Cork

as a building material

Technical Manual

Portugal

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Cork as a Building Material
Technical Manual

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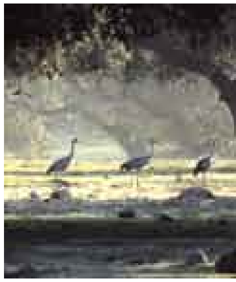
SUMMARY

Cork is a material that has accompanied mankind since ancient times distinguishing itself, at an early stage, in applications linked with construction, particularly in the Mediterranean countries, from where it originates.
At present, the use of cork in flooring, wall coverings and insulation has expanded worldwide due to the development of new cork-derived materials; the improvement of cork's characteristics; the growing importance of natural and sustainable materials as well cork's exotic character in some distant markets.
New products, new patterns and designs, new colours and applications have allowed the interest in cork flooring and wall covering products to expand, with new do- it- yourself installation techniques making it all the more easy.
Nevertheless, installers and final users are not always well aware of the characteristics of these materials and the best application and maintenance techniques - a void which this Technical Manual intends to fulfill.
The topics in this Technical Cork Manual are stated in the Index with bibliographical references indicated throughout the text for further details, information and conclusiveness regarding each subject matter respectively.

Index

1 Introduction

1.1 – The ecology of the cork oak forests



The European Union is the largest cork producer (> 80%), namely in the Southern Mediterranean countries, of which Portugal distinguishes itself (> 50%). The cork oak forests are extremely well-adapted to the semi-arid regions of southern Europe, preventing desertification and providing the perfect habitat for many animal and plant species. Almost the total amount of cork is processed in the European Union, which also imports some cork from Northern Africa, contributing thus to the European economy and employment market.
In addition to forestry production and the activities associated with cork harvesting, other activities such as hunting, beekeeping, mushroom and aromatic and medicinal herb picking are of great importance to these cork oak regions.
The cork oak forests have been a blessing to the wild fauna and flora. There is a mention of 42 dependant bird species, including some rare species in extinction. There are indications that in only 1m^2 of cork oak forest, 60 plant species have been identified. Other references show that the cork forests are the habitat of 140 plant and 55 animal species, a potentially incomparable fact on a European level (www.portalflorestal.com).
Given that cork oak trees can take up to 30 years to become productive, reduction in cork's economical viability can lead to insufficient investments in the cork forests. Saving the cork oak, increasing the forest areas, as well as the quantity and quality of cork produced and developing new products, of greater added value, are all fundamental aspects. An important economic loss in the activities of the cork industry, would lead to an uncertain future for the cork forests, promoting losses in biodiversity, land desertification, social imbalance and the disappearance of one of the most sustainable industries.

1.2 - What is cork

Cork is a material with applications that have been known since ancient times, some of them related to building, although it was mostly seen as a floating artifact and a closure, whose market, as of the beginning of the 20th century, underwent an enormous expansion namely due to the development of different cork based agglomerates. These agglomerates were considered a strategic material used in multiple applications, from wine closures to aeronautics.
By definition, cork is a parenchyma suberose originating from the meristem suber phelloderm of the cork oak (Quercus suber L.), consisting of the covering on the bark and branches of the cork tree. Macroscopically, cork is a light, elastic material, practically impermeable to liquids and gases, a thermal and electrical insulating material and acoustic and vibration absorber, being also innocuous and practically incorruptible, providing a compression capacity with practically no lateral expansion. Microscopically, cork is composed of cell layers, alveo-

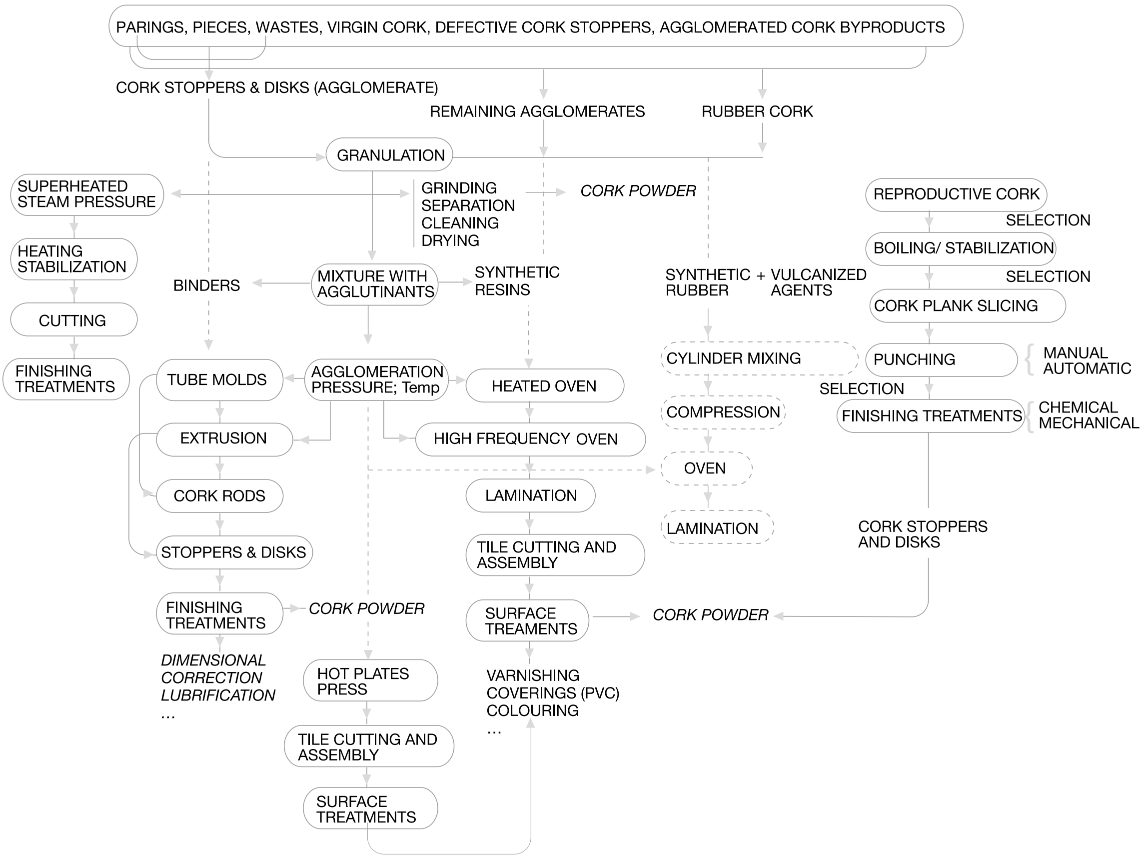
lar in shape, whose cellular membranes have a certain degree of impermeability and are full of a gas, usually considered similar to air, occupying nearly 90 % of its volume (Gil, 1998).
When cork is compressed, its cells become curved and bent, without practically any lateral expansion, with a subsequent recovery taking place given the compressed gas activity found in the cells' interior. Cork is, in addition, a material that disperses deformation energy. It has an average density of around 200 kg/m3, and a low thermal conductivity. Cork is also of a notable chemical and biological stability and is a good fire resistant. (Gil, 1998).

1.3 - Raw cork materials

Cork is extracted, mainly in summer, in the form of semi-tubular planks that are withdrawn from the trunk and branches of the cork tree, at a minimum legal periodicity of nine years (in Portugal). The harvesting begins after the tree has reached 0,7m in perimeter at 1,3m from the ground. The cork tree cannot be completely harvested of its suberous covering, as it may not survive such an operation. This activity is carried out manually, with the aid of an axe, although there already are existing mechanical processes.
The first harvesting (known as *"desbóia"* in Portuguese), produces cork called virgin, with a very irregular exterior surface. Successive harvestings give birth to cork with a more uniform exterior surface, known as reproductive cork or amadia. The first reproductive cork, still with some irregularities, has the specific name of "*secundeira*" (in Portuguese), and like virgin cork is mainly used for grinding, to obtain granules, for the subsequent production of agglomerated cork. When pruning the cork tree branches, a byproduct – "*falca"* - is obtained, a mixture of virgin cork, inner bark and wood, traditionally removed with an axe or adze or by using specific equipment (Gil, 1998; Oliveira, 2000).
In the manufacture of composition cork, the granules used are obtained by grinding virgin cork, other cork pieces, wastes and byproducts as a result of other processes, such as parings (from punching strips, cutting etc.), defective closures, left over agglomerates etc. In the manufacture of expanded agglomerated cork a larger granule size is used (Fernandez, 1971), obtained essentially by grinding "*falca"* and other lower grade cork.



Cork Manufacturing Processes Diagram



1.4 - Manufacture of cork products for the building industry

In taking, as a reference, the Portuguese Cork Industry into account, and dividing the various types of cork products available for construction in relation to the total number of cork products (Anonymous 2000), we obtain the following data, referring to some years back:

Agglomerates for coverings - 17 % (10 million m^2)
Expanded agglomerated cork– 6 % (150000 m^3)

Other Portuguese exports data obtained from I.N.E. (*Instituto Nacional de Estatística* – National Institute of Statistics - Portugal), referring to 2004, presented the following values:

- 4501.90.00.0 – cork byproducts, granulated or pulverized cork = 26269 tons
- 4504.10.91.0 – cubes, blocks, plates, sheets, strips, tiles, solid cylinders in agglomerated cork with agglutinant = 22463 tons
- 4504.10.99.0 – *ditto* without agglutinant = 28267 tons
- 4504.90.99.0 – agglomerated cork and agglomerated cork works = 15720 tons

The most common cork products used in building are: thermal, acoustic and vibration insulators (walls, ceilings, flooring); suspended ceilings; wall coverings, flooring and ceilings; baseboards; linoleums; granules as fillers and mortar mixtures; insulating, expansion or compression joints; and for industrial purposes: anti-vibration for machinery and insulation for industrial cold storage.

1.4.1 – Granulated cork

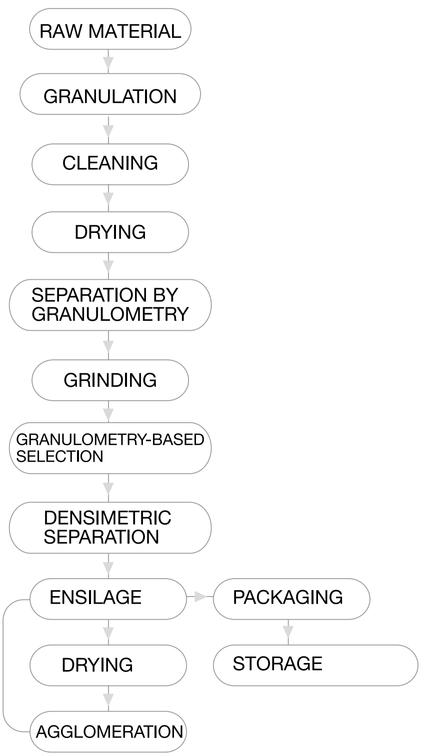
Granules are obtained by the operation of various mill types depending on the product to be ground and the desired granule type (EGF, 1982). For the most part a drying process, with circulating hot air, is also carried out, usually with rotating dryers, giving the granules the desired level of moisture.

1.4.2 –Composition cork

Composition cork is manufactured using granules and is the result of an agglutination process. The granules with a specific granulometry and volumetric mass are placed under the combined operations of pressure, temperature and an agglutinant agent, depending on the type of final product and the desired performance. Following the automatic or manual dosage operation, the mixture of the granules with the agglutinant, and potentially other auxiliary agents, is usually carried out by a mechanical process (usually in shovel mixers or helicoidals), using a roller process in the case of “rubbercork” (Gil, 1998).

