez G., Ballesta A., El Bachawati M. Green roof substrates influencing the provision of ecosystem services: A review. (2024) Journal of Environmental Chemical Engineering, 12 (6), art. no. 114795. DOI: 10.1016/j.jece.2024.114795
- Greenroofs.com, 2026. <https://www.greenroofs.com/>
- Kapetas L. Portico, 2025. Renaturing the roofscape of Metropolitan Barcelona: Join the TOP SEC's journey!. <https://portico.urban-initiative.eu/urban-stories/european-urban-initiative/renaturing-roofscape-metropolitan-barcelona-join-top-secs-journey-7652>

# EVALUATION OF THE MECHANICAL PROPERTIES OF CEMENT MORTARS WITH ALUMINUM AND STEEL FIBERS

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**Keywords:** mortar, cement, fiber, steel, aluminum

## Abstract

The incorporation of commercial steel fibers into mortars and concretes improves their flexural strength, increasing their ductility and reducing cracking (Viera, 2023; Thomas, 2007). Furthermore, globally, approximately 76% of the aluminum produced annually is recovered and recycled, reflecting one of the highest recycling rates among all metals (Lu, 2025). Valorizing this waste as raw material for new mortars is an alternative with mechanical and economic advantages (Jesus, 2025). Based on these premises, the objective of this study is to compare the mechanical behavior of reinforced cement mortars with commercial steel fibers and recycled aluminum fibers. For the tests, 4x4x16 cm cylindrical specimens were fabricated and subjected to various physical and mechanical tests. The mortar mix (cement:sand:water) is 1:3:0.67, and the fiber quantities used are 15, 30, and 45 kg/m<sup>3</sup> of steel fiber and 3.5, 7, and 10.5 kg/m<sup>3</sup> of aluminum fiber. The types of fibers used can be seen in Figure 1.



Fig. 1. Fibers used. Aluminum fibers (left); b) Steel fibers (right).

The results indicate that incorporating 3.5 kg/m<sup>3</sup> of aluminum fibers into cement mortars was the optimal dosage for this type of mortar, increasing their ductility compared to the reference mortars. In mortars with steel fibers, the highest strength was achieved with 45 kg/m<sup>3</sup> of steel fibers, maintaining their strength relative to the reference mortars and increasing their deformation capacity.

## References

- Jesus, S. D. et al. (2025). Waste of aluminum composite material applied to cement-based mortars and their chemical, microstructural, and mechanical properties. *Next Materials*, 7, 100393. <https://doi.org/10.1016/j.nxmte.2024.100393>
- Lu L. Reciclaje de aluminio: convertir los residuos en un recurso sostenible. 14 de noviembre de 2025. <https://www.eabel.com/es/reciclaje-de-aluminio/>. (accessed: January 15, 2026).
- Thomas, J., & Ramaswamy, A. (2007). Mechanical properties of steel fiber-reinforced concrete. *Journal of Materials in Civil Engineering*, 19(5), 385–392. [https://doi.org/10.1061/\(ASCE\)0899-1561\(2007\)19:5\(385\)](https://doi.org/10.1061/(ASCE)0899-1561(2007)19:5(385)).
- Viera, P., Zapata, E., & Vega, S. (2023). Use of recycled steel fibers to improve the structural behavior of rigid pavement. *Universidad Ciencia y Tecnología*, 27, 8–18. <https://doi.org/10.47460/uct.v27i120.727>.

# BEHAVIORAL STUDY ABOUT POROSITY AND SURFACE HARDNESS OF MIXED MORTARS WITH RECYCLED MATERIALS

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**Keywords:** mixed mortar, open porosity, superficial hardness, ELT, recycled aggregate

## Abstract

Currently, the construction sector is closely linked to the circular economy, driven by the interest in developing materials that reduce the environmental impact associated with the slow degradation of waste and its limited recovery and valorization. This has encouraged experimental research into new, more sustainable construction alternatives.

End-of-life tires (ELTs) constitute one of the most extensively studied urban solid wastes in recent decades. Despite the existence of regulations and companies dedicated to their management, they continue to generate significant environmental impacts, particularly due to CO<sub>2</sub> emissions resulting from their use as fuel and from the production of new steel. Similarly, although recycling processes for construction and demolition waste are available, the consumption of natural aggregates remains high.

Several studies and patents have demonstrated that commercial steel fibers significantly enhance the mechanical properties of cement mortars and concretes. This research evaluates the feasibility of using recycled steel fibers from ELTs as reinforcement in a lime–cement mixed mortar matrix, aiming to mitigate the reduction in technical performance caused by replacing natural aggregates with recycled ceramic aggregates. For this purpose, physical and mechanical characterization tests were conducted, including open porosity and surface hardness, considering three variables: fiber type, aggregate type, and mortar age.



Fig. 1. Test performed: Open porosity and surface hardness. (Source: Own production)

A general analysis of the results indicates that mortar age is the most influential factor affecting material behavior. For open porosity, reductions of up to 14% were observed at prolonged curing ages, with statistical analysis confirming that increased age leads to a greater decrease in pore content within the initial matrix. Regarding surface hardness, favorable results were obtained, with increases of up to 10% at 180 days; however, statistical analysis revealed that the most significant differences occur at early testing ages ( $p$ -value =  $1.72 \times 10^{-6}$ ). In terms of property correlation, a 44% dependence between variables was identified, which may be considered a reliable descriptive model.

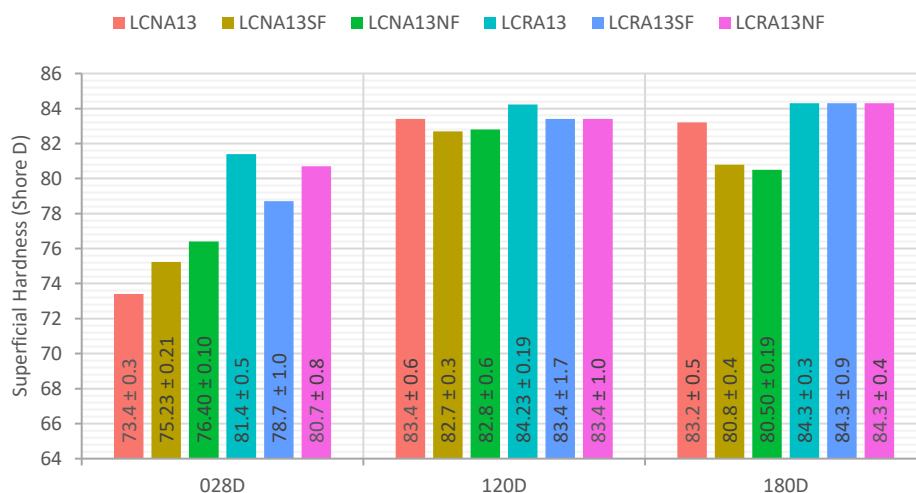


Fig. 2. Superficial hardness of mixed mortars. (Source: Own production)

The results are consistent with other experimental studies on similar materials, indicating that fiber incorporation and the use of recycled aggregates do not significantly alter the behavior of the initial mixed mortar matrix, even at extended curing ages. This supports the use of these recycled waste-derived materials as sustainable alternatives for the construction industry, contributing to circular economy objectives by reducing natural resource consumption and promoting the recycling of high-impact waste.

## References

- Parlamento Europeo. (2025, October 20). Estrategia Española de Economía Circular y Planes de Acción. Economía Circular Europa. <https://www.miteco.gob.es/es/calidad-y-evaluacion-ambiental/temas/economia-circular/estrategia.html>
- Métodos de Ensayo Para Piedra Natural. Determinación de La Densidad Real y Aparente y de La Porosidad Abierta y Total, UNE-EN 1936 (2007).
- Plásticos y Ebonita. Determinación de La Dureza de Identación Por Medio de Un Durómetro (Dureza Shore), UNE-EN ISO 868 (2003).
- Barrios, A. M., Vega, D. F., Martínez, P. S., Atanes-Sánchez, E., & Fernández, C. M. (2021). Study of the properties of lime and cement mortars made from recycled ceramic aggregate and reinforced with fibers. *Journal of Building Engineering*, 35. <https://doi.org/10.1016/j.job.2020.102097>

# STATISTICAL EVALUATION OF THE IMPACT OF THE EXTERNAL THERMAL INSULATION COMPOSITE SYSTEM (ETICS) ON THE ENERGY OPTIMIZATION OF A RESIDENTIAL BUILDING IN MADRID

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**Keywords:** *energy efficiency, ETICS, insulation, statistical analysis, thermal comfort*

## Abstract

Currently, the rehabilitation of the existing building stock in Spain is essential to achieve energy consumption reduction targets, supported by international initiatives aligned with the Sustainable Development Goals aimed at the creation of resilient and sustainable cities in accordance with the United Nations 2030 Agenda. At the European level, this is reinforced through Directive (EU) 2024/1275 on the energy performance of buildings. This regulation establishes the objective of reducing average primary energy consumption by 16% by 2030, compared to 2020 levels, as well as achieving a zero-emission building stock by 2050.

