



# **The potential applications of eco-materials in improving sustainability in buildings: the case of cork**

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## **Abstract**

The use of natural materials in the construction and retrofitting of buildings is a recent strategy used to increase the environmental sustainability of cities. In this sense, the Iberian Peninsula concentrates 85% of the cork world production, a natural material with significant properties for the building sector. This study presents the results of a comprehensive analysis conducted by a project team made up of professionals from different sectors: building, energy efficiency, product design and ecology. The analysis comprises panels of experts, creativity sessions and questionnaires. This analysis aims to identify possible potential applications of cork into buildings, in addition to the existing ones; taking into account its physical, aesthetical and environmental properties. Regarding the physical properties of cork, its insulation capacity makes possible its current extended use as thermal and acoustic insulation material in the building envelope. But also due to its great water vapour permeability and good mechanical properties, cork can be used in the construction of green roofs, green façades or lightweight roofs. Moreover, cork is the only insulation material that can be installed without external cladding, because of its level of degradation. In this sense, the cork sector has to introduce design in this kind of products to help the acceptance of the strong visual aesthetic of cork. In short, the aesthetic of cork has to be promoted as a hardwood and natural material; and communicate the genuineness and purity of this material. In conclusion, the use of cork in buildings also contributes to the decrease of the environmental impacts and energy consumption, because of being a natural material and with high possibilities of recycling, reusing and recovering



in the end-of-life of the building. For this reason, it is advisable to extend the life cycle approach in the selection of building materials and building ideation.

*Keywords: sustainable construction, cork, insulation material, creativity, product design.*

## 1 Introduction

The cork material is extracted from the cork oak (*Quercus suber* L.) forests, one of the best examples of balanced conservation and development in the world. The cork oak tree is a long-lived species (250–350 years) with an outer bark, or cork. Cork extraction is a sustainable process because it does not damage the tree, and following extraction, new bark regrows. This process occurs every 9–14 years, depending on the area, until the tree is approximately 180–200 years old [1]. The majority of cork exploitation is concentrated in Portugal and Spain, with these two countries providing 80% of the cork extracted worldwide (161,504 tonnes) [2]. Cork has a significant physical properties, among them cork is elastic, impermeable, light, absorb impacts and good thermal insulation [3]. Nowadays, the market of cork is mainly focused in the wine sector, 80%; but due to its good properties, cork has a high potential for new applications. Portuguese cork sector has developed new products for different markets, among them: transport, furniture, lighting or covering (Figure 1). But these examples are still a minority, and the sector not takes advantage of its properties, and is fully oriented towards conventional products and applications.

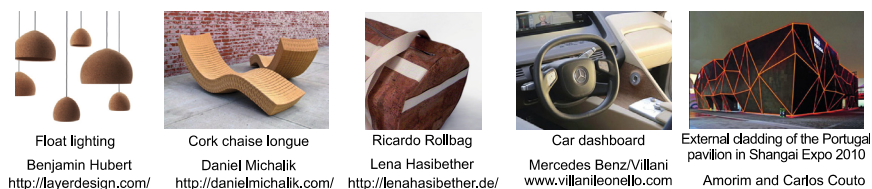


Figure 1: Examples of cork applied as material.

The potential of cork as insulating material applied in construction is perceived as an opportunity for which a series of creative activities have been carried out to define ideas of new applications, concept generation and the validation of these based on criteria of technical, market impact and improvement in the life cycle. The use of creative techniques pertains to the process of product design and also it is applied on eco-design and eco-innovation in reducing the environmental impact. The main difference between eco-design and eco-innovation is the target expected as a result of the applications of these techniques, eco-design [4] is useful for integration of changes and improvements in product redesign due to the results of applying quantification tools such as LCA. However, eco-innovation [5] involves novelty, is aimed at generating new solutions in products and processes and the generation of assessable concepts through the aforementioned tools.

## 2 Objectives

The main objective of this work is to make visible the qualities of cork as a natural material of great quality and potential for new applications in the context of the construction, taking into account the significant properties of cork. It is intended to propose the cork as an alternative to the most commonly used materials in construction, these materials have been evaluated with a high environmental impact [6, 7].