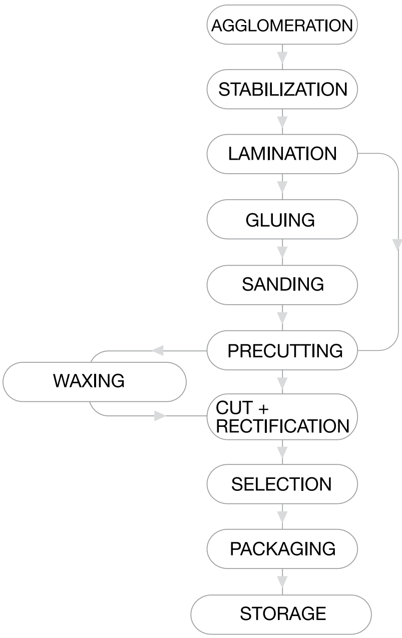
For example, in the case of composition cork for decorative purposes, a cork agglomerate with a density between 200 and 350 Kg/m^3 and granules of fine-medium caliber are used. Regarding composition cork destined for flooring, the den-

Granule Production Diagram

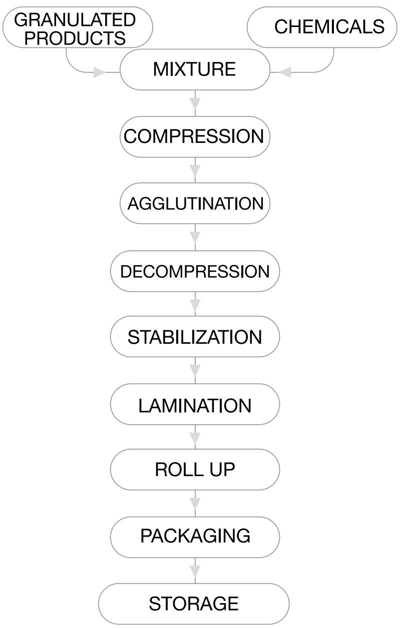


sity is normally superior to 450 Kg/m^3 and may attain 600 Kg/m^3 . Expansion joints are manufactured with granules of medium caliber and the agglomerated cork has a density of 250-350 Kg/m^3 (Gil, 1998).
To manufacture this type of cork agglomerate, synthetic resins of polyurethane, phenolics (phenol - formaldehyde) and melamines are mainly used, and also, at times, resins of vegetable origin (EGF, 1982; Pereira, 1988; Silva, 1982).
The mixture is measured and placed in molds, usually metallic and parallelepiped in shape (for the production of cork rolls, cylindrical molds are used), after which the lids are placed and compression takes place, locking the lids under a set amount of pressure. The molds, containing the pressed mixture, are placed in (for the polymerization of the agglutinants) which are either heated or are continuous (tunnels) or intermittent high-frequency systems . In the first instance, temperatures between 110-150ºC are generally applied, with a duration period between 4 to 22 hours (Gil, 1987; Silva, 1982). In the second case, fiberglass molds are used, being a much quicker process the curing lasts between 3 to 4 minutes (EGF, 1982; Gil, 1987).
After the “curing” process, the mold is removed and cooling/stabilization takes place resulting in a block of agglomerated cork that is laminated in sheets, at times, while it is still hot.
The next phase is sanding, which serves to correct cork’s thickness and attain the desired surface roughness. The sheets are then cut, usually in square or rectangular tiles, and are subject to dimensional and squareness corrections (Gil, 1998). In the case of cork rolls, these are “unrolled” by the continuous lamination of the cylindrical block, producing a continuous cork sheet which is thereafter rolled up.
The various types of decorative items and coverings are obtained by means of a simple cork sheet or by overlapping several types of agglomerated cork or laminated natural cork, or yet, by the composition of cork with other materials,

Cork Tile Production Diagram

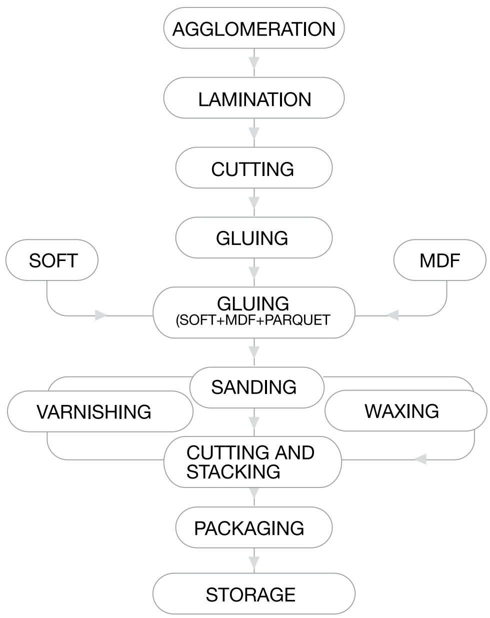


Cork Roll Production Diagram



namely agglomerated fiber or wood particles. This gluing operation is usually carried out with the aid of rollers or a press (Gil, 1987).
The boards, thus formed, can undergo various types of surface treatments: wax, varnish, various film coverings (for example, PVC) or even paint. When varnishing, a synthetic varnish (acrylic or polyurethane) is usually applied, followed by a treatment of Ultra Violet Radiation (UV) or by means of a forced hot air tunnel dryer. Agglomerated cork can also be coloured with pigmentation, during the agglomeration phase (mixture), or painted superficially, allowing for a diverse range of colours (Gil, 1998).
Some manufacturers have a sheet or tile selection phase according to colour tones (process carried out manually or automatically). Lastly, there is a manual/visual selection/rejection regarding defects (for example, broken corners, bad varnishing etc.).
There is also an agglomeration process (Gil, 1987; Silva, 1982) in which the mixture (granules + agglutinant + optional agents), with a desired granulometry, is distributed onto a conveyor belt and sent to a heated plates press resulting in a single sheet with a specific thickness and with operational parameters usually within the following values: Plate Temperature = 120-180ºC; Pressure = 5-15$^{\text{kgf/cm}^2}$; Pressure Duration = 3-8 minutes (Gil, 1998).

Floating Floor Manufacture Diagram



1.4.3 - Floating Floor Panels

The so-called floating floors are usually made of an intermediate layer of MDF or HDF (medium or high density agglomerated wood fibers), with an agglomerated cork sheet on the lower plane and a decorative agglomerated high density cork sheet on the upper plane. The attachment of the different layers is carried out by applying glue on both sides of the intermediate layer and thereafter on the upper and lower cork layers. This assemblage (or "sandwich") is then pressed together, with the use of heated or cold plates. The panels thus obtained may then undergo a surface treatment similar to that of traditional agglomerated cork flooring. After cutting the panels a specific size, the edges are milled to form the appropriate contour necessary for installation (for example, tongue-and-groove or the mechanical interlocking "click").

1.4.4 - Linoleum

For the manufacture of linoleum, the finest and densest granules are used, which in addition to oxidized linseed oil, resin, jute, saw, metal oxides and colouring, gives rise to a compact product, very resistant to wear and tear, easy to clean and essentially used for flooring (Gil, 1998).

1.4.5 – Agglomerated cork with rubber

Another type of cork based agglomerate, with quite a different manufacturing technology and with some different applications, is designated *"rubbercork"* or *"corkrubber"*. This type of agglomerate is used essentially for joints and flooring, mainly in places with high traffic (Gil, 1987; Gil, 1998). In its different formulations, and in addition to granulated cork and rubber, vulcanized agents, anti-oxidants, polymerization accelerators, colourings, etc, are also applied. The manufacturing process can be summarized as follows:

The mixture to be agglomerated - comprised of granulated cork, rubber (in powder form or small particles) and remaining agents - is homogenized, compressed and heated in rotating cylindrical mixers. The mixture is then passed onto a hot-press, until it forms a homogeneous mass (Garrett, 1946). This paste is cut into boards and is placed in molds, pressed and treated, much the same way as is the case of common composition cork (Gil, 1987; Gil, 1998), obtaining, thus, blocks which are then divided into specific dimensions. In the case of a high-frequency "curing" (EGF, 1982) the duration of the treatment is between 10-12 minutes.

1.4.6 – Expanded agglomerated cork

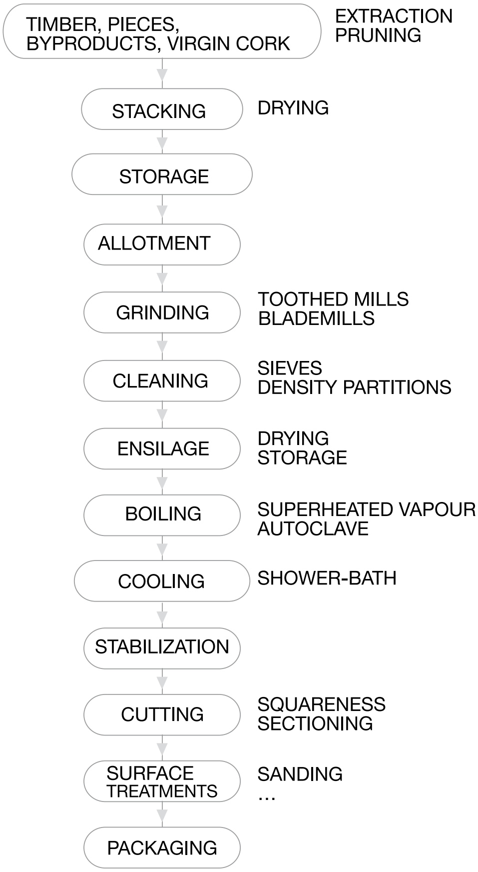
The expanded agglomerated cork industry uses cork, which is not normally processed in the other granule/agglomerate industries, in particular "*falca".* The use of unprocessed virgin cork, as is the case of "*falca"*, is positive, in that it has a higher extractive level compared to the remaining types of cork, functioning as a natural inter-granular binder.

The granulation process is similar to what is carried out on other types of agglomerated cork. The granulometry that is finally obtained is dependent on the job function of the agglomerate. For example, it can vary from 3 to 10mm for acoustic agglomerated cork and from 5 to 22mm for thermal agglomerated cork. The following phase eliminates the impurities, namely wood and inner bark, with the aid of density partitions (vibrating), sieves and lastly, pneumatic partitions or conveyor belts. Thereafter the granules are stored and dried until they reach an ideal moisture level. (Gil, 1998)

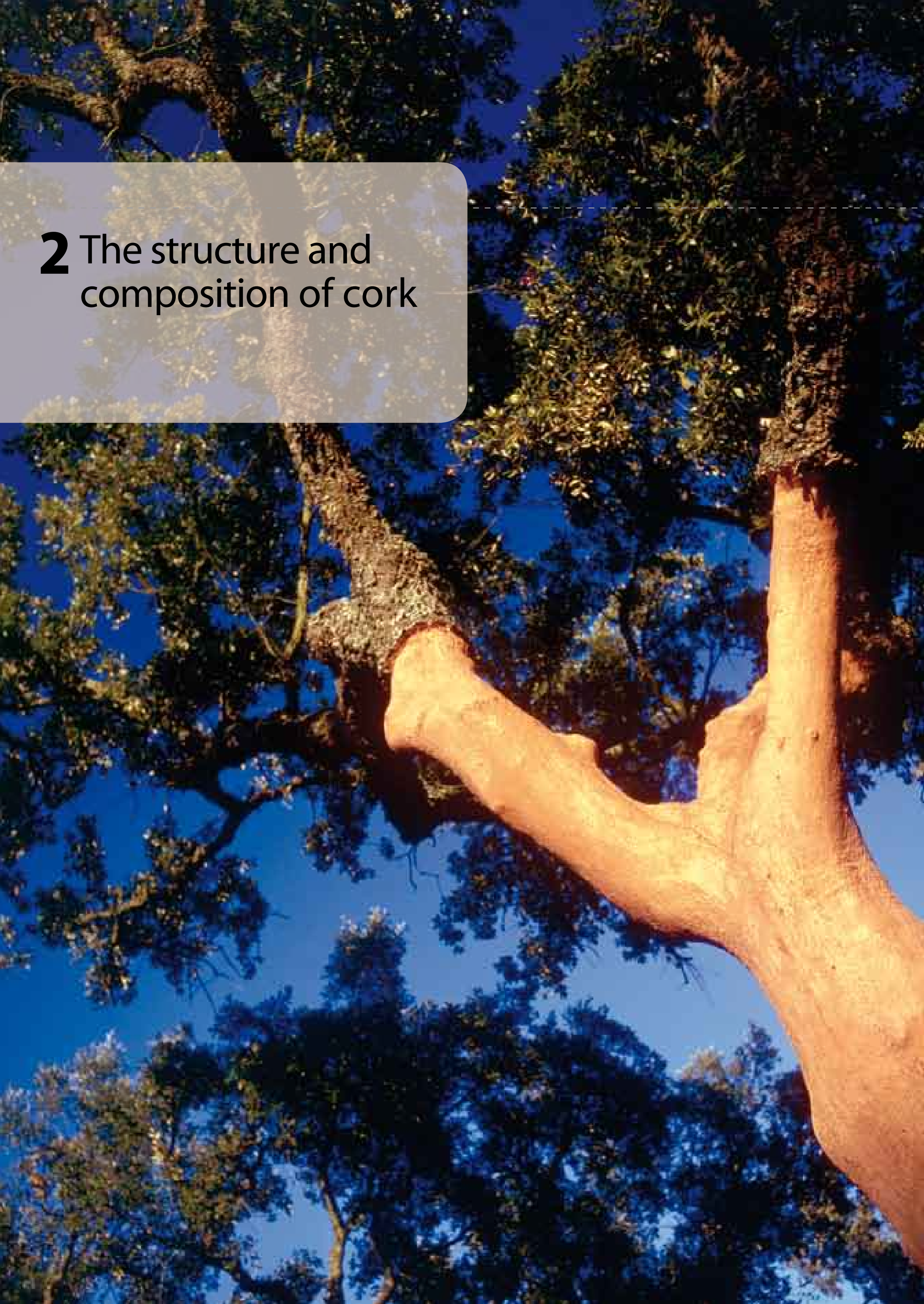
Agglomeration is carried out by an autoclave process that also functions like a mold. The granules are unloaded and after closing the mold are slightly compressed. The boiling process is carried out by steam, superheated to a temperature of around 300-370ºC. The superheated steam passes through the granule mass resulting in the secretion of the cork resin to the granule surface and an increase in its volume which, by being confined to an autoclave,

determines its agglutination. The boiling time, in the most common cases, is between 17 to 30 minutes (Gil, 1998), depending on the initial humidity level of the granules.
The manufactured blocks are then cut into boards of varying thicknesses, normally using a band saw, followed by corrections in size and squareness, usually using a disk saw. The slabs may still undergo sanding on one or both sides.
The rejected blocks (due to irregularities on the upper or lower sides) the defective boards or those obtained from demolitions, produce regranulated expanded cork by means of pulverization.