According to the National Statistics Institute, there are more than 5 million dwellings in Spain that are over 60 years old, and 475,105 dwellings were built prior to the 1960s. This situation implies the existence of construction deficiencies resulting from a lack of maintenance or refurbishment of façades, as well as inadequate maintenance of heating systems. In this context, it becomes necessary to propose reliable and accessible solutions that, following a rehabilitation or retrofit process, improve the thermal performance of the building façade, as is the case of the system known as ETICS (External Thermal Insulation Composite System).

This study aims to assess surface temperatures during the winter period over a monitoring campaign of 25 days, with data recorded at 2-minute intervals using data loggers installed on the interior and exterior surfaces of the building façade, both in its original condition and after energy retrofit. The collected data were processed using SPSS software, and statistical correlations ( $R$  and  $R^2$ ) were obtained. These indicators enable the evaluation of the impact of the External Thermal Insulation Composite System (ETICS) on the thermal comfort performance of a residential dwelling located in Madrid, specifically in the Moratalaz district.

The results obtained show a significant improvement estimated at 26%, which is reflected in a reduced dependence of the internal surface temperature on the external temperature (Table I). Consequently, the façade incorporating ETICS exhibits greater thermal stability, leading to a reduction in temperature fluctuations within the interior of the analyzed dwelling (Fig. 1).

In conclusion, the study confirms that the incorporation of the External Thermal Insulation Composite System (ETICS) contributes positively to energy efficiency and to the improvement of thermal comfort in retrofitted residential buildings that previously did not comply with the thermal requirements established by the Spanish Technical Building Code (CTE), as well as in new buildings that incorporate this system within their building envelopes.

TABLE I  
CORRELATION BETWEEN EXTERIOR AND INTERIOR SURFACE TEMPERATURES OF A RESIDENTIAL FAÇADE

| Statistical measure                    | Initial state | Retrofitted state (ETICS) |
|--|---------------|---------------------------|
| Correlation coefficient (R)            | 66,81%        | 57,40%                    |
| Coefficient of determination ( $R^2$ ) | 44,63%        | 33,00%                    |

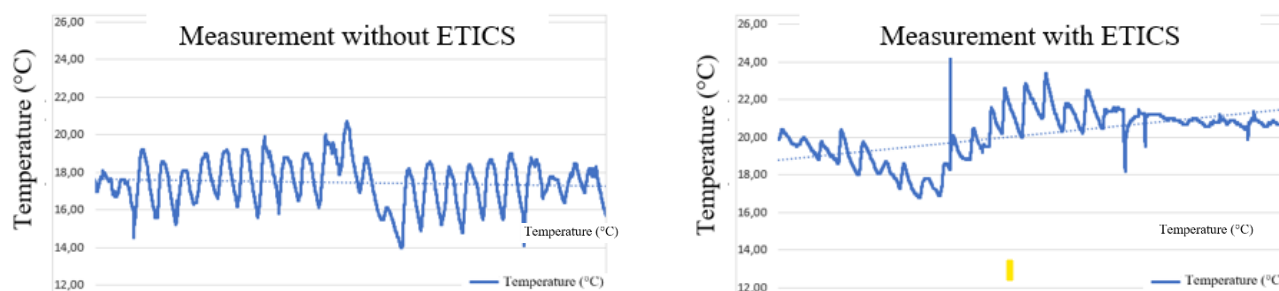


Fig. 1. Diagram of surface temperature oscillations inside the house, before and after ETICS

## References

- European Parliament & Council of the European Union. (2024, May 8). Directive (EU) 2024/1275 on the energy performance of buildings (recast). Official Journal of the European Union. <https://www.boe.es/doue/2024/1275/L00001-00068.pdf>
- National Statistics Institute. (2021). Survey on essential characteristics of the population and housing: 2021. <https://www.ine.es/dynt3/inebase/index.htm?padre=8981&capsel=9595>

# VALORIZATION OF PHENOLIC BOARD WASTE IN CEMENT MORTARS: A BIBLIOGRAPHY REVIEW

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**Keywords:** Mortars, Phenolic boards, Industrial waste, Sustainability, Circular economy.

## Abstract

The construction sector faces significant sustainability challenges derived from the high consumption of raw materials and the generation of waste associated with production processes. In this context, the incorporation of industrial residues into cement mortars is considered a relevant strategy to reduce the environmental impact of construction materials and to advance towards circular economy models. Among these residues, those derived from phenolic boards are beginning to attract interest. However, the available information on this subject is still limited, highlighting the need to assess their compatibility and effects when incorporated into cement mortars.

Current research on the use of residues in cement mortars can be grouped into three main lines: the use of industrial residues in cement mortars, the incorporation of wood residues and lignocellulosic fibers into cement mortars, and the study of phenolic-containing materials incorporated into cement mortars and, complementarily, into other construction composites as contextual references. Several studies on industrial residues have shown that the partial replacement of mortar components, such as fine aggregate or cement, can be technically feasible when parameters such as residue particle size distribution and replacement ratio are properly controlled (Yamanel et al., 2019). In the case of organic or lignocellulosic residues, the bibliography emphasizes the importance of adjusting the water-to-binder ratio and specifically evaluating fresh and hardened properties, due to their higher water absorption and their influence on workability and mechanical strength (Sabrina et al., 2024).

In general terms, the reviewed studies agree that increasing the residue content tends to reduce workability and cause variations in mechanical strength; however, for moderate replacement levels, the obtained values remain within acceptable ranges for cement mortars potentially suitable for non-structural applications. Regarding residues with phenolic content, the available literature is more limited, but it highlights the ability of cement mortars to immobilize certain potentially problematic compounds, reducing their leaching and improving the environmental safety of the resulting material (Łaźniewska-Piekarczyk et al., 2023).

From both an environmental and constructive viability perspective, the need to address the performance of this new material and its technical properties through life cycle assessment (LCA) methodologies becomes evident. LCA enables an integrated evaluation of the feasibility of using phenolic board residues in cement mortars and their construction applications. It is presented as a key tool to quantify the reduction in virgin raw material consumption, the decrease in waste sent to landfill, and the impacts associated with the material's life cycle. Overall, the review supports the potential of phenolic board residues in cement mortars as a pathway toward circular economy practices and justifies the development of integrated experimental and environmental studies.

## References

- Yamanel, K. et al. (2019). Influence of waste marble powder as a replacement of cement on the properties of mortar.  
Sabrina, R. et al. (2024). Recycling of different industrial wastes as supplement of cement for sustainable production of mortar.  
Łaźniewska-Piekarczyk, B. et al. (2023). Comparison of the effectiveness of reducing the leaching of formaldehyde from immobilized wool in geopolymer and cement mortar.

# COMPARATIVE STUDY OF THE CONSTRUCTION OF TIMBER-FRAMED STRUCTURES IN CORRIDOR HOUSES OF MADRID AND MÁLAGA

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**Keywords:** Nineteenth-century buildings; traditional architecture; courtyard housing (corridor houses); rehabilitation

## Abstract

The social and economic transformations experienced by the historic centers of major cities during the early decades of the nineteenth century led to a notable increase in building rehabilitation works (Nuere & Cabeza, 2021). This context makes it particularly timely to examine the characteristics of their construction systems in order to approach any intervention with due respect and to establish precise guidelines for their protection and conservation. Understanding how these buildings were originally conceived and built is essential for ensuring that rehabilitation processes do not compromise their historical and structural value (Ger y Lobe, 1898).