The environmental diagnosis of thermal insulation products currently used in the construction sector is an objective. And the main cork insulation products, agglomerated and expanded cork boards, are also discussed. It aims to identify and analyse potential cork niche markets for market diversification.

To achieve this goal, it is necessary to develop a study and analysis of: the current situation in the cork market, the potential for the introduction of new insulation applications in the construction sector and its impact on the environment and the market. This analysis has been conducted by an interdisciplinary group of specialists in fields like construction, ecology, energy efficiency and product design. The objective is to get ideas and input from experts from various disciplines that intersect in the common objective of the analysis, the contributions have been obtained in a creative session to generate ideas and developed in an evaluation session to define new concepts in the field of construction.

The results of the creative workshop establish the specifications to produce concepts that meet the targets of synthesis of ideas. These ideas were evaluated according to a set of predetermined criteria, this assessment will serve to apply the findings in order to fully define the concepts and prioritizing the potential of each concept.

## 3 Material and methods

This study is part of a project where the possibilities for the introduction of cork in the building sector in a more extended way are analysed. First, the systems for the insulation of building are assessed from an environmental approach. Second, the current cork insulation products are also analysed and compared with the most common insulation materials in Europe. Finally, from the conclusions of the previous studies, the ideation of new cork products used in building is proposed and presented in this study.

The whole creative process developed for this study is structured into four stages, within these stages can be found two kind of sessions, divided by objectives, techniques and participants. Two specialist have been conducted the stages for preparation and reviews and also have been coordinated and summarized the creative process. The creative session run as a creative workshop. The creative session is a process where the techniques are based on problem analysis and idea generation, and participants have a deep technical knowledge or have a profile linked to construction. The session for concept generation aims to assess the previous ideas applying evaluation and selection techniques.



The structure of the whole creative process follows the scheme presented in Table 1.

Table 1: The structure of the whole creative process.

Stage	Activities
Preparation of creative sessions	Definition of objectives, structure and preparation of creative sessions. Selection of creative methods. Time management. Resources, materials and expert group selection.
Creative session	Idea generation, discussion and conclusions. Exposition and application of creative methods, recording of ideas, debate and final summary of the session.
Review and concept generation	Review of the material generated in the creative session. Transcription of the recordings. Hierarchization of ideas and concept generation.
Review and final synthesis	Analysis of the data recorded in the session evaluation, review and management thereof, conclusions and final synthesis of the concepts evaluated.

### 3.1.1 Preparation of the creative session

The sessions are structured and defined by two specialists in product design, one with expertise in eco-design and eco-innovation, and the other with experience in management of creative methods and groups. The activities are planned based on the objectives set out above.

To properly coordinate the creative session, these are divided into two parts: the first consists in an inductive phase to generate ideas spontaneously and the second is a creative phase leading to established objectives. In the preparation of each part, the time allocation fits the creative methods selected and the number of participants. For each part of the creative session its own methods are established, the first part using divergent methods with no established objectives, and the second part using converging methods focused on targets.

It is also necessary to check the requirements of the workshop, list the materials needed for the development of the sessions and how to record the ideas. The materials required for the workshops are very basic, computer and video projector for presentations, cards and photocopied datasheets for recording ideas, sticky notes, and audio and video recorder for groupware.

The participants' selection is done based on the objectives of the session and their knowledge. For the creative session profiles of technical experts in construction, environment and energy efficiency are requested combined with designers and creative people, the aim is that creative people made questions and suggestions for new ideas to be introduced in the construction and building sector, and the experts in this field are able to answer and complete the ideas with their specific knowledge. The group of specialists is wide, and in every activity the group has been divided into smaller groups, maintaining the diversity of profiles. The methods of the creative session are based on consultation to the expert. These

methods have been modified and adapted to record ideas in an appropriate manner to enable further processing and use.

The reviews and concept generation sessions were carried out by the two previously mentioned specialists. The method for idea selection is the checkered, where aspects of every idea are evaluated on a scoreboard on various criteria.