Expanded Agglomerated Cork Manufacture Diagram

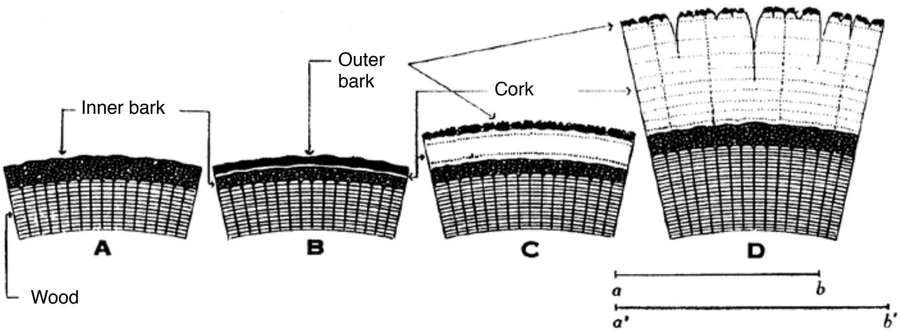


2 The structure and composition of cork



2.1 - Macroscopic structure of cork

When cork is extracted from the cork oak tree, the tree exposes the exterior part of its inner bark, which is being “pushed” by the successive layers of new cells that are formed in its interior, giving rise to what is known as *“raspa”* in Portuguese, the main constituent of the cork tree’s outer bark, that dries out, contracts and hardens, creating openings in the bark due to the growth process. Analogously, the internal part of the suberous tissue, which corresponds to the most recent layer of annual growth, is known as the “belly”. It is less elastic than the other layers and presents openings due to the lenticels (pores). The porosity is



strictly connected with the quality of cork (Gil, 1998; Oliveira, 2000). Virgin cork does not present *“raspa”* (outer bark).

Along the thickness of cork, growth rings can be observed that are distinguishable because of the cell formation, differing in dimension and wall thickness, which occurs during the spring/summer or autumn/winter seasons.

There are some exterior aspects usually considered indicative of the quality of cork: the light colour of virgin cork, and the straight, smooth and thin outer bark of amadia cork. As a last analysis, the quality of cork is determined by the homogeneity of its “body”. Within the bark’s descontinuities are lenticels that cross the cork’s radius and transversally give rise to pores. The pore types, size, quantity and distribution, are a determining factor (porosity) in the quality of cork (Gil, 1998).

There are a series of structural and other cork defects (for example, yellow and green stains, insect defects etc.) that are an important aspect when dealing with cork wine closure applications but not for building products.

Cork’s structure is anisotropic. The three main directions of cork are: radial (parallel to the trees rays), axial (vertical to the tree) and tangential (perpendicular to the other two, tangent to the circumference of the tree). The sections perpendicular to these three directions are designated tangential, transversal and radial, respectively (Gibson, 1988). However, anisotropy loses its significance regarding agglomerated cork given the random direction of the granules, as is the case of cork building products.

2.2 - Microscopic structure of cork

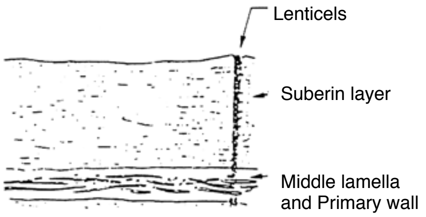
Cork is a tissue composed of cells, laid out in a compact and regular manner, with no free space, whose contents have disappeared during growth, undergoing a subsequent process of suberization (impermeability) of its cell membranes. It isn't only the tissue structure that gives cork its characteristics, for its properties are also due to the nature of the cell membranes. The cells inter-communicate by micro-channels that cross the cellular wall (plasmoderm). The volume of the cell walls is about 10-15 % of the total volume (Gil, 1998), or rather, there is an existing empty space of approximately 85-90%, which is what gives this material its insulating and resilient properties. The cell walls are composed of a structural base of lignin and cellulose with suberine, polyphenols and also extractable waxes. The cellular wall of the cork cell presents five layers: two of cellulosic nature that cover the cellular cavities; two inner suberous layers (with suberin and waxes; conferring impermeability) and a middle hardened/woody layer (bestowing rigidity and structure) (Gil, 1998).

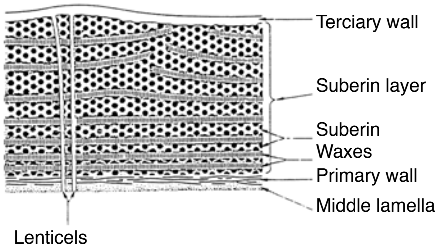
The cell membranes are thinner in thickness when produced in spring/summer (1 to 1,25μm) and thicker in autumn/winter (2 to 2,5μm). This fact, associated with the larger and smaller cell dimensions, also interferes in the mechanical and physical properties of cork (Gil, 1998).

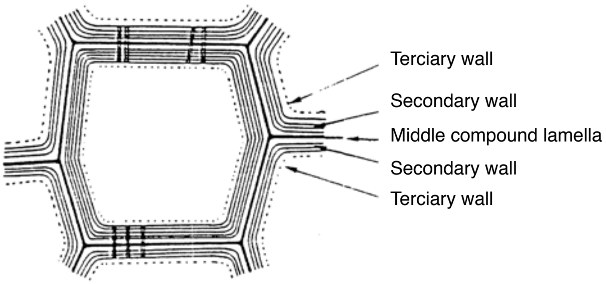
One can say that a hexagonal section of a prism can represent a medium cork cell, with a varying polygonal contour, usually between four and nine sides but, preferably between five and seven. Its average dimensions are between 30 and 40μm in width (being able to go from 10μm to 50μm) and 35-45μm in height with limits between 10 and 70μm.

Cork 1cm^3 in size has, on average, 30 to 42 million cells. Each annual ring is comprised normally of 50 to 200 cell layers in width (1 to 6mm), with this variation being the main reason for differing thicknesses in cork's annual growth. The differences in the cell sizes and cell wall thicknesses allows for the delimitation of the annual cork rings, since the cells formed in autumn (smaller and thinner) are darker in colour (Gibson, 1988; Gil, 1998).

The characteristics of cork insulation are due to the fact that the minuscule compartments (cells) are full of air. Cork cells are much smaller than the cells of other common materials, which helps justify its exceptional insulating properties. The transfer of heat by conductivity only depends on the quantity of solid material found in the cell structure, which is less for expanded cork for thermal insulation (hence, the use of expanded agglomerated cork for these purposes). Convection depends on the size of the cells, and for smaller cells (as is the case of cork) it does not contribute significantly. Radiation depends also on the size of the cells: the smaller the size (as is the case of cork), the greater number of times heat has to be absorbed and re-irradiated (Gil, 1998).







2.3 - Chemical composition of cork

The chemical composition of cork includes several types of compounds, which are traditionally divided into five groups (Gil, 1998):

a) Suberin (45 % - responsible for cork's compressibility and elasticity);
b) Lignin (27 % - structure of the cell walls);
c) Polysaccharides (12 % - also linked with the structure of cork);
d) Wax (6 % - repels water and contributes to its impermeability);
e) Tannins (6 % - colour and protection/preservation of the material) and
f) Ash (4 %)

Thus, cork is comprised of both structural components, of an extensive and complex polymeric form, and also non-structural components. The latter are categorized by extractive and non-extractive. The extractive components are divided into wax-like, which influence the impermeable characteristics of cork, and phenolic compounds, which seem to play a protective role against the attacks of biological organisms (Gil, 1998).

3 Cork products and their mechanical and physical characteristics

3.1 - Agglomerated cork for coverings (flooring and walls)

Cork flooring has become all the more acknowledged for its characteristics, given that it conjugates both beauty and various advantageous technical characteristics. If some years ago it was considered out of fashion, recently it has become a product of excellence in the world of interior designing. The popularity of natural flooring has grown in the last few years, however problems related with noise, prevented it from obtaining additional positive acclaim. Nevertheless, cork products demystify the idea that all resistant flooring options create much noise and cold environments (Anonymous, 2005).

Regarding the behaviour of cork, as a flooring option, it is interesting to consider the following comment:

The friction that occurs between a shoe and a floor surface has two origins. One is adhesion, when atomic exchange forces take place between two contact surfaces, and the need to break and re-establish those connections, if one were to slip. This effect is the only one to take place, for example, between a rigid shoe sole and a stone surface, and since it is merely a surface effect, it can be cancelled, for example, by polishing the surface. The other origin is due to unelastic collision (due to energy loss). When a shoe sole slips on cork flooring it deforms it. If cork were perfectly elastic, there would be no need for restitution as cork would recover its form after the incident; but since cork has a high energy dissipation coefficient, it is like riding a bicycle in the sand: the energy that is lost goes into deforming the object (sand) and hence, there is no restitution. This is the principal effect taking place when rough surfaces slide on cork and since this process is the consequence of what takes place beneath cork's surface, it is not affected by surface films, coverings, polishing or treatment. The same thing occurs when a cylinder or a sphere rolls over cork.

Besides these friction related properties, cork is resilient and absorbs shock in motion (reducing percussion noises and providing comfort when walking) (Gil, 1998). Cork's resilience allows this type of flooring to relieve tension in both the spinal cord and body articulations, being pleasant to the touch even when barefoot - an important fact in certain cultures - notwithstanding that cork fails to easily retain dirt and reduces impact noise when walking.

Regarding cork parquet, the tiles present a density of approximately 450-500 Kg/m^3 and a thermal conductivity coefficient of 0,064 W/m.K to 0,099 W/m.K. The dimensions can vary although the most common are 300 X 300 mm and 600 X 300 mm, also available are 900 X 300 mm and 900 X 150 mm with varying thicknesses between 3,2 and 8 mm (Andrade, 1980; Borges, 1988).

Studies carried out on a series of currently commercial products achieved results between 0,036 and 33,86 mg / kg of dry sample levels of formaldehyde (Mauricio, 2003), very much below the permissible maximum value ($\leq$95 mg / kg of dry sample, according to the EN12781 standard).

The values presented by some manufacturers, for the breaking tension on traction (Tensile Strength) of traditional cork parquet is 1,5-2,0MPa.

The index values obtained for insulating a solid concrete slab weighing 250kg/m^2, from differing noise percussions (B-bass, M-moderate, S-sharp), using different composition cork coverings (Anonymous, 1973) are:

Density (Volumic Mass) 570 kg/m^3, thickness 5 mm: IB=0 dB; IM=4 dB; IS=34 dB
Density (Volumic Mass) 503 kg/m^3, thickness 5 mm: IB=0 dB; IM=4 dB; IS=40 dB
Density (Volumic Mass) 400 kg/m^3, thickness 6 mm: IB=0 dB; IM=11 dB; IS=47 dB
Density (Volumic Mass) 490 kg/m^3, thickness 12 mm: IB=0 dB; IM=13 dB; IS=41 dB

Studies on the dimensional stability of agglomerated cork parquet, in environments with differing air humidity, also allowed us to conclude that this variation would be inferior to 1 % (LEEC, 1977, 1978).

As for the soft agglomerated cork with a density in the range of 200-300 kg/m^3, the moisture dimensional variation is in the same order of greatness as parquet, with a breaking tension on traction (Tensile Strength) of nearly 0,2-1,2MPa and a thermal conductivity coefficient of 0,061-0,064 W/m. K (Gil, 1998; Manufacturers' Catalogues).

In terms of the oxygen index (flamability), various types of soft decorative composition corks were tested, always presenting values between 20,5 and 21 %. Whereas cork parquet, normal or with PVC, presented higher values in the order of 26,5-27 % (Borges, 1986). It is noteworthy that the higher the value the less prone to flammability.

The water vapour permeability of a composition cork of about 480 kg/m^3 is 0,0002 g/m.h.mm Hg (Fernandez, 1984).

A floating cork floor is normally composed of an agglomerated cork base of 1-3 mm, an intermediate layer in MDF or HDF of 6-7mm and a surface cork wear layer of 2,5-3,2mm, totaling 10-12mm in thickness. Currently the most common sizes are 900 x 300mm, with installment systems of the tongue-and-groove type for glue down or of the mechanical interlocking click type.

The durability of cork coverings (wall and floor panels) is renown, so long as appropriate maintenance is carried out, namely by periodically renewing the protective application on the product. Some proven cases of durability are:

- The library at Escuela Técnica Superior de Ingenieros de Montes, in Madrid, is a high traffic location with a cork flooring that was installed in the 50's and still found to be in good condition in the 90's;

- Even today there are wings of the Santa Maria Hospital, in Lisbon, where the cork flooring is well maintained even after decades of use (extreme high traffic);

- Many 40's and 50's buildings throughout the city of Lisbon (but especially in Lapa and Avenidas Novas) have still, to date, their original flooring and wall paneling in use.

3.2 - Agglomerated cork for thermal and acoustic insulation

In this field, we have thermal insulation for buildings (ceiling, flooring and walls) namely, for the protection of concrete from attaining thermal amplitudes, for reducing energy losses, protecting flooring surfaces and, in addition, hindering, obstructing or reducing superficial water condensation on walls and ceilings. In the acoustics field, we have what is called acoustic correction by acoustic absorption and reduction in the reverberation time of certain environments, in addition to diminishing or reducing impact sound transmission in special applications (Gil, 1998; Medeiros, n.d.).