During the nineteenth century and the early years of the twentieth century, the rapid arrival of a working-class population from surrounding rural areas created an urgent need for housing in large cities. As a result, most courtyard housing complexes, known as *corralas* in Madrid and *corralones* in Málaga, as well as multi-storey rental housing blocks, were developed during this period (Fernández Martín et al., 2016; García Gómez, 2017). In order to accelerate construction processes and reduce costs, builders relied on well-established knowledge and techniques inherited from vernacular architecture. Traditional and durable materials, particularly timber, were widely used, leading to the extensive adoption of timber-framed structural systems in multi-storey urban buildings (Santa Cruz-Astorqui & del Río Merino, 2014). Cities such as Madrid and Málaga became prominent examples of this construction practice (González-Redondo, 2020).

Over time, the need to modernize these buildings, together with their natural deterioration, has often resulted in the partial or complete loss of their original structural systems. In many cases, entire buildings were demolished or internally stripped, preserving only the façade—and occasionally the staircase—as



Fig. 1. Left: Corralón Santa Sofía (Málaga). Right: Corrala Ribera de Curtidores (Madrid)

protected elements. These rehabilitation processes were rarely documented, which has significantly limited the understanding of historic timber structures and contributed to a shortage of specialized literature, analytical studies, and technical references, beyond those found in a small number of historical treatises (Ger y Lobe, 1898; Nuere & Cabeza, 2021).

Furthermore, historical building permit procedures typically required only a façade elevation and a basic floor plan, offering minimal information about structural systems. Consequently, this research adopts a theoretical approach supported by on-site surveys of various buildings in both urban contexts, allowing for a broader and more accurate documentation of the construction techniques employed (Santa Cruz-Astorqui & del Río Merino, 2014). Despite the relevance of this topic, there remains a significant lack of comparative research addressing different typologies and providing detailed analyses of their structural systems, as existing studies tend to focus primarily on historical narratives (Fernández Martín et al., 2016).

## References

- Fernández Martín, R., Santa Cruz-Astorqui, J., Arbaiza Blanco-Soler, S., & del Río Merino, M. (2016). Caracterización tipológica del espacio edificado de las casas de corredor: El caso de las ciudadelas del casco histórico de La Habana y las corralas madrileñas. *Informes de la Construcción*, 68(541). <https://doi.org/10.3989/ic.15.0367>
- García Gómez, F. (2017). Rosario Camacho y la arquitectura malagueña del XIX. *Boletín de Arte*, (34), 382–384. <https://doi.org/10.24310/bolarte.2013.v0i34.3547>
- Ger y Lobe, F. (1898). *Tratado de construcción civil*. Establecimiento Tipográfico de Badajoz.
- González-Redondo, E. (2020). Las “casas a la malicia” en Madrid y su transformación en edificios de entramado de madera “modernos” (1656–1868): Construcciones originales vs. estructuras añadidas. *Informes de la Construcción*, 72(559), 358. <https://doi.org/10.3989/ic.74057>
- Nuere, E., & Cabeza, P. (2021). *Rehabilitación: Madera en la edificación*. AITIM. <https://isbnsearch.org/isbn/9788487381546>
- Santa Cruz-Astorqui, J., & del Río Merino, M. (2014). Modelo de comportamiento estructural de muros entramados de madera en el siglo XIX en España. *Informes de la Construcción*, 66(536). <https://doi.org/10.3989/ic.14.030>

# CONSTRUCTIVE EVOLUTION OF THE TRADITIONAL TIMBER-FRAMED STRUCTURE OF THE BUILDINGS AT PUERTA DEL SOL IN MADRID

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**Keywords:** *Timber structure; Puerta del Sol; traditional Madrid architecture; rehabilitation*

## Abstract

Madrid's Puerta del Sol has been, since the fifteenth century, one of the most significant urban and symbolic centers of the city (Gómez de la Serna, 1987). Throughout its long history, it has acted as a silent witness to countless historical, political, and social events that have shaped both the capital and the country as a whole (Arnaiz Gorroño, 1981; Gómez de la Serna, 1987). Its continuous transformation reflects the changing needs, values, and architectural approaches of different periods, making it a key reference point for understanding the urban evolution of Madrid (Arnaiz Gorroño, 1981).

This document seeks to complement existing studies on the historical development of Puerta del Sol by adopting a constructive and technical perspective (Bailliet Fernández, 2015). Specifically, it focuses on the analysis of the configuration and construction systems of the timber-framed structures of one of the buildings that define the square, located at number 9 Puerta del Sol (González-Redondo, 2015). The research undertakes a comprehensive review of all the interventions and modifications that the building has undergone since its original construction, with the aim of reconstructing its architectural evolution over time (González-Redondo, 2022).

In order to properly contextualize these transformations, it has been necessary to identify contemporary parallels and significant historical milestones that help explain the influences and consequences of broader social, economic, and technical changes on the architectural alterations of the building under study (Bailliet Fernández, 2015; Alberch, 2010). By establishing these connections, the research aims to provide a more solid foundation for understanding why certain constructive solutions were adopted and how external factors may have guided decision-making processes throughout different periods (Alberch, 2010).



Fig. 1. Left: Lucio del Valle's project, 1860. Source: General Central Archive of Alcalá de Henares (AGA).  
Right: Construction of the Puerta del Sol fountain, 1862. Source: National Library of Spain (BNE), reference number 17/13.

Interventions in timber-framed structures remain insufficiently documented, largely because many buildings that have survived to the present day lack detailed technical studies and systematic analyses of the successive alterations they have experienced (González-Redondo, 2015). As a result, valuable information about traditional construction techniques, structural behavior, and historical repair strategies is often fragmented or entirely absent (Nuere, 2000). This lack of documentation poses significant challenges for conservation, restoration, and future interventions (Nuere, 2007).

For these reasons, one of the main objectives of this research is to emphasize the importance of producing thorough graphic and written documentation of past and present interventions in such buildings (Nuere, 2007; González-Redondo, 2015). Creating a clear and well-supported record not only contributes to the preservation of architectural heritage but also provides essential knowledge for professionals involved in the maintenance and rehabilitation of historic timber-framed structures (Bailliet Fernández, 2015; Alberch, 2010). Ultimately, this study aims to enhance the understanding of traditional construction systems while promoting more informed and respectful approaches to architectural conservation (Nuere, 2000; González-Redondo, 2022).

## References

- Alberch, M. L. (2010). *Architectural heritage as a resource for teaching history and social sciences* [in Spanish]. *Enseñanza de las Ciencias Sociales*, (9), 41–50.
- Arnaiz Gorroño, M. J. (1981). *Urban reform of Puerta del Sol in the 19th century* [in Spanish].
- Bailliet Fernández, E. (2015). *History of architectural heritage protection in Spain, 1933–1985* [in Spanish]. Escuela Técnica Superior de Arquitectura, Universidad Politécnica de Madrid. (Doctoral thesis).
- Gómez de la Serna, R. (1987). *History of Puerta del Sol* [in Spanish]. Ediciones Almarabú.
- González-Redondo, E. (2015). A timber-framed construction system preserved: The historic centre of Madrid. *Journal of Architectural Conservation*, 21(2), 113–135. <https://doi.org/10.1080/13556207.2015.1112125>
- González-Redondo, E. (2022). Adding new floors to old timber-framed buildings: An assessment of demolished and preserved courtyard houses in the historic centre of Madrid. *Frontiers of Architectural Research*, 11(2), 255–277. <https://doi.org/10.1016/j.foar.2021.10.009>
- Nuere, E. (2000). *Spanish timber roof construction* [in Spanish]. Munilla-Lería.
- Nuere, E. (2007). Wood in restoration and rehabilitation [in Spanish]. *Informes de la Construcción*, 59(506), 123–130.

# INITIAL STUDY AND MODELING OF RADON EXHALATION IN HERITAGE WALLS

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**Keywords:** Radon, heritage, walls exhalation, mitigation, monitoring

## Abstract

The presence of radon in historic buildings poses a dual challenge for public health and heritage conservation. Recent studies have revealed that radon sources in these structures are not limited to the underlying soil but also include the construction materials forming their walls (Frutos et al., 2021). This significantly complicates the implementation of remediation strategies, as conventional radon measurement and control techniques cannot be applied.