### 3.2 Creative session

The creative phase begins with the presentations of: the invited participants, the objectives of the session and data related to the cork sector and existing applications. After these short presentations, the creative technique to be carried out in the initial phase is exposed, in this case it is a random input method based [8] on the technique of “forced relationship” [9]. The initial session is an inductive phase [10, 11] for participants to know each other and creates a supportive work environment for creativity. At this stage there is no limitation of thought and it is intended that participants feel comfortable during the session, the initial session have to plot the line of thought for the rest of the session and working on the target subject. In this case the target is the new cork applications enhancing its features in various areas of application within the construction sector, it seeks to establish new “feature + area of application” partnerships through forced relations.

The method consists of thinking of new applications based on relationship that involves a feature and an area of application in construction. The feature and the area of application come randomly from two decks of cards, one for features and the other for areas of application. The ideas are recorded on datasheets with three columns, the first one registers the product idea, the second the particular application and the third the comments raised in the debate between the group participants. On each datasheet the combination of the two random words used is noted. If the two words no longer generate more ideas, two new words are randomly taken out and the process continues. If new areas of application or features proposed by participants arise during the generation of ideas, anonymous cards can be used. The aim of the activity is to generate a large number of ideas with comments for each. After the activity ends, every idea is read and comments or remarks on each idea are recorded on the datasheets.

After the first part of the workshop, there is a coffee-break, then the session continues with the idea generation that will lead to the concept generation. In this part of the session, some solutions about insulation in buildings made with other non-renewable materials, with similar characteristics to cork, are presented. Again, the group is divided into two, participants are mixed from the previous session. The objective of this part is fully explained; synthesize ideas well-defined and detailed for the application of cork as insulation material in the construction sector. The session is a debate within the group, which begins with a series of questions prepared and related to the problems encountered in the insulation materials used in construction.

In this session the ideas are recorded in a table in which there are four columns, the first column will record the problem solved for each idea (WHAT), the second the way it is solved (HOW), the third the difficulties to be solved and the fourth the elements that differentiate this solution from other existing ones. It

also has a datasheet on which the pros and cons of each idea and comments that arise in the debate are recorded. The interview is a creative technique based in “the art of questioning” [12,13], a debate between the creative and experts is developed using prepared questions, in order to generate hypotheses to validate and develop later.

The method consists of preparing a list of questions related to the purpose of the session, which treat problems involving high knowledge on the subject for answers from experts. Each group has a leader who directs, moderates the session and records the ideas in the datasheets. Then, the leader starts the discussion with a question from the list, participants start a debate and every idea is recorded by filling the columns in the table. When the idea generation for each question ends, then a new question from the list is posed. Once the number of ideas is high enough the leader asks the group to list the pros and cons of each idea in a different datasheet. At the end, the ideas of each group are read; comments or remarks on each idea are made and recorded on the datasheets.

At the end, there is a summary of the whole workshop and the group concludes with a few general ideas to develop later, these conclusions portray the main developing lines that describe the future concepts.

### 3.3 Review and concept generation

All the recordings and tables are gathered and reviewed, then there is a time for transcription of the audio recordings that allow to complete the datasheets and tables in order to extract the details that can be missed during the debate. The video recordings allow to extract visual expressions of the participants, which cannot be registered by writing or by the audio. All the ideas from the workshop are listed and hierarchized, some of the ideas are grouped by analogy and some others are combined. The main lines summarized at the end of the previous session are the scaffold to build the concepts following the points presented in Table 2. All the details from the transcriptions will help to describe the concepts.

Table 2: Main points for concept definition.

	Point for concept definition
<b>Problem</b>	A brief description of the identified problem to solve. The description is based in the comments of the experts in construction and data registered in the four columns table.
<b>Existing solution</b>	The already existing solution, that represents the state of the art in building isolation with other materials, based in the comments of the experts in materials and energy efficiency.
<b>Benefits</b>	The benefits by the use of cork in that problem, based in the knowledge of the previous market study and characteristics of the cork brought by the experts in cork materials.
<b>Technical definition</b>	The technical definition of the solution based in the details expressed by all the participants in the discussions and registered by the audio and video recordings.
<b>Technical requirements</b>	The technical requirements to develop the solution based on the datasheet of pros and cons registered during the second session.