Table 1 – Mean characteristics of expanded agglomerated cork (thermal)**.**

Density	**100-140 kg/m³**
Thermal Conductivity Coefficient (θm = 23ºC)	0,039-0,045 W/m.ºC
Specific heat (to 20ºC)	1,7-1,8 kJ/kg.ºC
Thermal Expansion Coefficient (20ºC)	25-50 X 10^{-6}
Maximum pressure in elastic conditions	50 kPa
Modulus of Elasticity (compression)	19-28 daN/cm²
Thermal Diffusion	0,18-0,20 X 10-6 m²/s
Poisson Coefficient	0-0,02
Water Vapour Permeability	0,002-0,006 g/m.h.mmHg
Modulus of Rupture (Bend Strength)	1,4-2,0 daN/cm²
Tensile Strength, Transversal	0,6-0,9 daN/cm²
Tensile Strength, Longitudinal	0,5-0,8 daN/cm²
Dimensional Variation 23-32ºC, 50-90 % HR	0,3%
Oxygen Index	26%
Tension Deformation at 10 % (compression)	1,5-1,8 daN/cm²
Temperature Deformation (80ºC)	1,4 a 2,4% (thickness)

Table 2 –Mean characteristics of expanded agglomerated cork (acoustic)

Density	**≤ 100 kg/m³**
Sound Absorption Coefficient (500-1500 c/s)	0,33-0,8
Thermal Conductivity Coefficient (θm = 23)	0,037-0,042 W/m.ºC
Modulus of Rupture (Bend Strength)	1,4-1,6 daN/cm²
Water Vapour Permeability	0,004-0,010 g/m.h.mmHg
Tensile Strength, Longitudinal	0,3 daN/cm²
Water Absorption (immersion) (capillarity)	9,2 % 1,9%
Dimensional Variation 32-66ºC, 90-0 % HR	0,4%

Another specific case of thermal insulation, in which the densest expanded agglomerated cork is used, is that of refrigeration areas where high, fixed or movable pressures are exerted and insulation is applied, namely as a flooring option or in loading/unloading areas.
In terms of percussion, expanded agglomerated cork can be applied as a layer placed between the lining and the flooring system (floating floors). Covering both ceilings and walls, expanded agglomerated cork absorbs a part of the total incident sound energy thus reducing the intensity of the reflected sound. In this respect its irregular surface is a contributing factor, being full of cavities it increases the reflection of the sound waves, resulting in a loss of energy for each wave.
The thermal conductivity of expanded agglomerated cork, thermal type (λ), varies in a linear form, with an average temperature™ testing (from -150 to 50ºC) and density (ρ), in this case according to the following formula (LEEC, 1974):

$$\lambda = (220 + 1{,}36\ \rho) \times 10\text{-}4\ \text{W/m. K (for } T_m = 22{,}6^{\circ}\text{C and } \rho = 120\text{-}350\ \text{kg/m}^3\text{)}$$

Concerning the compression-recovery of expanded (thermal) agglomerated cork when under a static load, studies indicate the following relations (Fernandez, 1974, 1987):

$$d_a = d_1 + 2d_2 \quad \text{and} \quad d_p = d_1 + 3d_2$$

being:

d_a = maximum acceptable deformation;
d_p = maximum foreseeable deformation;
d_1 = deformation after 24 hours;
d_2 = deformation in the period of 1 to 11 days.

Regarding the acoustic absorption of expanded agglomerated cork, the thicker the material, the greater the sound absorption. With a reduction in thickness, maximum absorption moves to higher frequencies (Fernandez, 1974). Thus, depending on the type of sounds that need to be insulated it is possible to choose the most appropriate material.
Studies carried out regarding the transmission of B-bass, M-moderate and S-sharp percussion noises on various sound insulation flooring types, comprising of expanded agglomerated cork panels, obtained the following results (Anonymous, 1973):

Concrete slab at 250 kg/m2 with:

Expanded agglomerated cork 25 mm, 108 kg/m^3: IB=2 dB; IM = 19 dB; IS=43 dB
Expanded agglomerated cork 20 mm, 111 kg/m^3: IB=0 dB; IM = 19 dB; IS=47 dB
Expanded agglomerated cork 25 mm, 132 kg/m^3: IB=1 dB; IM = 16 dB; IS=46 dB
Expanded agglomerated cork 25 mm, 102 kg/m^3: IB=2 dB; IM = 10 dB; IS=40 dB
Expanded agglomerated cork 40 mm, 120 kg/m^3: IB=1 dB; IM = 24 dB; IS=48 dB
Expanded agglomerated cork 15 mm, 114 kg/m^3: IB=1 dB; IM = 9 dB; IS=41 dB
Expanded agglomerated cork 10 mm, 112 kg/m^3: IB=4 dB; IM = 9 dB; IS=38 dB

Expanded agglomerated cork 10 mm, 95 kg/m^3: IB=4 dB; IM = 14 dB; IS=43 dB
Expanded agglomerated cork 20 mm, 191 kg/m^3: IB=1 dB; IM = 21 dB; IS=49 dB
Expanded agglomerated cork 5 mm, 194 kg/m^3: IB=1 dB; IM = 8 dB; IS=39 dB
Expanded agglomerated cork 25 mm, 260 kg/m^3: IB=5 dB; IM = 21 dB; IS=45 dB

The usage temperature limits for expanded agglomerated cork easily cover the scale of values found in building applications (-20ºC to 90ºC) without leading to incidents of degradation, deformation or irreversible alterations to the properties of cork, even after decades of use (Gil, 1996). Its composition allows it to support, without detriment, the application of melt bitumen, used to glue and waterproof terrace coverings (Manufacturers' Catalogues).
For fridge applications, the thicknesses that are usually considered are those stated in Table 3, and are dependant on the temperature to be maintained in the fridge chamber interior (Medeiros, n.d.).

Table 3 – Thickness of Expanded Agglomerated Cork depending on the desired interior temperature of the insulated system.

Temperature (ºC)	Thickness (cm)
-40 to -25	25-30
-25 to -18	20
-18 to -10	17,5
-10 to -4	15,0
-4 to +2	12,5
2 to 16	10,0
16 to 20	7,5
20	5,0

The properties required for a thermal insulating material are: low thermal conductivity coefficient, non-moisture absorption, adequate mechanical resistance given its usage, pliability, fire resistance, unscented, non prone to rodent attacks, durable, low density and price. Expanded agglomerated cork addresses these requisites quite well, and is used, in particular, in low temperature insulation areas (Andrade, 1962) or for cargo loading and/or visitation zones.
On the other hand, agglomerated cork is also one of the most advantageous insulating materials, since its density is comparatively high, the same regarding its specific heat, leading to a very low thermal diffusion when compared to insulating materials with similar λ, being, thus, an excellent heat (or cold) preserver (Fernandez, 1987). The thermal resistance provided by the standard thicknesses of expanded agglomerated cork easily guarantees the values stated in the directives regarding the thermal characteristics of buildings (Manufacturers' Catalogues).
One of the important aspects to consider when applying thermal insulation, and more specifically expanded agglomerated cork, is determining the necessary insulation to attain specific thermal conditions and avoid superficial condensation. (Lissia, 1977). Various considerations

must be undertaken and the elements on which the calculations are based are as follows:

k – total wall transmission coefficient, which is taken into account along with the transmission coefficient of each element

e - wall thickness
e_i - insulation thickness, to be determined
λ' - thermal conductivity coefficient of the wall elements
λ - thermal conductivity coefficient of the insulation
$a1$ – interior laminate coefficient
$a2$ – exterior laminate coefficient

It is generally considered appropriate that:

$k = 0{,}60$ Kcal/m^2.h.ºC
$\lambda = 0{,}033$ Kcal/m.h.ºC
$a_1 = 8$
$a_2 = 25\text{-}30$

The wall transmission coefficient will be given by:

$$k = 1 / (1/8 + e/\lambda' + 1/25)$$

The insulated wall transmission coefficient will be given by:

$$k' = 1 / (1/8 + e/\lambda' + e1/\lambda + 1/25)$$

The thermal resistance, R (=1/k), is given by:

$$R = (1/8 + e/\lambda' + 1/25)$$

Therefore, as an example, a wall made up of two cement block rows, 40cm in thickness, with a 2cm inner plaster and a 2cm exterior cement plaster - by obtaining values from the λ or k charts for building materials and elements - we obtain:

Blocks: $\lambda 1=1{,}0$; $e1=0{,}40$; $k1=1{,}0/0{,}40=2{,}5$; $R1=1/2{,}5=0{,}400$
Inner Plaster: $\lambda 2=0{,}7$; $e2=0{,}02$; $k2=0{,}7/0{,}02=35$; $R2=1/35=0{,}003$
Exterior Plaster: $\lambda 3=0{,}7$; $e3=0{,}02$; $k3=0{,}7/0{,}02=35$; $R3=1/35=0{,}003$

The total resistance of the walls will be:

$$R_t = 1/8 + 0{,}400 + 0{,}003 + 0{,}003 + 1/25 = 0{,}571$$

In this manner, the total transmission coefficient will be:

$$k_t = 1/R_t = 1/0{,}571 = 1{,}75$$

The value of λ for expanded agglomerated cork is 0,033 kcal.m/m^2.h.ºC, whereby by the value of k (λ/e), for 1 cm of this material, will thus be 3,3 and the respective resistance:

$$R = 1/3{,}3 = 0{,}303$$

Considering the value of 0,60 kcal/m^2.h.ºC as the ideal value for the wall transmission coefficient, the resistance will be:

$$R = 1/0{,}6 = 1{,}666$$

Since the walls had a value of R = 0571, to be able to increase this value to 1,666, via insulation, we would need:

$$1{,}666 = 0{,}571 + 0{,}303 . e_i \Rightarrow e_i = 3{,}6 \text{ cm}$$

In other words, in order to obtain the required insulation, under these conditions, a 3,6 cm thick expanded agglomerated cork would be sufficient.
Regarding superficial condensation, however, the required insulation can be determined by applying the following empirical formula:

$$1/k = [0{,}15.(\Delta T - 22) + 3] / [(T/100 + 1).(95 - H)/5]$$

in which

T – Interior environment temperature
H – Interior environment humidity
ΔT – Temperature difference between the interior desired environment and exterior minimum to be considered

1/k', pertaining to the wall, must be subtracted from the 1/k coefficient obtained, via the formula. Knowing that each centimeter of expanded agglomerated cork has a thermal resistance of 0,303, by dividing the result of the previous difference by this value, we obtain the number of insulation centimeters necessary to avoid condensation.

Considering T=20ºC, H=80 % and ΔT=24ºC, we have:

$$R = 1/k = [0{,}15.(24 - 22) + 3] / [(20/100 + 1).(95 - 80)/5] = 0{,}916$$

Now taking into account the previous wall with $R_t = 0{,}571$

$$e_1 = (0{,}916 - 0{,}571)/0{,}303 = 1{,}14 \text{ cm}$$

Or rather, in this case, to avoid condensation an insulator 1,14cm thick would be sufficient. As for thermal insulation we would need 3,6 cm of expanded agglomerated cork, which would also avoid condensation.
Good thermal insulating materials are usually good correctors or acoustic absorbers, but bad sonic insulating materials (via air). Regarding sound barriers there are three aspects to consider (Fernandez, 1987):

a) Sound insulation via air (e.g. from the street to the residence interior);
b) Noise percussion insulation (by impact on a floor or wall);
c) Sound absorption (reduction in the reverberation or echo time).

As a wall filler, expanded agglomerated cork has a vibration frequency different to the exterior panels due to its elastic and flexible qualities, reason for it being advantageous. In terms of percussion, expanded agglomerated cork can be applied as a layer placed between the lining and the flooring system (floating floor). As a ceiling and wall covering it absorbs a part of the total incident sound (Fernandez, 1987).
The properties required of a material acoustic absorber are: adequate absorption coefficient, durability, visual appearance, resistance to fire, weight, light reflection coefficient, method of application and cost. In this field, expanded agglomerated cork is also the material that better corresponds to these global requisites. In the case of impact sound transmission, insulation can be achieved by using structural descontinuities, made possible with several types of agglomerated cork (Andrade, 1962).
Expanded agglomerated cork is an acoustic absorber with a porous structure which absorbs part of the incident resonant energy. The coefficient (α) of a material (at a given frequency), is the relation between the sound energy absorbed by its surface and the incident energy. Expanded agglomerated cork presents low absorption coefficients for frequencies inferior to 800 Hz and higher absorption coefficients for higher frequencies up until 4000 Hz; albeit if there is an increase in thickness, α increases regarding frequencies inferior to 800 Hz and decreases for higher frequencies (Anonymous, 1986).
It is also necessary to consider the behaviour of expanded agglomerated cork regarding moisture (Fernandez, 1987). As one knows, the insulating capacity of a material is reduced to the same extent as its moisture contents is increased, since the thermal conductivity of air is 0,023 kcal/m.h.ºC (at 0ºC) and that of water is of 0,50 kcal/m.h.ºC (at 0ºC). The absorption of water depends on the chemical constitution and alveolar or cellular nature of the material's structure. Furthermore, besides the moisture absorption and transmissibility, the fact that water is not stored in the interior of the material is also of interest. Cork, in its composition, contains several hydrophobic constituents which do not facilitate the retention of moisture.
As for its behaviour to fire, tests carried out in accordance with the Federal American Standards (SS-A-118b) presented, for expanded agglomerated cork with a nominal thickness of 50 and 76mm, results of an incombustible or combustion retardant material (Fernandez, 1974; Pinto, 1988). The flame produces a superficial carbonization that gives rise to a practically incombustible layer.
The fumes that are released are considered non-toxic. They do not present chlorides nor cyanides, with quantities of released carbon monoxide and carbon dioxide, during combus-

tion, of about 0,6% and 2,4% respectively (Pinto, 1988), or between 0,1 to 0,6% and 0,1 to 2,3% respectively, in accordance with manufacturers' data.