The RADIANT Project (*Radon Assessment and monitoring using robotics, Digitization, and Artificial Intelligence technologies in heritage buildings* – PID2024-159276OB-C41) addresses this challenge through the development of innovative methodologies for assessment and monitoring. In this initial phase, experimental techniques for measuring wall exhalation are explored, employing exhalation chambers and gamma radiation detection. In parallel, simulation models are developed with COMSOL Multiphysics to analyze exhalation behavior, estimate its magnitude under different construction configurations, and propose mitigation systems adapted to radon sources

Preliminary results lay the groundwork for defining non-invasive measurement protocols and for the future integration of digital, robotic, and artificial intelligence technologies in radon monitoring within heritage buildings. This project is funded under the Spanish State Plan for Scientific, Technical, and Innovation Research 2024–2027.

## References

Frutos, B., Martín-Consuegra, F., Alonso, C., Perez, G., Peón, J., Ruano-Ravina, A., Barros, J. M., & Santorun, A. M. (2021). Inner wall filler as a singular and significant source of indoor radon pollution in heritage buildings: An exhalation method-based approach. *Building and Environment*, 201. <https://doi.org/10.1016/j.buildenv.2021.108005>

# KEY FACTORS FOR SUSTAINABLE REHABILITATION: POLYMER MORTARS

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**Keywords:** *Rehabilitation, sustainability, mortars, polymer waste, circular economy*

## Abstract

Rehabilitation has become a fundamental pillar in the construction sector for meeting the Sustainable Development Goals (SDGs), in a context where the sector is responsible for a large part of the waste generated (Green Building Council Spain [GBCe], 2023). This research addresses the recovery of construction and demolition waste (CDW), specifically polymeric waste from electrical cables, for its reincorporation into the production chain under the principles of the circular economy. The main objective is to develop and characterise a mortar that partially replaces natural aggregate with plastic waste from electrical cable coating, a technology that is backed by a proprietary patent (Vidales Barriguete et al., 2025).

The experimental methodology was based on comparing a reference mortar with four dosages with different percentages of aggregate replacement by polymer from the cable coating (25%, 35%, 45% and 55%) against a reference mortar, maintaining a constant water/cement ratio of 0.68 and CEM II/B-L 32.5R cement.

An exhaustive testing campaign was carried out, focusing on durability and physical-mechanical behaviour, including tests on density, porosity, mechanical strength, water absorption, vapour permeability, frost resistance, salt crystallisation and fire resistance.

The results show that the incorporation of the polymer reduces the apparent density of the material by up to 26.64% at the maximum dosage and increases open porosity. This lightness facilitates installation and reduces dead loads in rehabilitation projects. Although mechanical strength decreases, adhesion and resistance values remain within the regulatory ranges for use as a coating. A critical finding is the improvement in the elasticity of the material, which minimises shrinkage and the appearance of cracks.

Hygrothermally, the mortar stands out for its dramatic improvement in resistance to water vapour transmission, reaching values up to 863% higher than the reference in the 45% dosage. Finally, in fire tests, the mortar maintained its dimensional stability despite the higher temperatures generated by the decomposition of the polymer.

In conclusion, polymer mortars represent a viable technical solution for plastering and cladding, offering competitive advantages in terms of impermeability, flexibility and lightness, in line with sustainable construction strategies.

## References

- Green Building Council España. (2023). Economía circular en la edificación. GBCe.  
Vidales Barriguete, A., Piña Ramírez, C., Navarrete Ocaña, S., Del Rfo Merino, M., & Atanes Sánchez, E. (2025). Mortero de cemento que incorpora agregado polimérico (Patente ES 2 973 008 B2). Oficina Española de Patentes y Marcas

# SMART E-SUPPLY CHAIN MODELS USING ARTIFICIAL INTELLIGENCE FOR CONSTRUCTION MATERIAL PROCUREMENT: A STUDY OF KUWAIT AND OTHER GCC COUNTRIES

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**Keywords:** artificial intelligence, e-SCM, constructions, operation, logistics.

## Abstract

The rapid evolution of digital technologies has led to the transformation of SCM (Supply Chain Management) with AI (Artificial Intelligence) as the key driver for improving performance in procurement, inventory operations and logistics (Samuels, 2025). The GCC (Gulf Cooperation Council) region's construction industry plays an important role in economic development, it still continuously faces challenges that are related to construction material procurement, such as supply disruptions, longer lead time, limited visibility of supply chain, and cost overruns. Smart e- supply chain models that are enabled by AI offers new opportunities to address these challenges with enhanced data-driven decision-making, real-time solution and predictive analysis (Toorajipour et al., 2020).

Empirical researches consistently shows that AI applications make a significant contribution to enhanced supply chain performance by improving forecasting accuracy, inventory optimization, and automating redundant tasks (Al-Huzaili et al., 2025; Kasih & Yulianti, 2024). For instance, AI powered predictive analysis improves inventory management and demand forecasting, which leads to reduce stockouts and efficiency allocation of resources (Anumula et al., 2025). In a similar way, systematic review on AI adoption in SCM shows that AI technologies enhance procurement processes significantly by improving selection of suppliers, automated workflows and proactive risk management (Al-Huzaili et al., 2025).

This research study aims to explore the role of smart e-supply chain models using AI in enhancing construction material procurement performance in Kuwait and other GCC countries. This research focuses on gaining understanding the degree of AI adoption in e-supply chain systems, identifying the vital AI technologies used, and empirically evaluating their impact on procurement performance outcomes like reducing lead time, inventory optimization, supplier reliability and cost efficiency, while also identifying contextual and organizational factors that offer facilitation or hinders its successful adoption. Despite the advances, the research on GCC construction sector and adoption of AI enabled e-Supply chain procurement systems is still evolving. Although, technology adoption models mention that AI reduces manual efforts and improve operational responsiveness, and other factors such as organizational readiness, digital infrastructure that influences successful integration (Samuels, 2025).

This research study employs a quantitative survey design, collects data from supply chain professionals in Kuwait and other GCC countries to investigate the relationship between AI-enabled e-supply chain models and procurement performance in construction material procurement. It measures the degree of AI integration in procurement systems, procurement performance outcomes and enabling factors (supply chain agility & responsiveness, end-to-end visibility, data quality & integration, organizational readiness). This research will adopt SEM (Structural equation modelling) and descriptive statistical analysis to test the relationships between AI enabled e-supply chain capabilities and procurement performance outcomes.

It is expected that higher levels of AI integration will be associated positively with improved procurement performance which are consistent with the results obtained by Kasih et al. (2024). In practical, this study offers supply chain managers and policymakers with evidence-based insights on how AI investments can help yield operational benefits. It also outlines implications related to workforce skill development and organizational change management that helps support successful AI adoption in complex supply chain settings.

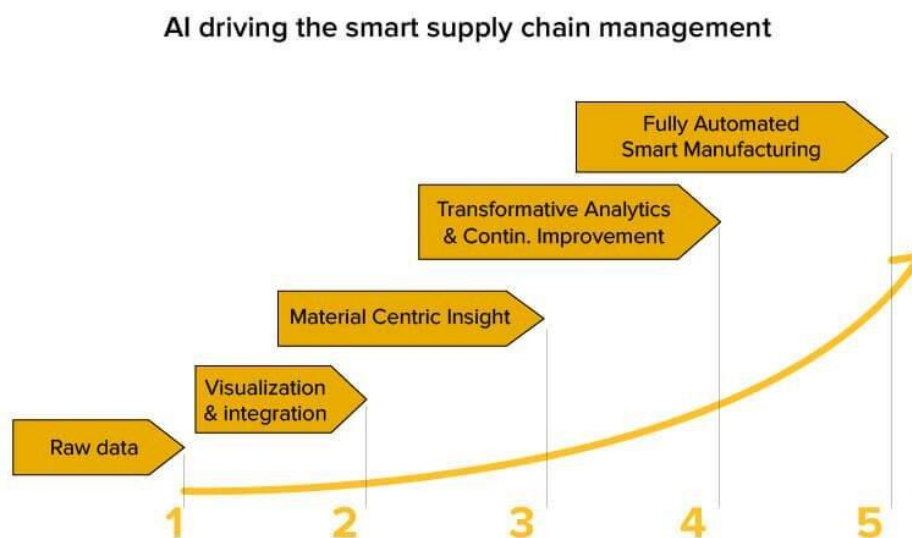


Figure 2 AI driving the Smart Supply Chain Management (Groenewald et al., 2024)