### 3.4 Review and final synthesis

Once completed the creative session, the specialists in product design collect and organise all the extracted information, also reviewing the recorded information. From this information, concepts are developed based mainly from the second part of the session and using also short ideas in the first part. The requirements established for concepts are evaluated from different criteria: the degree of technical and economic feasibility, the impact on the market and the improvement in the life cycle of existing products. "During the creative session, experts have commented the pros and cons of cork as building materials. These comments are used to completely define the concepts.

## 4 Results

The creative session results in different type of information and ideas; these ideas have diverse level of definition because the generation process was different.

In the first part of the session, a large number of ideas were generated (Table 3). As commented above, ideas were generated from the forced relationship between a cork feature and an area of application. Ideas were organised and defined with the final comments of the discussion part. The most highlighted ideas of product were related to coverings; external cladding for façades; light structures and roofs for different types of building; take advantage of the cork properties of cork such as good thermal inertia and its permeability to the water vapour; use of cork in the current sustainable architecture systems: green façades and roofs; other novel applications: blinds, building entirely made of cork, cork as water purifier on roofs.

At the end of the first part of the session, all the generated ideas were discussed and the main pros and cons of cork were commented. These comments, in addition to those discussed in the second part, are summarised in Table 4, and they have been used to define the final concepts.

The second part of the session was mainly focused in the problems and needs identified in the current insulation of building. Experts from energy efficiency, architecture and construction commented this topic from a professional point of view. Based on these problems, and taking into account the cork properties, new ideas of product to solve these problems were generated. These ideas were developed further into a discussion among all participants of the session. Table 5 presents the main concepts of product, after the processing of the recorded information.

As commented above, the most interesting concepts have been further developed following the comments of pros and cons presented in Table 4. Finally, each concept is evaluated from different criteria. The *technical and economic feasibility* criterion is measured based on the state of the art to produce the new product. If the product can be already produced without a significant investment the valuation is 10, if the manufacturing processes have to be adapted and investments have to be made the valuation is 5, and if to produce the new product,



Table 3: Main new ideas for cork application in the building sector.

Pair of words	Product idea	Application
· Toy · Lightness	Floor slabs	Floor in playroom
· Wellness · Non-toxic	Floor textured non-slip	Changing room, spa, pool
· Wellness · Shock absorption	Anti-impact and anti-noise laminate	Kitchens, hallways, hotels, libraries, hospitals
· Sustainable · Mechanical strength	Bearing wall of cork, acoustic and thermal insulation	Structural partition
	External cladding for façades	ETICS without external cladding for insulation board
· Security · Impermeable	Protective pipes and electrical pipes	It could place exposed pipes, avoiding embedding in walls
	Slip and permeable coating	Coating showers and tubs
· Elastic · Retrofitting	Building retrofits	Applications such as sealant
· Lightness · Security	Light structures, building roofs	Construction of industrial buildings, lightening the overall weight
· Thermal inertia · Lightness	Change the thermal inertia of a wall	Thermal insulation of walls and roofs
· Environment · Chemical agent resistant	Water purification on roofs for domestic consumption	Green roofs, used as substrate, gathering and debugging water
· Environment · Hydroponic	Green façades	Retains moisture. Material for making drawers for plants that do not require substrate
	Green roofs	Using cork boards as insulation and as substrate on roof
· Sanitary · Chemical agent resistant	Coating for operating rooms	Walls and ceiling coating
· Machinery · Acoustic insulation	Soundproofing of industrial buildings	Walls and ceiling coating
· Impermeable · Sustainable	Coating of roof	Roof tiles
	Blinds	Moulded into the window. Rainproof and insulation
	Building made entirely of cork	Emergency modules for temporary camps
	Integration of external furniture on the facade	Eaves of the facade used as external banks and flowerpots



Table 4: Summary of comments from experts on the pros and cons of cork.