According to the ASTM-C-209 standards and the Schulter test, cork demonstrated a good behaviour to fire (Fernandez, 1987). During a test, a block of expanded agglomerated cork, 2 inches thick, was placed on a Bunsen burner with a temperature of 1500ºF, taking the cork 4 hours to be burnt through by the flame. Being a slow burning material, cork forms a barrier against fire, as is the case of buildings salvaged against worse damages, by this barrier. (Guttridge, 1972).
Expanded agglomerated cork, in comparison to other organic insulation materials (e.g. cellular plastics), presents advantages, as it does not fuse easily as these materials do, which end up losing total resistance and form, and is still able to have an additional protective layer of anti-fire paint applied to it. Furthermore, cork does not present compatibility problems with other contact materials, failing to present any major issues when interacting with solvents, resins, hydraulic binders, glues, asphalts, etc. (Manufacturers' Catalogues).
In relation to the durability and useful lifespan of applied expanded agglomerated cork, several cases can be referenced (although some are not very recent, there are no significant differences regarding the current situation):

- In 1959, in Monza, a floor and a wall, which had been previously insulated in 1922, were being reconstructed. The insulating material was still in such perfect condition that it could have been commercialized (Lissia, 1967);
- Even after World War II, the General Refrigerators of Trieste had their insulation, (previously applied in World War I) in perfect conditions (Lissia, 1967);
- In 1996 a report was disclosed, which studied the thermal conductivity of expanded agglomerated cork, obtained from demolished buildings in existence for 50 (refrigeration chamber) and nearly 30 years (building, laboratory). The study presented identical values to that of new agglomerated cork (Gil, 1996), not to mention the similar visual appearance to that of a newly manufactured product.

3.3 - Agglomerated cork for vibration insulation

In the anti-vibration field the densest agglomerated cork is used (for example, 180-200 kg/m3) and applied namely as a vibration shock absorber to the machinery's support system, as a means of reducing the vibration transmission of the working machine to its structural base; with the same objective it is applied as insulation to the foundation (Medeiros, n.d.) and also, for example, under railway tracks.

The vibration insulation of machinery is also carried out by *"rubbercork"*, at times also designated *"corkrubber"*, depending if cork is the layer inferior or superior to that of rubber. This product is also currently used as an underlay, particularly for floating floors.

In terms of behaviour, as an anti-vibration insulator, a thicker based expanded agglomerated cork corresponds to a lower resonance frequency and a higher resonance amplification factor. As for its density, the lower the value the lower the resonance frequency but the higher the resonance amplification factor (Prates, 1993). The natural frequency (f) of expanded agglomerated cork, as an anti-vibration support, is related with the final maximum deformation of the material (d) under a determined static load, via the relation $f = 5/\sqrt{d}$ with f in c/s and d in cm. Being F the vibration frequency of the machine to be insulated (value is known), we need that $F/f > 4$ (Fernandez, 1974, 1987), for the vibrations to be effectively reduced. With an increase in the thickness of the agglomerated cork, its natural frequency is reduced, improving the vibration transmission insulation.
There is a reference indicating the efficient support system provided by anti-vibration agglomerated cork in machines with a speed rotation superior to 1200 rpm (Andrade, 1948).
Regarding its lifespan, the following cases are usually indicated:
- 6 rotary "Super-palatia" machines were vibratically insulated with expanded agglomerated cork at Georges Lang Graphics in Paris, and had a continued office use of more than 25 years (Katel, 1956);
- Other machines from the "Wool Gazet van Antwerpen" were insulated with expanded agglomerated cork, and are still functioning 29 years later (Katel, 1956).

3.4 - Agglomerated cork for expansion joints

Due to cork's high compressibility and recovery, certain types of composition cork are used as expansion joints between rigid elements, such as concrete slabs. Placed between the flooring/paving and the subfloor of the construction, they also help provide good sound and even thermal insulation.
Composition cork for expansion joints can typically present characteristics such as a 50 % reduction in its initial thickness for loads between 0,35 to 10,5Mpa, and a 90% recovery in its original thickness after a 50% compression, and an expansion of nearly 6mm for this same compression (Gil, 1998).
"Rubbercork" can also be applied to expansion joints.

3.5 - Granulated and re-granulated cork

Granulated cork is considered such when the cork fragments have a granulometry superior to 0,25mm and inferior to 22,4mm. The particles inferior to 0,25mm are considered cork powder (NP-114 standard).

The granules and/or re-granulated cork can be used as a final product for the purpose of thermal insulation, to fill empty spaces between double walls or as a ceiling application on the last floor of a building. Granules are also used in the preparation of mortar with concrete, to lessen the weight in certain construction elements, or even in the manufacture of construction parts/blocks.

Within this field it is necessary to stress that regranulated cork is a byproduct of expanded agglomerated cork. Its primary application is as a wall, terrace and covering filler. Its usage can also be extended to concrete mixtures.

The technical characteristics of re-granulated cork (Manufacturers' Catalogues) can be referenced as follows:

- Density (Volumic mass) = 70-80 kg/m3
- Thermal conductivity coefficient = 0,048 W/m.ºC
- Granulometry = 0/3 – 0/15 – 0/10 – 3/15 mm

For the insulation of concrete slabs, regarding percussion noise transmission, a layer of granulated cork can be used.

In an experiment (LEEC, 1977), with a massive 250 kg/m^2 of concrete, 4cm thick, with a surface layer of granulated cork 2cm thick, a granulometry of 0,5mm and a density of 50 kg/m^3, the following noise reduction, regarding impact sound transmission, was achieved:

I Bass - 18 dB; I Moderate- 23 dB; I Sharp- 43 dB

The following tables can be considered for re-granulated cork, obtained from expanded agglomerated cork (Manufacturers' Catalogues).

Table 4 – Characteristics of lightweight concrete with re-granulated cork

ASPECT VOLUME			Weight/m^3	Compression Resistance	Thermal Conductivity
Cement	Sand	Re-granulated	Kg	daN/cm^2	W/m.ºC
1	0	6	400	2	0,13
1	0	4	500	6	0,18
1	2	6	900	11	0,24
2	3	8	1100	17	0,60

3.6 – Standardization and essential cork product requisites for building

The TC 16 is the Technical Standardization Committee for Cork, established at a national level to handle the standards related with cork. The Technical Committee ISO/TC 87 was created on an international scale. At a European level, three European Technical Committees for Standardization cover frameworks directly linked with some agglomerated cork applications: thermally *"expanded"* cork (CEN/TC 88), *"parquet"* (CEN/TC 134) and wall coverings in panels and rolls (CEN/TC 99) (Bicho, 1999).
The following tables refer to cork product standardization for construction, with an indication of the demands and test procedures and their respective standards (quoted from Cork – Standardization Guide (Bicho, 1999) with updates). It is important to note that the ISO-Cork standards were annulled (with an exception for acoustic agglomerated cork and expansion joints) but are still indicated herein as they are both a reference and useful for certain purposes.

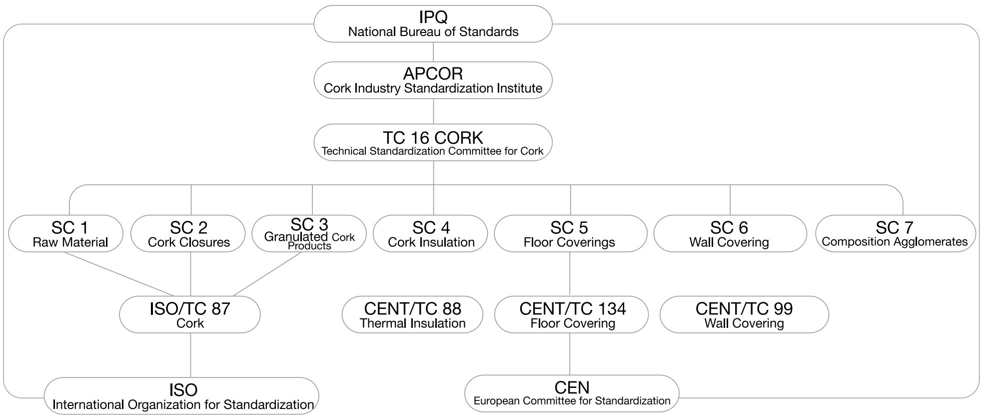


Table 5 - Granulated cork (characteristics, demands and methods).

CHARACTERISTICS	DEMANDS	TEST PROCEDURE
Classification	Density and Granulometry	NP 605 ISO 2031 and NP 115 ISO 2030
Moisture	≤10 %	NP 606 ISO 2190
Powder Content	≤ 0,4 %	NP 115 ISO 2030

Source - specification documents: NP 114:1994 and ISO 1997:1992

Table 6 - **Composition cork** (characteristics, demands and methods).

CHARACTERISTICS		DEMANDS	TEST PROCEDURE
Thickness		Tolerance limits without nominal value:	
	≤ 3 mm	± 15 %	NP 2372
	> 3 mm	+ 15% 0	ISO 7322
Density		To be stated by manufacturer	NP 2372 ISO 7322
Compressibility **Recovery**		To be stated by manufacturer	NP 2372 ISO 7322
Breaking Tension on Traction		≥ 200 kPa	NP 2372 ISO 7322
Resistance to boiling water		It should not separate	NP 2372 ISO 7322

Source - specification documents: NP 3004:1997 and ISO 4714:2000

Table 7 – Composition cork for expansion joint fillers
(characteristics, demands and methods).

CHARACTERISTICS	DEMANDS	TEST PROCEDURE
Length	Tolerance limits without nominal value: ± 6,4 mm	NP 1777 ISO 3867
Width	Tolerance limits without nominal value: ± 3,2 mm	NP 1777 ISO 3867
Thickness	Tolerance limits without nominal value: ± 0,15 mm	NP 1777 ISO 3867
Density	To be stated by manufacturer	NP 1777 ISO 3867
Recovery	≥140 % of its initial thickness	NP 1777 ISO 3867
Compression	≥ 340 kPa and ≤ 1035 kPa	NP 1777 ISO 3867
Extrusion	≤ 6,4 mm	NP 1777 ISO 3867
Expansion in water (only applicable to auto-expansive agglomerated cork)	≥ 140 % of its initial thickness	NP 1777 ISO 3867

Source - specification documents: NP 1778:1997 and ISO 3869:2001

Table 8 – Sound absorbent composition cork
(characteristics, demands and methods).

CHARACTERISTICS		DEMANDS	TEST PROCEDURE
Side Length		nominal value: 300 mm tolerance: ± 1 mm	NP 2804 ISO 9366
Thickness		minimum value: 4,8 mm tolerance:	NP 2804 ISO 9366
	without bevel	± 0,2 mm	
	with bevel	± 0,3 mm	
Squareness **Straightness**		≤ 0,3 ° ≤ 1,5 mm	NP 2804 ISO 9366

Breaking Tension on Traction	≥ 200 kPa	NP 2372 ISO 7322
Sound absorption (reverberation room)	Present graph indicating the absorption for each frequency band tested	NP EN 670 ISO 354

Source - specification documents: NP 1552:1999 and ISO 2510:1989

Table 9 – Sound absorbent natural agglomerated cork
(characteristics, demands and methods).

CHARACTERISTICS	DEMANDS	TEST PROCEDURE
Length	tolerance: ± 0,4 %, with maximum 3 mm	NP 1551 ISO 2509
Thickness	least: 20 mm; tolerance: ± 0,4 mm	NP 1551 ISO 2509
Squareness	≤ 0,3 º	NP 2804 ISO 9366
Modulus of Rupture (Bend Strength) (for thicknesses ≥ 20 mm)	≥ 140 kPa	NP 603 ISO 2077
Moisture	≤ 4 %	NP 1042 ISO 2066
Sound absorption (reverberation room)	To present graph indicating the absorption for each frequency band tested	NP EN 670 ISO 354

Source - specification documents: NP 1551:1999 and ISO 2509:1989

Table 10 - Expanded agglomerated cork
(characteristics, demands and methods).