## References

- Al-Huzaili, S. A. F., Mokhtar, A. I. B., & Muhamat, M. R. B. (2025). The Role of Artificial Intelligence in Enhancing Procurement Processes and Supply Chains. *International Journal of Supply Chain Management*, 14(4), 64–78. <https://doi.org/10.59160/ijscm.v14i4.6328>
- Anumula, S. krishna, Krishnapillai, V., & Rai, D. K. (2025). Optimizing Supply Chain Management with AI-Powered Predictive Analytics. *Journal of International Commercial Law and Technology*, 6, 244–252. <https://doi.org/10.61336/Jiclt/25-01-20>
- Groenewald, C. A., Garg, A., Yerasuri, S. S., S, J., Sharma, H., & Groenewald, E. (2024). Smart Supply Chain Management Optimization and Risk Mitigation with Artificial Intelligence. 28, 261–270.
- Kasih, E. W., & Yulianti, G. (2024). Exploring the Impact of Artificial Intelligence on Supply Chain Management Performance: A Scoping Review.
- Samuels, A. (2025). Examining the integration of artificial intelligence in supply chain management from Industry 4.0 to 6.0: A systematic literature review. *Frontiers in Artificial Intelligence*, 7. <https://doi.org/10.3389/frai.2024.1477044>
- Toorajipour, R., Sohrabpour, V., Nazarpour, A., Oghazi, P., & Fischl, M. (2020). Artificial intelligence in supply chain management: A systematic literature review. *Journal of Business Research*, 122, 502–517. <https://doi.org/10.1016/j.jbusres.2020.09.009>

# EXPERIMENTAL STUDY ON THE SURFACE PENETRATION RESISTANCE OF CEMENT MORTAR SPECIMENS IN THREE MAIN STATES

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**Keywords:** *surface penetration; mortar; resistance; Shore D*

## Abstract

Surface hardness is an essential property of cement mortars, as it represents resistance to surface penetration, scratching, or abrasion. It is also directly related to compressive strength, a key property for the characterization of this material widely used in construction. This parameter has been investigated in numerous studies, showing improvements when different types of nanotubes are incorporated (Jayakumari et al, 2023; Xie et al, 2026).

Resistance to mechanical attacks affects the durability of buildings, resulting in a long-term impact by increasing the service life of construction elements made with this material. Improved performance of mortar in this regard can contribute to the achievement of more durable construction units, potentially reducing the embodied carbon footprint associated with these cementitious elements, which represents a major challenge for the sector.

In this initial study, the results obtained from Shore D penetration resistance tests, carried out on thirty mortar specimens, are presented. Fifteen of these specimens were produced using CEM III and the remaining ones with CEM IV, two cement types expected to be increasingly used due to their lower clinker content. All specimens were subjected to oven-drying processes to determine their dry weight and to saturation processes to obtain their saturated weight, in addition to measurements taken at ambient conditions. Using these data and additional complementary parameters, it was possible to study and quantify variations in penetration resistance depending on the type of binder used and the condition of the specimen (dry, ambient, and saturated).

Preliminary studies on CEM III specimens show reductions in penetration resistance of approximately 12% when water content increases under saturated conditions, while in the dry state an increase of about 4% has been observed. On the other hand, specimens produced with CEM IV exhibit highly variable percentages in the dry state, with reductions of up to 11%, as well as increases of the same magnitude. In the saturated state, penetration resistance increases by up to 14%, attributed to reactions with the pozzolanic compounds present in their composition.

In summary, this study analyzes the variability of the surface penetration resistance in two types of cement that are highly likely to be widely used in the future. In addition, the relationship between the amount of water present in the specimens and the measured resistance under the three testing conditions has been examined.

## References

- Jayakumari, B. Y., Swaminathan, E. N., & Partheeban, P. (2023). A review on characteristics studies on carbon nanotubes-based cement concrete. *Construction and Building Materials*, 367, 130344.
- Xie, J., Liu, B., Wang, X., Tang, Y., Wei, J., Luo, J., & Chen, Z. (2026). Mechanical properties and abrasion resistance of CNTs cement mortars: Hydration behavior and microscopic mechanisms. *Construction and Building Materials*, 510, 145263.

# ENHANCING URBAN BIODIVERSITY DURING THE BUILDING CONSTRUCTION PHASE

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**Keywords:** *urban biodiversity; construction phase; building works; urban ecology; habitat conservation*

## Abstract

Cities constitute highly constrained environments for non-human species, where biodiversity is limited by social norms, planning regulations, and human preferences, allowing mainly selected or opportunistic species to persist (Segura Moreno, 2014).

Nevertheless, when the urban environment is understood as an artificial ecosystem in which nature is both necessary and possible, it becomes connected to fundamental biological processes and to the beneficial interactions between living organisms (González Vives, 2014). Urban areas are continuously colonised by diverse plant and animal species attempting to establish themselves despite adverse conditions.

A substantial body of research demonstrates that increasing the interaction between nature and the urban environment generates significant social, ecological, psychological, and economic benefits. These include improvements in environmental quality, urban agriculture and nutrition, social inclusion, employment, and reductions in stress, anxiety, and depression among residents of biodiverse neighbourhoods (Cuvi, 2016; Lepczyk et al., 2017).

The presence of biodiverse natural spaces in cities contributes to mitigating the urban heat island effect, reducing noise pollution, improving air quality through particulate filtration and CO<sub>2</sub> sequestration, enhancing physical and mental health, strengthening social interaction, and reinforcing citizens' sense of place (Fernández Calvo, 2019).

Within this framework, nature-based solutions for urban resilience often prove more cost-effective than conventional approaches, as they reduce surface runoff, improve soil infiltration, filter stormwater, alleviate pressure on wastewater systems, and create habitats that support biodiversity.

This paper highlights the building construction phase as a critical and often overlooked opportunity for biodiversity conservation in urban areas. The training of construction professionals, the implementation of species protection protocols on site, and improved knowledge of vulnerable species can significantly reduce habitat disruption during building works. In many cases, existing urban biodiversity results from long-term ecological processes that can be rapidly reversed through uninformed construction practices. Preventing habitat destruction and species loss during this phase is therefore essential to maintaining urban ecological value.

## References

- Cuvi, N. (2016). Introducción: biodiversidad y agricultura urbana. *Letras Verdes. Revista latinoamericana de estudios socioambientales*, 19, 1-2. <https://doi.org/https://doi.org/10.17141/letrasverdes.19.2016.2223>
- Fernández Calvo, I. C. (2019). 100 Medidas para la conservación de la biodiversidad en entornos urbanos. En Sociedad Española de Ornitología SEO BirdLife (Ed.), *Programas de cooperación e investigación* (1ª).
- González Vives, C. (2014). *Arquitectura antidesertización. Fluidez, biodiversidad, hidrofilia y transpirabilidad*. [Universidad Politécnica de Madrid]. <http://oa.upm.es/33774/>
- Lepczyk, C. A., Aronson, M. F. J., Evans, K. L., Goddard, M. A., Lerman, S. B., & Macivor, J. S. (2017). Biodiversity in the City: Fundamental questions for understanding the ecology of urban green spaces for biodiversity conservation. *BioScience*, 67(9), 799-807. <https://doi.org/10.1093/biosci/bix079>
- Segura Moreno, J. (2014). Biodiversidad en el ámbito urbano. *Jábega*, 106, 8-21.