Pros	Cons
Water vapour permeability Possibility of using as external cladding Thermal inertia Acoustic insulation Mechanical strength Environmental aspect New wave for natural materials use Good hygrometry Good end of life Not burn	Price Degradation and colour changes Aesthetic limitation Limited range of insulation products Rudimentary products, processes are very archaic. Without design Synthetic agglutinants in cork agglomerated products Adhesion problems
Comments	
It should be able to control the aesthetic variability Change the manufacturing process to obtain boards with larger dimension. Expansion process in autoclave. Modular thickness to get the required one. It has a good performance in wet environment. It allows the ventilation of moisture through transpiration Natural and pure material. These attributes have not been properly communicated	

new technologies or research have to be developed, the valuation is 0. The *impact to market* criterion is evaluated depending on a similar product is or not already in the market. If not, then the valuation is 10; if a similar product made out of non-renewable material already exists, the valuation is 5; if a similar product made of cork exists, the valuation is 0. The *improvements in the life cycle* criterion evaluates if the use of cork to produce this product, generates some improvement in the life cycle of the building; if the improvements exist, the valuation is 10, if not the valuation is 0.

A summary of the evaluation for the 9 concepts developed can be seen in Table 3. The criterion for *impact to market* does not make any difference among the concepts, because all of them have the same value, 5; all the concepts have certain impact on the market and the novelty is the use of a natural material. There are 4 concepts with a 0 in the *improvements in the life cycle* criterion that can be discarded. There are 3 out of 5, with 10 in the *improvements in the life cycle* criterion, that have a 10 in the *technical and economic feasibility* criterion, these represents the most complete and the ones with the most interest due to the features of self-supporting, thermal insulation or a combination of both.

Table 5: Summary of the new ideas generated. Criteria: 1 – technical and economic feasibility; 2 – market impact; 3 – improvements in life cycle.

Problem or need detected	Product ideas	How?	Validation			
			1	2	3	TOTAL
Rehabilitation of external walls in historical buildings	Self-supporting of cork allows the reversibility of the actions by reducing the perforations.	Increasing the thickness to avoid buckling. Assemblies of boards keeping the vertical and horizontal continuity.	10	5	10	25
Irreversible moisture in the rehabilitation of historical buildings walls	Wall cladding system using cork boards	Minimising of structure used due to self-supporting of cork. Breathability to water vapour avoids the ventilation systems. Cork as internal cladding	5	5	10	20
Lightweight roofs are fragility	Substitution materials, adding value to the interior finishing	Analyse the substitution and other possibilities of structure materials, including fire resistance.	Board size	5	0	10
Increase the roof insulation	Green roof for agriculture to increase the insulation	Cork can be use as support with an air chamber of the roof combined with a structure.	5	5	10	25
Noise pollution in environments with high transit	Room partition for offices, museums, hotels	Using cork attached to a metallic or plastic structure, facilitating changes in distribution and improving the acoustic insulation of spaces.	Board size	5	0	10
Interior insulation systems use a large quantity of materials	Use cork boards to insulate interior walls without an intensive metallic structure	The self-supporting of cork allows to minimise the conventional anchoring systems or use a new system.	10	5	10	25
Reduce condensations	Multilayer board of wood and cork.	Insulation part with air chambers of alveolar forms. Wood as external and internal cladding.	0	5	10	15
Low insulation in mobile or portable houses.	Housing unit made of cork, minimising the necessary.	Cork could completely be the enclosure using a wooden lightweight structure	5	5	0	10
The aesthetics of the cork is not accepted	Design new attractive textures for boards without coverings.	Research common manufacturing processes to introduce new aesthetic. Process adaptation	Board size	5	0	10



## 5 Conclusions

The use of cork in the building sector is focused in the insulation boards, expanded or agglomerated. This study presents the potential applications of cork in new market niches due to the diverse concepts generated. Some specific physical characteristics of cork (self-supporting or water vapour permeability) show the potential for new application in buildings and they are the origin for new concepts of products such as the minimisation of materials used in the internal insulation systems or the treatment of moisture.

The interdisciplinary creative sessions increase the group knowledge, interchange information between participants in the discussion and also allow direct consultation to experts, obtaining immediate answers and the possibility to build concepts at the same time. On the other hand, the introduction of creative session has permitted us to get a large list of ideas. The analysis of these ideas allows establishing the concept requirements and determining a series of criteria to evaluate the concepts later. The evaluation of these concepts permits ranks them. On the criteria, the impact to market, has not been fully met. It would be interesting to refine the criteria in future sessions.

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