CHARACTERISTICS	DEMANDS	TEST PROCEDURE
Thermal Conductivity **Thermal Resistance**	≤ 0, 060 W/m.K ≥ 0, 025 m².K/W	ISO 8302 ISO 8301
Length **tolerance**	Class L1: nominal value ± 3 mm Class L2: nominal value ± 5 mm	NP EN 822
Width **tolerance**	Class W1: nominal value ± 2 mm Class W2: nominal value ± 3 mm	NP EN 822
Thickness **25 mm < thickn. ≤ 50 mm** **thickn. > 50 mm**	Tolerance: Class T1: ± 1 mm Class T2: ± 2% with maximum 2mm	NP EN 823
Squareness **Length and width** **Thickness**	≤ 4 mm/m ≤ 2 mm/m	NP EN 824
Flatness	≤ 2 mm	NP EN 825
Dimensional stability at (23±2)ºC and (50±5)% hr **length and width** **flatness**	≤ 0,5% ≤ 1 mm/m	NP EN 1603
Dimensional stability under temp. and moisture actions **length and width** **flatness**	≤ 0,5% ≤ 1%	NP EN 1604

Deformity under specific conditions of compression and temperature	≥DLT	NP EN 1605
Handling	≥ 130 kPa	EN 12089 Method B
Moisture content	≤ 8 % (m/m)	NP EN 12105
Fire resistance	Classification	NP EN 13501-1
Apparent Density	≤ 130 kg/m^3	NP EN 1602
Compression Behaviour (10% deformity)	Level CS (10)90 ≥ 90 kPa Level CS (10)100 ≥ 100 kPa Level CS (10)110 ≥ 110 kPa	NP EN 826
Point Load	≥ stated level	NP EN 12430
Compressibility **Thickness** **Compressibility** **Long Term Reduction**	≤ stated value ≤ stated value see below	NP EN 12431
Compressive Creep	see below	EN 1606
Tensile strength perpendicular to faces	Level TR 40 ≥ 40 kPa Level TR 50 ≥ 50 kPa Level TR 60 ≥ 60 kPa	NP EN 1607
Bending behaviour	≥ 130 kPa	EN 12089 Method B
Shear resistance	≥ 50 kPa	NP EN 12090
Water absorption (short duration)	≤ 0,5 kg/m²	NP EN 1609 Method A
Water vapour transmission	≥ stated value	NP EN 12086
Apparent Density	≥ stated value	EN 1602
Air flow resistance	≥ stated value	EN 29053
Sound absorption properties	≥ stated value	EN ISO 354:1993/A1 EN ISO 11654

Source - specification documents: NP EN 13170: 2001

Compressive Creep

The Compressive Creep, ε_{ct}, and the total relative reduction in thickness, ε_t, should be determined after a minimum testing period of one hundred and twenty two days, for the stated compression, ε_c, given in steps of, at least, 1 kPa with an extrapolation of the results by thirty times to obtain the declared levels, in accordance with the EN 1606. The compressive creep must be expressed in levels, i_2, and the total relative reduction in thickness must be expressed in levels, i_1, with intervals of 0,5 %, for the declared load, $\varepsilon_{c.}$ No test result must exceed the reference levels for the load.

Note 1: Examples of reference levels for Compressive Creep

Level	Nr. of test days	Extrapolation time in years	Declared load kPa	Demands %
$CC(i_1/i_2\ \%,10)\sigma_c$	122	10	σ_c.	$i_1/i_2 \leq i$
$CC(i_1/i_2\ \%,25)\sigma_c$	304	25	σ_c.	$i_1/i_2 \leq i$
$CC(i_1/i_2\ \%,50)\sigma_c$	608	50	σ_c.	$i_1/i_2 \leq i$

Note 2: Regarding the designation code according to section 6, a reference level, for example, of CC (2,5/2 %, 10) 50, indicates a compressive creep value which does not exceed 2 % and a reduction in total thickness of 2,5 %, prior to a 10 year extrapolative period (i.e. 30 times a hundred and twenty two days of testing), under a declared load of 50 kPa.

Long term thickness reduction

When the load imposed on lightweight concrete exceeds 5,0kPa, only the products that have a level of compressibility equal to or inferior to 2mm should be used and their thickness reduction be determined over the long term.

Note: The load levels, imposed on lightweight concrete, were withdrawn from the ENV 1991-2-1 Eurocode 1 – Basis of design and actions on structures. Part 2.1 Actions on structures – Densities, self-weight and imposed loads.

The total relative reduction in thickness, ε_t, must be determined after a testing period of one hundred and twenty two days under the imposed weight and that of the lightweight concrete, in accordance with the EN 1606 and extrapolated thirty times, corresponding to a ten year period. The ten year value must not exceed the compressibility level in reference.

Table 11 - Agglomerated cork with rubber for flooring (characteristics, demands and methods).

CHARACTERISTICS	DEMANDS	TEST PROCEDURE
Length **rolls or sheets:**	≥ nominal value	NP EN 426
Width	Tolerance limits without nominal value: ≤ 0,15 %	NP EN 426
Thickness of the inside face	≥ nominal value	NP EN 429
Squareness **Straightness** **≤ 610 mm:** **> 610 mm:**	≤ 0,35 mm ≤ 0,50 mm	NP EN 426
Residual indentation average value:	≤ 0,25 mm	NP EN 433
Dimensional stability permitted variation:	≤ 0,4 %	NP EN 434
Tear Resistance average value:	≥ 20 N/mm	ISO 434 (Method B, Testing A)
Flexibility	must not create openings	NP EN 435 (mandrel 20 mm)
Abrasion Resistance	≥ 250 mm^3	ISO 4649, Method A (vertical load (5±0,1) N)
Hardness	≥ 75 Shore A	ISO 7619
Peel Resistance	average value ≥ 50 N	NP EN 431

Resistance to light exposure	minimum 6	ISO 105-BO2 Method 3
Resistance to cigarettes stubbed: burnt:	 ≤ 1 ≥ 4	NP EN 1399

Source - specification documents: NP EN 1817:1999

Table 12 - Agglomerated cork tiles for flooring
(characteristics, demands and methods).

CHARACTERISTICS	DEMANDS	TEST PROCEDURE
Side length	Divergence from nominal value ≤ 0,2 % and maximum of 1mm	ISO 9366 NP EN 427
Thickness (wear layer) average value: individual values:	Divergence from nominal value 0 a 0,25 mm 0 a 0,50 mm	ISO 9366 NP EN 428
Squareness and Straightness side ≤ 400 mm: side> 400 mm:	 ≤ 0,50 mm ≤ 1 mm	ISO 9366 NP EN 427
Apparent Density average value: individual values:	 ≥ nominal ≥ 95 % nominal	NP EN 433
Mass per unit area average value:	nominal ± 10%	NP EN 430
Dimensional stability permitted variation:	≤ 0,4 %	NP EN 434
Curling	≤ 6 mm	NP EN 434
Moisture	To be stated by the manufacturer	NP EN 12105

Source - specification documents: NP EN 12104: 2000

Table 13 - Agglomerated cork tiles for flooring with poly (vinyl chloride) wear layer
(characteristics, demands and methods).

CHARACTERISTICS	DEMANDS	TEST PROCEDURE
Side length	Nominal value divergence ≤ 0,1% and maximum of 0,5mm	NP EN 427
Thickness (wear layer) average value: individual values:	Tolerance limits without nominal value: + 0,18 mm - 0,15 mm ± 0,20 mm	NP EN 429
Squareness and Straightness side ≤ 400 mm: side> 400 mm:	 ≤ 0,25 mm ≤ 0,35 mm	NP EN 427
Dimensional stability	≤ 0,4 mm	NP EN 434
Curling	≤ 6 mm	NP EN 434
Mass per unit area average value:	Tolerance limits without nominal value: + 13 % - 10 %	NP EN 430
Density (wear layer) average value:	Tolerance limits without nominal value: ± 0,05 g/m^3	NP EN 436

Thickness of the inside face average value:	Tolerance limits without nominal value: ± 10 %	NP EN 429
Peel Resistance average: individual values:	≥ 35 N/50 mm ≥ 125 N/50 mm	NP EN 431

Source - specification documents: NP EN 655:1997

Table 14 - Floor panels for floating floor installation (characteristics, demands and methods).

CHARACTERISTICS	DEMANDS	TEST PROCEDURE
Dimensions of wear layer	Divergence from nominal value	NP EN 427
Square panels Length and Width	± 0,10 % c/ max 0,5 mm	
Rectangular panels Width	± 0,10 % c/ max 0,5 mm	
Length	max 2,0 mm	
Total thickness average individual values	Nominal ± 0,25 mm Maximum divergence from average: ± 0,30 mm	NP EN 428
Squareness	≤ 0,50 mm	NP EN 427
Straightness measured on wear layer	≤ 0,30 mm	
Levelness of panel in relation to		NP EN 14085 Appendix A
Length Concave / convex	≤ 0,50 % / ≤ 1,0 %	
Width Concave / convex	≤ 0,10 % / ≤ 0,15 %	
Expansion allowance between panels average individual values	≤ 0,15 mm ≤ 0,20 mm	NP EN 14085 Appendix B
Levelness between panels average individual values	≤ 0,15 mm ≤ 0,20 mm	NP EN 14085 Appendix B
Dimensional variation caused by humidity alterations in atmosphere	≤ 5 mm	NP EN 14085 Appendix C

Source - specification documents: NP EN 14085:2003

Table 15 - Agglomerated cork underlay for flooring (characteristics, demands and methods).

CHARACTERISTICS	DEMANDS	TEST PROCEDURE
Length and Width rolls or sheets	≥nominal value	NP EN 426
Total thickness	Tolerance limits without nominal value:	NP EN 428
≤ 5 mm	± 0,2 mm	
> 5 mm	± 5 % with a maximum 0,5mm	
Mass per unit area	tolerance: nominal value ± 10 %	NP EN 430
Breaking Tension on Traction	≥ 200 kPa	ISO 7322
Flexibility	must not crack or split	NP EN 435, Method A
Moisture	To be stated by manufacturer	NP EN 12105
Noise Impact Reduction	To be stated by manufacturer	ISO 140-6 or ISO 140-8

Source - specification documents: NP EN 12103: 1999

Table 16 - Agglomerated cork panels for wall coverings
(characteristics, demands and methods).

CHARACTERISTICS	DEMANDS	TEST PROCEDURE
Side length	Tolerance limits without nominal value: ± 0,5 %	NP EN 427
Total thickness Type I: Type II and III:	minimum: tolerance: 10 mm ± 0,8 mm 2 mm ± 0,3 mm	NP EN 428
Squareness and Straightness side ≤ 400 mm: side > 400 mm:	≤ 0,5 mm ≤ 1 mm	NP EN 427
Breaking Tension on Traction	≥ 300 kPa	ISO 7322
Dimensional stability	Maximum variation: ≤ 0,4 %	NP EN 434
Curling	≤ 6 mm	NP EN 434
Moisture	≤ 7%	NP EN 12105
Apparent Density	To be stated by manufacturer	NP EN 672
Expansion joints resistance	must not unglue	ISO 8724
Formaldehyde contents	≤ 95 mg/kg	NP EN 12149

Source - specification documents: NP EN 12781: 2001

Table 17 - Agglomerated cork rolls for wall coverings
(characteristics, demands and methods).

CHARACTERISTICS	DEMANDS	TEST PROCEDURE
Dimensions width: length:	Tolerance limits without nominal value: ± 1 % ≥ nominal value	NP EN 426
Total thickness	Tolerance limits without nominal value: ± 0,3 mm	ISO 7322
Straightness	tolerance: 1 % for each 5m of length	NP EN 427
Breaking Tension on Traction	≥ 200 kPa	ISO 7322
Moisture	≤ 7%	NP EN 12105
Flexibility	must not crack or split	ISO 4708
Formaldehyde contents	≤ 95 mg/kg	NP EN 12429

Source - specification documents: NP EN 13085: 2001

Table 18 - Agglomerated cork with rubber for flooring
(classification).

Classification Demands							
Class / level of use	**21**	**22**	**23**	**31**	**32**	**33**	**34**
Total thickness	3,5 mm						
Thickness of wear layer	1,0 mm						
Office chair w/ wheels	surface appearance should not suffer significant alterations						

Source - specification documents: NP EN 1817:1999

Table 19 - Agglomerated cork tiles for flooring with a poly(vinyl chloride) wear layer (classification).

Classification Demands									
Class / level of use	**21**	**22**	**23**	**31**	**32**	**41**	**33**	**42**	**34**
Total thickness	2,0 mm		2,5 mm		3,5 mm		0,50 mm		0,65 mm
Thickness of wear layer	0,15 mm	0,20 mm	0,25 mm		0,35 mm		0,50 mm		0,65 mm
Residual indentation	average: ≤ 0,30 mm				average: ≤ 0,20 mm				
Board Resistance	average: ≥150 N/50 mm individual values: ≥ 120 N/50 mm								
Office chair w/ wheels	-				significant alterations should not take place				
Furniture leg	-	the surface should not present any significant alteration (Leg nr. 3)			the surface should not present any significant alteration (Leg nr. 2)				
Furniture leg with welded boards	-				the surface should not present any significant alteration (Leg nr. 0)				

Source - specification documents: NP EN 655:1997

Table 20 - Agglomerated cork flooring tiles (classification).

Classification Demands						
Class / level of use	21	22	23	31	32	41
Total thickness	≥ 3,2 mm		≥ 4 mm			
Apparent Density	≥ 400 kg/m³	≥ 450 kg/m³ (with or without decorative pattern)			≥ 500 kg/m³ (with or without decorative pattern)	
Residual indentation	≤ 0,4 mm				≤ 0,3 mm	
Office chair w/ wheels					significant alterations should not take place	
Furniture leg					surface should not present any significant alterations (Leg nr. 2)	

Source - specification documents: NP EN 12104: 2000

Table 21 – Panels for floating floor installation – cork wear layer (classification).