# GIS-BASED INTEGRATED ASSESSMENT OF SEISMIC VULNERABILITY AND ENERGY EFFICIENCY: A CASE STUDY OF A NEIGHBORHOOD IN ARMILLA, GRANADA (SPAIN)

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**Keywords:** *Seismic Vulnerability, Sustainability, GIS, Energy Retrofitting*

## Abstract

Seismic vulnerability assessment enables the reliable prediction of a building's behavior during an earthquake. This is achieved by quantifying the risk of collapse, as well as human and material damages and losses. Specifically, Granada (Spain) and its surroundings are located in one of the highest-seismic-hazard zones in the Iberian Peninsula (Justo et al., 2008). Therefore, it is essential to analyze the potential earthquake risks in this urban context. Within this reality, two complementary scenarios coexist: buildings constructed under different seismic codes and criteria, and buildings constructed in accordance with current energy efficiency guidelines. This study addresses the case study of the urban center of Armilla, a town adjacent to Granada. It aims to apply an innovative methodology to jointly evaluate seismic vulnerability and urban sustainability. The ultimate goal is to establish an Intervention Prioritization Index (IPI) to enable informed decision-making for future interventions in the municipality.

The methodology focuses primarily on data collection and processing. For the structural evaluation of buildings, a hybrid checklist is used, employing Google Street View for preliminary checks and a fieldwork template for subsequent verifications. This approach seeks to capture pathologies that simultaneously affect both indices, such as material degradation, which influences both safety and insulation. Benedetti and Petrini's method is used to analyze critical parameters (Moreto Tuesta et al., 2021), such as the current structural system, material quality, predicted strength, building position, floor system typology, geometric configuration, critical connections, low-ductility elements, non-structural elements, and the general state of conservation of the building. In parallel, a series of sustainability variables is integrated. These indices focus on the thermal envelope's efficiency, evaluating glazing types, potential thermal bridges, and the theoretical inertia of the building enclosures.

The initial data processing is compiled into a conventional spreadsheet where the relative weights of each parameter are calculated. These data points are then normalized on a scale of 0 to 100. Finally, the results are integrated into a Geographic Information System (GIS), generating bivariate mapping that crosses seismic fragility with the building's energy analysis (Ferrari, 2025). The results obtained warn of a direct correlation between the presence of buildings with clear structural seismic vulnerability and energy inefficiency. This "double vulnerability" becomes more evident in urban areas with non-renovated buildings. Consequently, several critical sectors have been identified for prioritized intervention. In conclusion, this study indicates that comprehensive rehabilitation within urban environments in Granada should be approached from an "Integrated Retrofitting" perspective.

## References

- Ferrari, L. (2025). GIS-based Analysis for Seismic Vulnerability Assessment of Strengthened Masonry Churches: The Case of Parma (Italy). *The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, XLVIII-M-9-2025, 481–488. <https://doi.org/10.5194/isprs-archives-XLVIII-M-9-2025-481-2025>.
- Justo, J. L., Azañón, J. M., Azor, A., Saura, J., Durand, P., Villalobos, M., Morales, A., & Justo, E. (2008). Neotectonics and slope stabilization at the Alhambra, Granada, Spain. *Engineering Geology*, 100(3–4), 101–119. <https://doi.org/10.1016/j.enggeo.2007.12.007>.
- Moreto Tuesta, C., Mechato Jiménez, M. J., & Díaz Jáuregui, G. A. (2021). Vulnerabilidad sísmica estructural de instituciones educativas públicas, aplicando el método de benedetti-petrini. *Revista Científica UNTRM: Ciencias Naturales e Ingeniería*, 4(2), 57–65. <https://doi.org/10.25127/ucni.v4i2.728>.

# GEOMATICS AND SATELLITE-BASED MONITORING FOR URBANIZED COASTAL LANDSCAPES: A TECHNOLOGICAL INNOVATION FRAMEWORK FOR BUILDING AND TERRITORIAL PLANNING

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**Keywords:** *Urban-coastal landscapes, Pollution monitoring, GIS and Geomatics, Satellite remote sensing, built environment and spatial planning*

## Abstract

Urbanized coastal zones represent dynamic and environmentally sensitive landscape systems where marine processes, land-use transformation, and infrastructure development interact, often generating spatially heterogeneous pollution patterns that directly affect the performance and resilience of the built environment (Xu & Zhang, 2022). Within the context of technological innovation in building and territorial management, this study proposes a geomatics-based framework for the spatio-temporal monitoring of pollution in urban-coastal landscapes through the integration of multi-source satellite remote sensing, Geographic Information Systems (GIS), and advanced spatial analytics.

The proposed methodology constitutes a scalable, technology-driven monitoring workflow designed to support evidence-based planning and design decisions in settings where conventional ground-based pollution measurements are spatially discontinuous or temporally limited. The framework is applied to a representative coastal zone undergoing rapid agricultural intensification and urban expansion, where nutrient-related pollution indicators and complementary physical parameters derived from satellite platforms are employed as geospatial proxies to characterize hydrodynamic behavior, land-sea interactions, and anthropogenic pressures associated with drainage infrastructure, urban discharge, and coastal development.

Multi-annual datasets are processed through automated geospatial pipelines incorporating data harmonization, raster normalization, temporal aggregation, and correlation analysis. These procedures generate consistent spatial layers and time series suitable for pollution mapping, landscape assessment, and infrastructure evaluation (Chen et al., 2025). Results demonstrate that satellite-supported geomatics can effectively capture fine-scale spatial gradients and seasonal variability of pollution across coastal landscapes, facilitating the identification of differentiated zones influenced by both oceanic forcing and terrestrial inputs.

This analytical capacity provides actionable spatial intelligence to architects, engineers, and planners engaged in coastal construction, landscape design, and territorial regulation, supporting more adaptive and risk-informed development strategies. The framework functions as a decision-support system that translates satellite-derived pollution indicators into planning-oriented knowledge, converting complex environmental datasets into operational information for the built environment sector (Cai et al., 2023). Its modular architecture enables integration with digital landscape models, urban monitoring platforms, and smart territorial management systems.

Finally, the methodology is transferable to other coastal landscapes experiencing comparable pollution pressures and can be adapted to diverse geographic and regulatory contexts. This highlights the strategic value of geomatics and satellite observation as enabling technologies for pollution-aware landscape management and innovation in building and spatial planning.

## References

- Cai, X., Wu, L., Li, Y., Lei, S., Xu, J., Lyu, H., Li, J., Wang, H., Dong, X., Zhu, Y., & Wang, G. (2023). Remote sensing identification of urban water pollution source types using hyperspectral data. *Journal of Hazardous Materials*, 459, 132080. <https://doi.org/10.1016/j.jhazmat.2023.132080>.
- Chen, L., Liu, L., Liu, S., Shi, Z., & Shi, C. (2025). The Application of Remote Sensing Technology in Inland Water Quality Monitoring and Water Environment Science: Recent Progress and Perspectives. *Remote Sensing*, 17(4), 667. <https://doi.org/10.3390/rs17040667>.
- Xu, W., & Zhang, Z. (2022). Impact of Coastal Urbanization on Marine Pollution: Evidence from China. *International Journal of Environmental Research and Public Health*, 19(17), 10718. <https://doi.org/10.3390/ijerph191710718>.

# ENVIRONMENTAL MITIGATION STRATEGIES THROUGH GREEN WALL DESIGN: A PROJECT PROPOSAL FOR THE ENERGY RETROFITTING OF THE FISCIANO CAMPUS (UNISA)

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**Keywords:** *green wall, living wall system, University of Salerno, energy efficiency*

## Abstract

The necessity of reducing climate-altering emissions compels a rethinking of the building envelope, no longer conceived as an inert barrier but as an active and "living" surface (Bellomo, 2009). This paper explores the potential of vertical green infrastructures (Green Wall Design) as a tool for redevelopment and energy efficiency (Skaran, 2015) with a specific application to university buildings.

Specifically, the work analyzes a pilot case study at the University of Salerno, focusing on Building E1 of the Faculty of Engineering. The research identified the south-facing façade as a critical and strategic area for testing the efficacy of vertical greening systems.

The proposed intervention involves the installation of a "Living Wall" system, integrated into the existing structure. Unlike a simple Green Façade (based on climbing plants), the design solution adopts vegetated modular panels anchored to a substructure, combined with the application of an additional insulation layer. A preliminary analysis of the current state of the perimeter walls guided the technological choice, aiming to optimize the building's thermal transmittance and surface mass.

The expected results highlight a dual benefit: on a microclimatic scale, the system contributes to reducing surface and surrounding air temperatures through evapotranspiration, as well as absorbing CO<sub>2</sub> and particulate matter; on a building scale, the "green cladding" ensures a significant improvement in passive energy performance, reducing summer thermal loads and winter heat losses. The UNISA case study thus serves as a replicable model for transforming the "grey" surfaces of public building heritage into resilient vertical ecosystems.

## References

- Bellomo, A. (2009). Pareti Verdi. Nuove tecniche. Sistemi Editoriali  
 Skaran, V. (2015). Exterior Green Wall Design. Images Publishing Group Pty Ltd

# TECHNOLOGICAL INNOVATION AS A CORE AXIS OF CONTEMPORARY SUSTAINABLE BUILDING

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**Keywords:** *technological innovation; sustainable building; BIM; educational infrastructure; innovation valorization*

## Abstract

Technological innovation has become a key driver in addressing the environmental, social, and economic challenges faced by contemporary building design (Azhari & Kim, 2020). In the context of educational infrastructure, particularly technical secondary schools, traditional construction models often fail to respond adequately to current demands related to energy efficiency, water management, indoor comfort, and long-term sustainability (Chatzipoulka et al., 2020). This paper presents a documentary and analytical approach to technological innovation as a core axis of sustainable building, emphasizing not only its technical implementation but also its capacity to generate measurable value and real-world impact.

The research is structured as a case-study-based analysis supported by mixed qualitative and quantitative methods. Advanced digital tools such as Building Information Modeling (BIM), energy simulation, water efficiency analysis, and Life Cycle Assessment (LCA) are integrated to evaluate the performance of a sustainable architectural prototype for educational facilities. The methodology follows recognized innovation and sustainability frameworks, ensuring technical rigor, reproducibility, and transferability to different contexts (International Organization for Standardization, 2006).

The proposed model incorporates bioclimatic design strategies, passive solar control, cross ventilation, efficient material selection, and renewable energy systems (Azhari & Kim, 2020). Simulation results indicate a potential reduction of approximately 40% in energy consumption, a significant decrease in CO<sub>2</sub> emissions, and up to 70% savings in potable water consumption through rainwater harvesting strategies. Additionally, indoor environmental quality analyses suggest improved thermal comfort conditions, which are directly linked to enhanced academic performance and user well-being (Chatzipoulka et al., 2020; D'Oca et al., 2018).

Beyond technical performance, this research highlights the importance of the valorization of innovation. The study analyzes how technological solutions can be transformed into viable, scalable, and transferable assets for both public and private sectors. By aligning innovation with market needs, public policy frameworks, and existing construction supply chains (European Union, 2018), sustainable building strategies move from theoretical proposals to implementable solutions with industrial applicability.

The findings demonstrate that technological innovation in building design is not merely a theoretical concept but a practical tool capable of transforming educational infrastructure. When innovation is approached holistically—integrating design, performance assessment, economic viability, and knowledge transfer—it becomes a catalyst for sustainable development (Cohen & Bordass, 2015). This contribution provides a replicable framework that supports decision-making processes, encourages the adoption of innovation, and reinforces the role of sustainable buildings as active agents of educational, environmental, and social transformation.

## References

- Azhari, M., & Kim, J. (2020). Energy-efficient design strategies for sustainable school buildings: A review. *Sustainable Cities and Society*, 63, 102450. <https://doi.org/10.1016/j.scs.2020.102450>
- Chatzipoulka, C., Nicol, F., & Wilson, M. (2020). Adaptive thermal comfort in school buildings: A critical review. *Energy and Buildings*, 219, 110024. <https://doi.org/10.1016/j.enbuild.2020.110024>
- Cohen, R., & Bordass, B. (2015). Assessing building performance in use: The PROBE studies. *Building Research & Information*, 43(1), 4–22.
- D'Oca, S., Hong, T., & Langevin, J. (2018). The human dimensions of energy use in buildings: A review. *Renewable and Sustainable Energy Reviews*, 81, 731–742.
- European Union. (2018). Directive (EU) 2018/844 on the energy performance of buildings. *Official Journal of the European Union*.
- International Organization for Standardization. (2006). *ISO 14040: Environmental management—Life cycle assessment—Principles and framework*. ISO.

# FROM LABORATORY DESIGN TO IN SITU VALIDATION: A METHODOLOGICAL FRAMEWORK FOR GEOPOLYMER MORTARS IN HISTORIC MASONRY

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**Keywords:** Geopolymer mortars; Historic masonry; Heritage conservation; Pilot intervention; Non-destructive monitoring

## Abstract

Historic masonry should be understood as a dynamic system in which moisture exchange, salt presence, microclimatic conditions, and material discontinuities govern alteration processes that are often slow yet cumulative. In this context, innovation in conservation materials cannot rely solely on laboratory optimisation and validation but must also be tested through application procedures and monitoring strategies capable of assessing performance over time.

This study proposes an integrated approach for the design and in situ application of geopolymer mortars for repointing porous historic masonry. Compatibility is addressed as a balance among physicochemical, hygrometric, mechanical, and chromatic and aesthetic requirements, while reversibility is considered an operational criterion aimed at reducing intervention impact and improving maintainability. The research is organised into three integrated stages—documentary analysis, laboratory experimentation, and full-scale verification—with the objective of linking performance under controlled conditions to behaviour in real application settings, while making explicit the variables that may influence system response on site.

Within this perspective, geopolymers are considered not only for their sustainability profile, including the potential to reduce CO<sub>2</sub> emissions compared with conventional binders (**Davidovits, 1989**), but also for their capacity to valorise secondary raw materials, including fractions derived from construction and demolition waste (**Liguori et al., 2017**), which may show material affinity with historic brick and stone substrates (**Ricciotti et al., 2017**). At the same time, the versatility of these systems makes scale transition essential: laboratory testing allows formulations to be selected and compared, whereas only in situ application can verify their actual suitability, practical compatibility, and short- to medium-term stability (**Capasso et al., 2023**).

The research is centred on a pilot intervention carried out at the archaeological complex of *Carminiello ai Mannesi*, in the historic centre of Naples, selected as a case study because of its urban exposure and complex microclimatic conditions. The intervention forms part of a broader doctoral research programme focused on the characterisation of geopolymer mortars for heritage conservation through physical and mechanical testing, durability assessment, and colourimetric evaluation.

For the in situ application, a chabazitic tuff-based geopolymer mortar was selected as the formulation best matching the yellow Neapolitan tuff substrate. Application followed a controlled sequence including cleaning, pre-wetting, progressive placement, compaction, and finishing.

From the earliest stages, the pilot intervention was accompanied by a non-destructive monitoring programme based on a post-application baseline and periodic surveys, including photographic documentation, mapping, surface moisture and salinity measurements, assessment of surface-layer condition, and colourimetric measurements. Early short-term observations have not revealed microcracking, dusting, significant chromatic alteration, or salt-related manifestations, suggesting a promising initial response under site-specific conditions. Although preliminary, these findings suggest that the proposed method offers a credible route for translating material innovation into responsible conservation practice by explicitly linking laboratory design, in situ application, and verification over time.

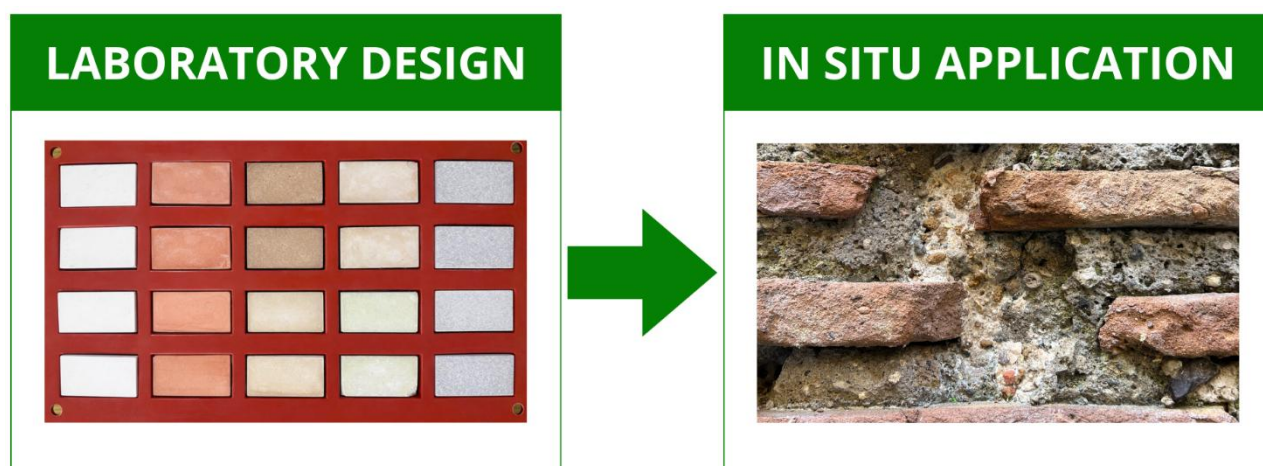


Fig. 1. Bridging laboratory research and in situ application in the development of geopolymer repointing mortars for built heritage conservation.