Classification Demands					
Class / level of use	**21**	**22**	**23**	**31**	**32**
Nominal thickness of wear layer	≥ 2,5 mm			≥ 3,0 mm	

Source - specification documents: NP EN 14085:2003

4 Application and maintenance of cork products

4.1 - Application examples

Concerning coverings, in the last few years, architects, designers and decorators have gained interest in natural materials, amongst them cork. This is due to the current multiple range of decorative/covering products available with differing textures, tones and colours, allowing for the creation of different environments and purposes, all associated with comfort - a quality inherent to cork. The use of cork in decoration has increased in popularity, not only for professionals, but also for the "*do-it-yourself*" installers. Particularly, in the latter case, modern application systems (glue-down, rolls, interlocking systems etc.) have increased the ease of use and the installment time (Gil, 1998).
As a flooring option, cork based products are varied and can be grouped as follows:

a) Agglomerated cork tiles;
b) Agglomerated cork tiles with elastomer;
c) Agglomerated cork tiles with PVC;
d) A resilient agglomerated cork base with a vinyl surface layer and an agglomerated cork surface layer with a PVC base;
e) Rubbercork flooring
f) Floating cork flooring with an upper or lower cork layer

In terms of insulation, the application possibilities of expanded agglomerated cork for construction are (Gil, 1998):

a) Terrace – thermal, vibration, moisture, and waterproofing insulations;
b) Walls and roofing - thermal insulation, prevention of condensation;
c) Partitions and doors - thermal and acoustic insulation;
d) Walls and ceilings - acoustic correction, thermal insulation, environmental comfort, decoration;
e) Floors - vibration and thermal insulation;
f) Bridges - thermal insulation, contraction/expansion joints.

More specifically, we have thermal insulation of buildings (ceiling, flooring and walls) – insulation of exterior walls (facades), double wall insulation (air chambers), insulation of flat coverings, thermal insulation of roofs and lofts, thermal insulation of ground level floors, thermal insulation of refrigeration chambers – against attainable thermal amplitudes, reducing energy losses, protecting tiles and, in addition, preventing or reducing superficial moisture on walls and ceilings. One of expanded agglomerated cork's main applications is thermal insulation for coverings, providing the dual function of an insulation material and that of a waterproofing support system, where cork's high temperature resistance and mechanical characteristics prove advantageous. In the case of exterior insulation, agglomerated cork sheets are glued/fixed onto the exterior walls and subsequently an appropriate covering is applied; such as, plaster (Manufacturers' Catalogues).

Another specific case of thermal insulation, in which the densest expanded agglomerated cork is used, is that of refrigeration chambers, wherein goods are preserved. Thermal insulation is applied namely to the floor of these chambers, where high fixed or movable pressures are applied (Gil, 1998; Medeiros, n.d.) given the circulation of loading/unloading equipment.

In the acoustics field, we have what is called acoustic correction via acoustic absorption and reduction of the reverberation time (reduction of the echo), in distinct environments, where the insulation material is exposable, and which, by association, ends up providing both thermal insulation and, in special applications, sound impact reduction (percussion), such as the case of agglomerated cork parquet, floating cork parquet or in cases where cork products provide discontinuity between rigid elements.

In the anti-vibration field, where the densest agglomerated cork is used and applied particularly as a vibration shock absorber to the support system of equipment, reducing the vibration transmission of a machine in operation to its base, the same also occurs regarding the insulation of the foundation. Agglomerated cork is especially appropriate for use in anti-vibration mats, especially for high frequencies (Garrett, 1946). It is also applied as contraction and expansion joints between rigid elements.

There are also some specific cork granule and regranulated construction applications, with the following specific functions:

a) Light filler for insulation improvement;

b) As an inert substance in concrete, reducing the weight of the concrete panels;

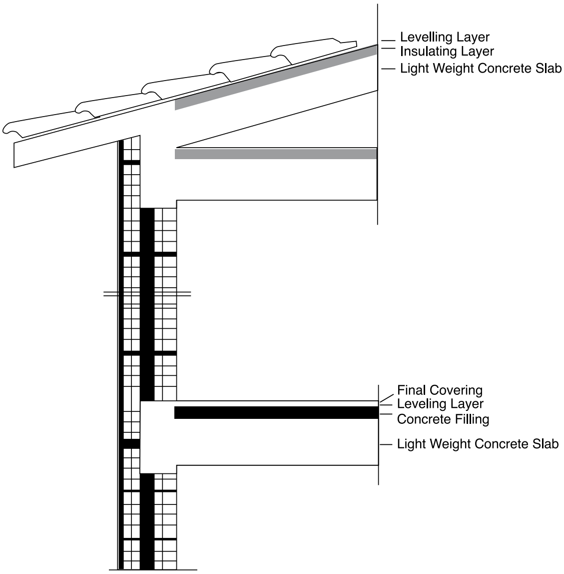
c) Thermo-insulation for light-weight and heavy concrete;

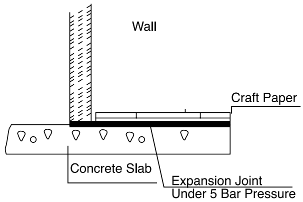
d) Anti-condensation for walls or coverings;

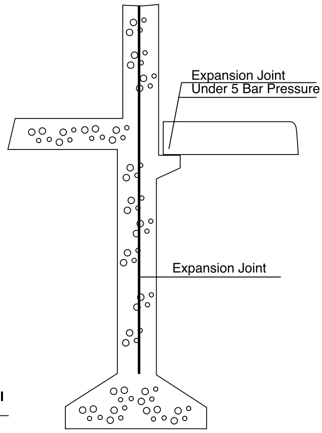
e) Acoustic-insulation material for floating floors;

f) Double wall fillers.

Cork Agglomerate Building Applications Diagram

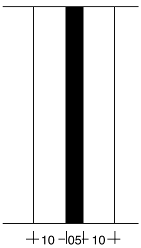




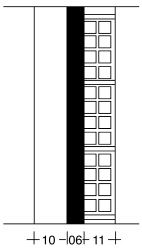


Expansion Joint in Column

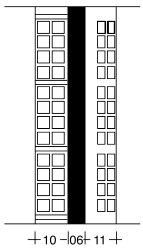
Double concrete wall

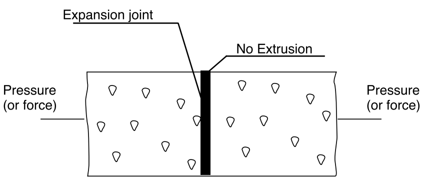


Double brick and concrete wall



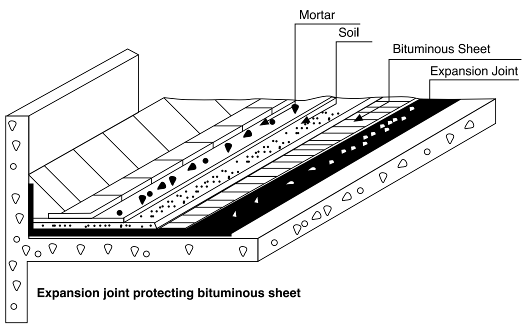
Double brick wall





When the temperature rises, the Concrete expands and tightens the joint

Expansion joint on a pavement joint (motorways; parking lots)



Expansion joint protecting bituminous sheet

4.2 - Application Methods

One of the aspects to take into account when applying cork products - to avoid complaints that are not necessarily due to the product, in particular “parquet” - is the preparation of the installation’s surface (subfloor), gluing procedure and maintenance.
Hence, the subfloor should be cleaned, any irregularities corrected; a quick drying contact glue should be used and, prior to installing the floor, a correct conditioning of the surface (hygroscopic balance) should be carried out. One also has to be careful that the surface to be covered (subfloor) has already attained a hygroscopic balance at the time of application; a period of 48 hours is usually the advisable period. These conditionals will avoid large moisture transfers, and, consequently, considerable dimensional variations or curling.
The old covering must be totally removed, should this be the case, and the whole sub-floor must be cleaned and structurally leveled. In the case of applying glue (for example, tiles), the glue must be compatible with cork (acrylic, neoprene). In the event that the surface is lightweight concrete, its residual moisture must not be superior to 2,5%. If the surface alkalinity is superior to 10, it is convenient to neutralize it before the installment of the floor (Manufacturers’ Catalogues).
The flooring type must also be selected prior to the installation, taking into account the traffic intensity of the location. Thereafter, the flooring needs to be maintained according to the type of surface treatment (for example, varnish).
The best solution to minimize percussion sound transmission on flooring consists of an application which is placed between the flooring type and the element supporting the load (subfloor); for this type of application several cork products can be used, such as, expanded agglomerated cork and composition cork.
In floating floors the intermediate layer, made of MDF or HDF, has a tongue-and-groove rim or is the self-lock type. In the first instance the union of the panels is carried out with glue (usually a glue thread, PVA type, is placed on the groove) and in the second case pressure is applied for the interlock (sometimes assisted by using a tapping block).
In the case of installing/maintaining a floating floor system, the following are some recommendations (Manufacturers’ Catalogues):

- avoid placing this type of flooring in very humid locations (bathrooms, laundries, saunas);
- place a polyethylene film before applying the flooring;
- leave a space of 8-10mm between the panels and walls (dimensional variation);
- do not attach the flooring to the subfloor (glue, nails, screws);
- install the panels in the same direction as the main source of light;
- clean with a vacuum cleaner or with a slightly damp cloth, avoiding any direct contact with water.

To avoid the incidence of unwanted condensation in the interior of buildings, when using expanded agglomerated cork as a thermal insulating material - and also other rival products, as is frequently the case - vapour barriers, such as polyethylene film, are normally applied on the inner side of the products (Manufacturers’ Catalogues).

For the exterior insulation of buildings, expanded agglomerated cork must be glued with an adhesive plaster and placed crossed joint, applying mortar thereafter to even the surface, followed by a fiberglass framework and lastly plaster. For the insulation of flat coverings, after correcting all irregularities, a vapour barrier is applied followed by cork panels, placed cross joint, a bituminous sheet, a protective filter and lastly gravel (Manufacturers' Catalogues).
In the preparation of lightweight concrete with re-granulated expanded cork, the granules must first be mixed with a bit of water, to moisten them, followed by the addition of cement and potentially sand (Manufacturers' Catalogues).

4.3 - Maintenance and cleaning

Agglomerated cork flooring is lasting, especially if it is cared for and well maintained, avoiding installation in areas where there is an incidence of permanent and direct sunlight (discolouration tendency). The durability and resistance of the flooring, its type of maintenance and usage are directly related to the type of surface treatment: wax, varnish, PVC. Cork flooring is indicated for premises where there are both fixed and movable items, without any special precautions to be had regarding common furniture. Cork is also appropriate for places where daily cleaning is generally carried out using water. Cork supports the presence of water as long as it is neither systematic nor prolonged; being also practically resistant to common household product stains. When cleaning cork flooring, it is advisable to use a vacuum cleaner or a slightly damp mop.

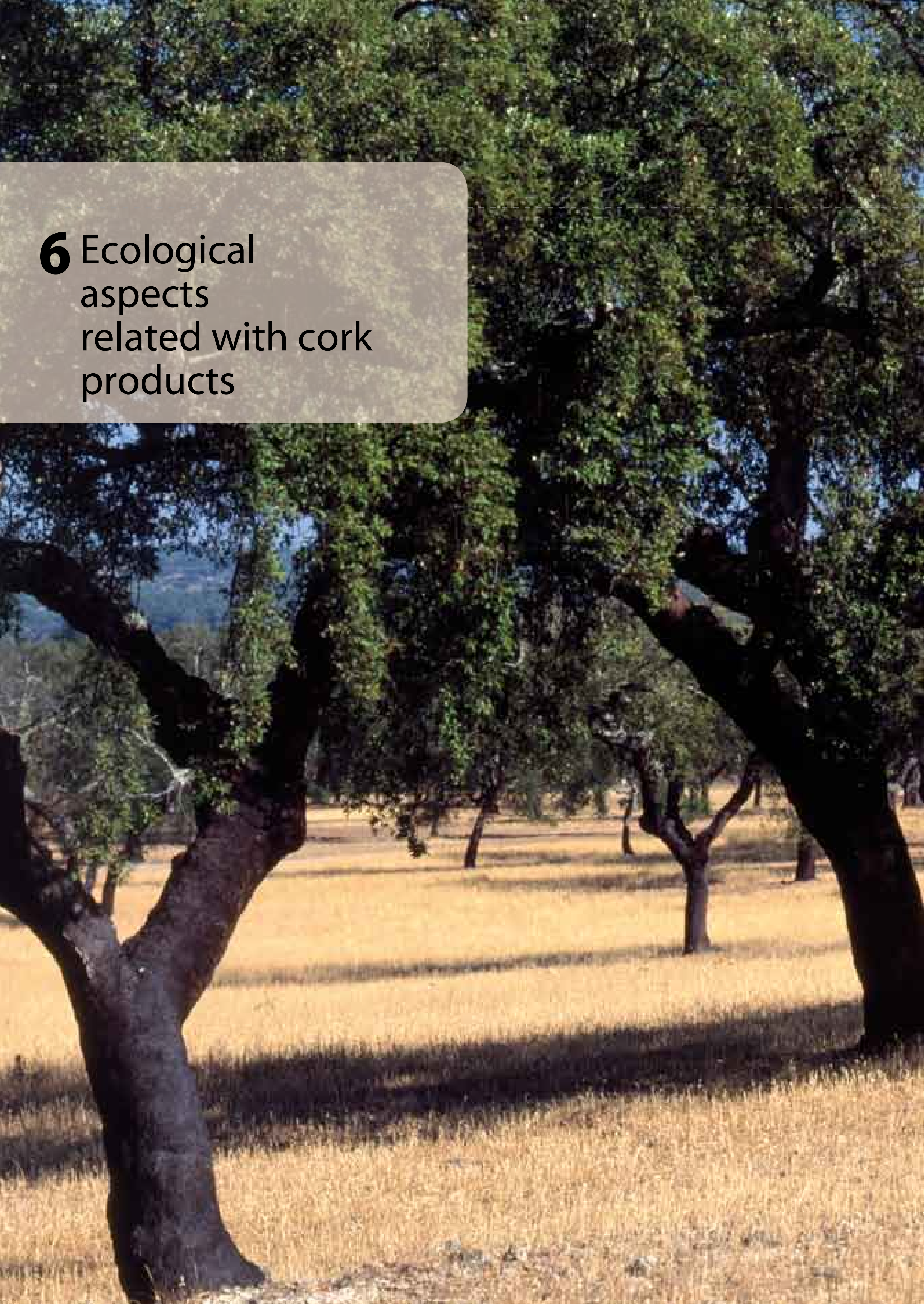
When a varnished floor needs to be renewed, all its applied products must be removed, the floor sanded carefully, dust cleaned off and then 1 or 2 coats of the recommended varnish applied. Furniture must not be dragged on the floor surface and the furniture legs must be protected (Manufacturers' Catalogues).
In the case of wall coverings, the precautions are similar to those of flooring products. As for exposed insulation, this is usually painted with an aqueous based paint, which can be renewed by merely painting over the previously applied layer.
In the case of other cork building product applications there are no special maintenance and cleaning cares to be considered.