## References

- Capasso, I., D'Angelo, G., Fumo, M., Del Rio Merino, M., Caputo, D., & Liguori, B. (2023). Valorisation of Tuff and Brick Wastes by Alkali Activation for Historical Building Remediation. *Materials*, 16(20), 6619. <https://doi.org/10.3390/ma16206619>
- Davidovits, J. (1989). Geopolymers and geopolymeric materials. *Journal of Thermal Analysis*, 35(2), 429–441. <https://doi.org/10.1007/BF01904446>
- Liguori, B., Capasso, I., De Pertis, M., Ferone, C., & Cioffi, R. (2017). Geopolymerization Ability of Natural and Secondary Raw Materials by Solubility Test in Alkaline Media. *Environments*, 4(3), 56. <https://doi.org/10.3390/environments4030056>
- Ricciotti, L., Molino, A., Roviello, V., Chianese, E., Cennamo, P., & Roviello, G. (2017). Geopolymer Composites for Potential Applications in Cultural Heritage. *Environments*, 4(4), 91. <https://doi.org/10.3390/environments4040091>

# THERMAL AND PHYSICO-CHEMICAL PERFORMANCE OF SHEEP WOOL AS A BIO-BASED BUILDING INSULATION

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**Keywords:** *Decarbonisation; Natural Insulation; low impact; high performance*

## Abstract

The demand for low-carbon building envelopes is accelerating the search for insulation materials that are renewable, locally available, and performance-competitive with conventional mineral-based solutions. Sheep wool has attracted growing interest as a bio-based thermal insulation due to its naturally crimped fibrous morphology, high porosity, and the keratin-based structure that can provide stable performance under typical service temperatures. Previous research has demonstrated that wool-based insulations can achieve thermal conductivities within the range required for building applications, while highlighting the strong influence of bulk density and fibre packing on heat transfer mechanisms (Corcadden et al., 2014; Ye et al., 2006).

This work evaluates the thermal and physical performance of felted sheep wool panels produced at controlled densities, establishing a structure–property relationship supported by complementary microstructural and thermo-analytical characterization. A total of three sample densities were manufactured by felting using identical geometry ( $24 \times 24 \times 5 \text{ cm}^3$ ): 30, 60, and 100 kg/m<sup>3</sup>. Thermal conductivity was measured for each density condition, showing a clear density-dependent trend. The obtained values were 70 mW/m·K (30 kg/m<sup>3</sup>), 50 mW/m·K (60 kg/m<sup>3</sup>), and 35 mW/m·K (100 kg/m<sup>3</sup>), indicating a substantial improvement in insulating performance as densification increased. This behaviour is consistent with the progressive reduction of pore size and the suppression of internal air movement as fibre packing becomes more compact, as reported in prior wool insulation studies.

To support the interpretation of the thermal results and assess suitability for building use, additional characterization was conducted. Scanning electron microscopy (SEM) was used to visualise fibre entanglement and microstructural consolidation after felting, while X-ray diffraction (XRD) was employed to examine structural ordering in the keratin-based matrix and potential processing-related changes. Furthermore, DSC and thermogravimetric analysis (TGA) were performed to describe thermal events and degradation behaviour, providing relevant information for processing limits and expected thermal stability in service conditions. Complementary performance indicators were also explored through total water absorption testing, addressing the moisture-related behaviour that is critical for natural fibrous insulation materials in real building environments (Ahmed & Qayoum, 2021; Ye et al., 2006).

Finally, the results were benchmarked against commercial rock wool insulation, enabling a direct contextualization of sheep wool performance relative to a widely adopted reference material. Overall, the study positions felted sheep wool as a technically promising bio-based insulation and provides density-driven insights to guide product design toward competitive thermal performance and practical durability.

## References

- Ahmed, A., & Qayoum, A. (2021). *Investigation on the thermal degradation, moisture absorption characteristics and antibacterial behavior of natural insulation materials*. **Materials for Renewable and Sustainable Energy**, **10**, 4. <https://doi.org/10.1007/s40243-021-00188-8>
- Corcadden, K. W., Biggs, J. N., & Stiles, D. K. (2014). *Sheep's wool insulation: A sustainable alternative use for a renewable resource?* **Resources, Conservation and Recycling**, **86**, 9–15. <https://doi.org/10.1016/j.resconrec.2014.01.004>
- Ye, Z., Wells, C. M., Carrington, C. G., & Hewitt, N. J. (2006). *Thermal conductivity of wool and wool–hemp insulation*. **International Journal of Energy Research**, **30**(1), 37–49. <https://doi.org/10.1002/er.1123>

# AUTOMATION IN STRUCTURAL DESIGN

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**Keywords:** structural design, BIM, automation

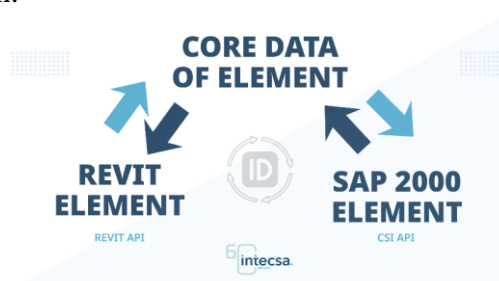
## Abstract

Structural design increasingly relies on complex digital environments in which geometry, analysis, and documentation coexist but rarely communicate seamlessly. Despite the widespread adoption of BIM and advanced calculation software, structural workflows remain fragmented, highly manual, and vulnerable to inconsistencies between models, calculations, and reports. Routine operations such as model rebuilding, data re-entry, load reassignment, and update tracking consume a disproportionate amount of engineering time while offering little added design value. This paper investigates automation as a systematic response to these challenges, proposing a data-centric approach to structural design that prioritizes continuity, traceability, and quality control.

Rather than treating automation as a set of isolated scripts or productivity shortcuts, the presented research frames it as an integrated design methodology. The core idea is to establish a fluid and rule-based data flow between BIM models and structural calculation environments, where each element carries not only geometry but also consistent identifiers, parameters, and engineering logic. In this context, BIM models function as structured databases capable of storing, updating, and validating structural information throughout the design process, rather than serving solely as sources of drawings.

The proposed approach was developed and tested through its application on real structural design projects, allowing the research to evaluate automation under practical conditions, including frequent design changes and evolving input data. Two applied examples are presented. The first demonstrates automated generation and updating analytical models derived from BIM data, ensuring consistency of geometry, materials, and element properties across design stages. The second example focuses on the automated creation of load and load combinations based on predefined engineering rules, enabling systematic alignment with calculation reports while introducing automatic checks for missing or inconsistent data.

The results show that this approach significantly reduces repetitive manual work while improving model consistency and transparency. Automation acts not only as a productivity mechanism but also as an additional layer of verification, capable of detecting discrepancies early and improving overall design reliability. The study concludes that rule-driven automation, guided by engineering judgment, can transform structural design workflows into more resilient, auditable, and efficient systems, with clear implications for both professional practice and engineering education.



**Figure 1:** Data exchange workflow.

## References

- R. A. Docs, «Revit APP Docs,» 25 September 2025. [En línea]. Available: <https://www.revitapidocs.com/>.  
I. Computers and Structures, CSiXRevit 2020, Berkley, United States: Computer and structures Inc, 2020.