5 Cork products within the context of the Construction Products Directive

Cork, per say, is not a building material, but some of its products are, as is the case of thermal insulation and flooring.
Following the technical harmonization, essential for the fulfillment of the Construction Materials and Products Directive, two significant scopes for building products were mandated, in 1989, and harmonized standards developed for: thermal insulation and flooring products, in which cork is integrated (CEN/TC-88 – expanded agglomerated cork was included in the first standards; CEN/TC-134 –cork flooring included in the second standards). In 1992, with the reactivation of the Technical Committee for "Wall Coverings", the Cork Work Group (CEN/TC 99/WG 3) was also established (Bicho, 1999).
The Construction Products Directive 89/106/CEE, was published in December of 1989, but was partially altered by the Directive 93/68/CEE, and clarified by the Decision of the Committee on the 31st of May 1995 and by subsequent documents regarding proof of conformity processes applied to stipulated "family products" (in which cork products are integrated, for example, thermal insulation materials).
The Directive (currently designated CPD, acronym formed by the English title), constituted, thus, the necessary platform for eliminating technical barriers by specifying that products must comply with, what is known as "*essential requirements*", mainly concerning safety and health criteria. These requirements are a criteria reference to be fulfilled by the construction industry. But in order for the industry to satisfy these requirements, without existing conditions of unfair competition, the functional behaviour and technical specification levels of the building products must be determined by European «*harmonized standards*», applied in all States. The CPD also indicates the basic proceedings that must be adopted to verify the products conformity to these requirements (Bicho, 1999).
A harmonized standard is a technical specification (European standard or harmonized document), adopted by the CEN – *Comité Européen de Normalisation* or European Committee for Standardization.
The implementation of the CPD is, thus, supported by the establishment of harmonized standards (hEN) which fulfill a practical and important role in its application.
The hEN are voluntary, as are other European standards, but are developed around essential requirements and prepared on the basis of the Committee's Mandates (Directive 98/34/EC), leading to a reference which is published in the Official Newspaper with a mandatory transposition to national standards. Once adopted, the former national standards, of the respective field, are withdrawn.
In addition, the Directive considers that a product is rendered apt when it is in compliance with a harmonized standard. This compliance is evident when a CE marking is placed on a product by the manufacturer, being the respective marking the exclusive responsibility of the manufacturer.

For applicable standards we have:
- thermal insulation: NPEN 13170, which will have an addendum for fitting and fastening;
- flooring: NPEN 12104, NPEN 655 and NPEN 1817 for parquet and PVC surface treatment.
For the compliance of the essential directive requisites the standard is NPEN 14041;
- wall coverings: NPEN 12781 and NPEN 13085

6 Ecological aspects related with cork products



6.1 - Reuse and recycling

Upon the demolishment of a building, very often imposed by the concluding useful lifespan of a building or construction, it may be viable to remove the entire expanded agglomerated cork panels, as these may be used in identical applications. Expanded agglomerated cork panel samples obtained from buildings over 50 years old showed that even after this time period their visual aspect and essential properties had remained unchanged (Gil, 1996; Gil 2002).

When the whole panel removal is not possible (panel breakage, contamination with other products) granulation is advisable producing regranulated cork which, like other cleaned re-granulated cork, is destined for new applications such as thermal insulation or as an inert substance in the manufacture of concrete and light mortars. (Gil, 2002).

Natural non-expanded granulated cork, when it is not mixed, can also be re-used as a filler or in the manufacture of agglomerated cork or yet in mortars.

In the process of obtaining cork products, free from contaminants (films, glues, mortars, etc.), these can be ground up and used or incorporated in technical products.

Composition cork for construction can incorporate various types of cork byproducts (for example, used cork wine closures, remains of agglomerated cork, etc.), thus contributing to global recycling.

6.2 - Ecological aspects

The manufacturing process of expanded agglomerated cork only employs superheated steam resorting to boilers fueled by granules obtained from byproducts, amongst others, without making use of any non-cork products. Agglomeration also takes place by means of cork's own resin, resulting in a product that is 100% ecological and natural - an advantage very difficult to equal by rival materials.
In the manufacturing processes of cork building products an important byproduct is produced - cork powder. This powder is currently burnt for the production of steam and/or energy used in the factories themselves or even granted to the electrical network, given the high energy content of this material. There is no cork byproduct that is not re-used or otherwise valued/employed.
The fact that cork products are thus used is also very important from an ecological point of view because cork is a renewable product of long duration, promoting CO_2 fixation. Furthermore, a cork oak tree that is harvested periodically, will produce between 250% and 400% more cork (Gil, 1998) than what it would produce had it not been harvested, developing a higher CO_2 fixation. Accordingly, the consumption of cork products leads to its

exploration and helps promote the development of additional cork forests and harvestings, consequently leading to the absorption of larger quantities of CO_2 (Gil, 2005).

Regarding the quantity of absorbed CO_2, specifically by cork building products, the following approximate calculations can be carried out:

- using the reference values indicated in 1.4, we have:

a) Coverings (flooring, walls and ceilings) = 10 million m^2/year, considering an average thickness of 4mm and an average density of 450 kg/m^3 = 18.000 tons/year

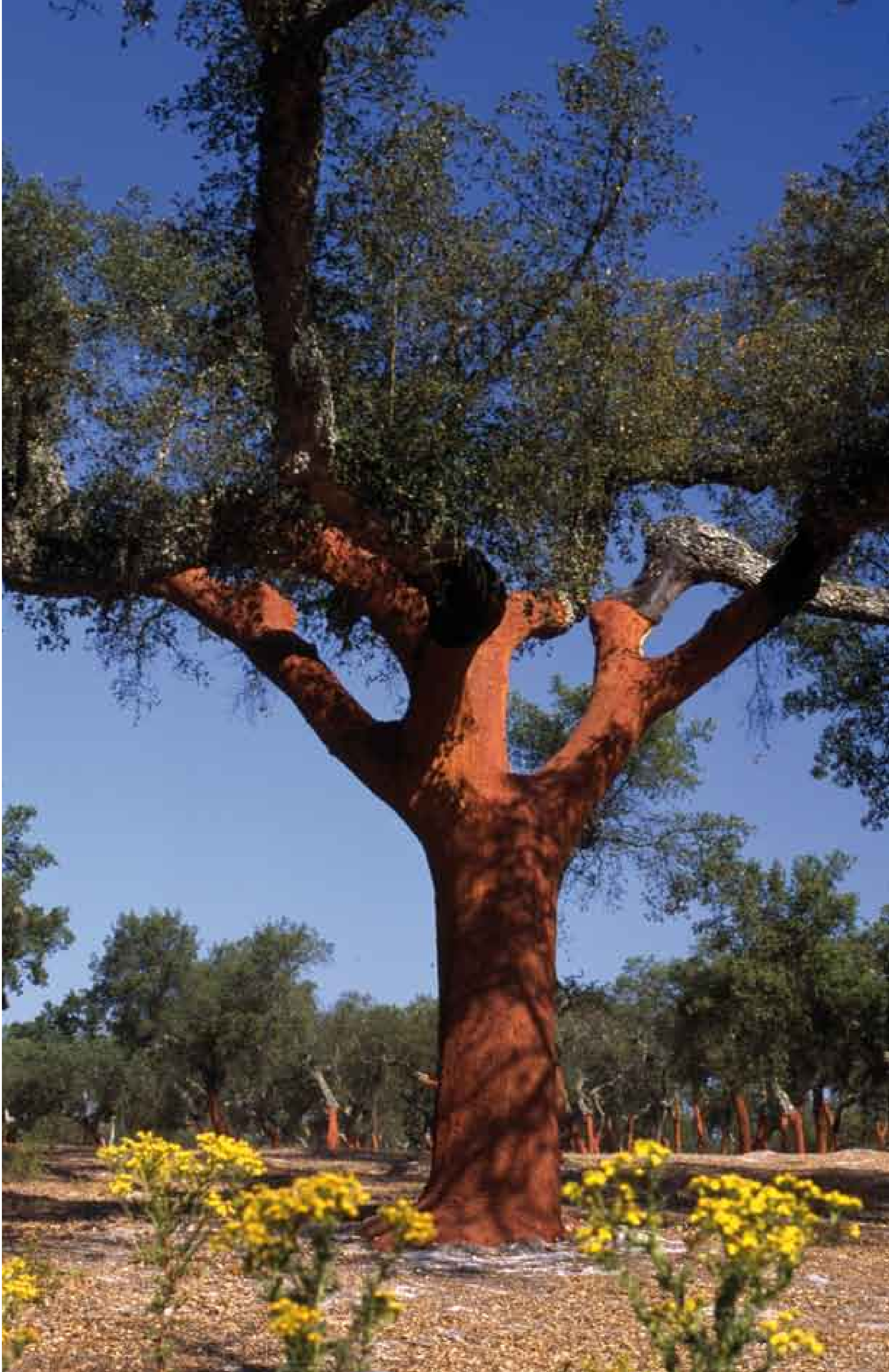
b) Insulation = 150.000 m^3/year, considering an average density of 120 kg/m^3 = 18.000 tons/year

Corresponds to a global value of 36.000 tons/year.

Knowing that the average carbon quantity of cork is 57,37 % (Gil, 2005), 36.000 tons of cork corresponds to 20.653 tons of carbon/year which corresponds to an absorbed quantity of 75.673 tons CO_2/year (CO_2/C = 3,664).
For a better perception of what this value is, the following conversions can be carried out:

- considering an average annual vehicle mileage of 17.500km and the average production of 170g of CO_2/km, we know that in a year this vehicle produces 2,98 tons of CO_2. Thus, we can easily conclude that 75.673 tons of absorbed CO_2/year by cork products for the building industry corresponds to the pollution produced by nearly 25.394 vehicles in a year.

Please note that these are approximate values, corresponding only to calculations regarding Portuguese production, not taking into account other cork products, such as expansion joints, re-granulated cork etc., being, nevertheless, an indicator of the ecological importance of cork products.
Concluding, there are few products that can compete with the ecological harmony of cork (Anonymous, 2005).



7 Future cork products for the building industry

The future development of expanded agglomerated cork will be in the adoption of densification techniques, which are already underway, conferring to cork different mechanical and physical characteristics whilst maintaining its special ecological traits. This also allows for the diversification of potential applications and an expansion in the current application markets (Gil, 1990; Gil, 2001).
Agglomerated cork for coverings and decorative purposes also have a future given the increased tendency for natural products, regarding these applications. By diversifying its patterns and material combinations, cork will maintain its importance, although it is relevant that these actions be carried out in conjunction with market studies and communication activities aimed at opinion leaders - namely decorators, designers, architects and civil engineers, very often responsible for the material selection- given that at times these audiences are not aware of these products. Notwithstanding, the communications activities also need to be perfectly coordinated with a sufficient product supply.
In the field of composition cork, the industrial manufacture of rigid agglomerated cork is yet to be explored, with a basis, in particular on plastic binders (Gil, 1998), expanding its current applications and making it possible to use industrial residues of added value.
An increase in the use of cork products, associated with other materials, is foreseeable for structural purposes, such as those in reference (Gil, 2005b), as well as the use of added value products such as new innovative applications for the building industry and other specific dominions.
Lastly, and still related with the building industry, a study was carried out which led to the development of a new product, which is currently in use (Gil, 1999), that projects cork particles thereby cleaning/removing dirt and existing deposits on materials exposed to environmental pollution. In this respect new applications are foreseen, such as the cleaning of monuments and building exteriors, constituting thus an important cork product application for the building industry.



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