# Newsletter nº 6

# Industrial trials demonstrate that LIFECERAM tiles, obtained from ceramic waste, are appropriate for outdoor use

## A Life Cycle Assessment was performed and tile technical characteristics and environmental impact parameters were studied.

### The industrial trials were a key LIFECERAM project action

Industrial trials confirmed the laboratory results. Some manufacturing problems were detected and actions were successfully undertaken to address these. Information was obtained on consumptions for a preliminary economic study and a Life Cycle Assessment (LCA) was performed of the new product.

During these trials, all the ceramic wastes considered in the project were sampled and used to prepare the body, engobe, and glaze composition of the new ceramic tile. Ceramic tiles were then fabricated and tile technical characteristics and environmental impacts (Life Cycle Assessment, hereafter LCA) were determined. Figure 1 shows some pictures of the industrial trials.

**Figure 1a. Different moments in the industrial trials.**

**Figure 1b. Industrial trials in other process stages.**

The technical characteristics and environmental impacts of the developed waste-based product and those of competing products used in urban flooring are compared below.

## Comparative study and technical characteristics

A comparative study was performed of the following products:

- LIFECERAM TILES. Size 330 mm x 330 mm.
- NATURAL STONE SLABS. Stone from Borriol, size 400 mm x 400 mm.
- TERRAZZO TILES. Size 400 mm x 400 mm.
- CONCRETE FLAGS. Size 250 mm x 250 mm.
- PORCELAIN STONEWARE TILES. Size 400 mm x 400 mm.

Figure 2 shows photographs of the alternative products, while Figure 3 shows the final appearance of the tiles developed in this project.

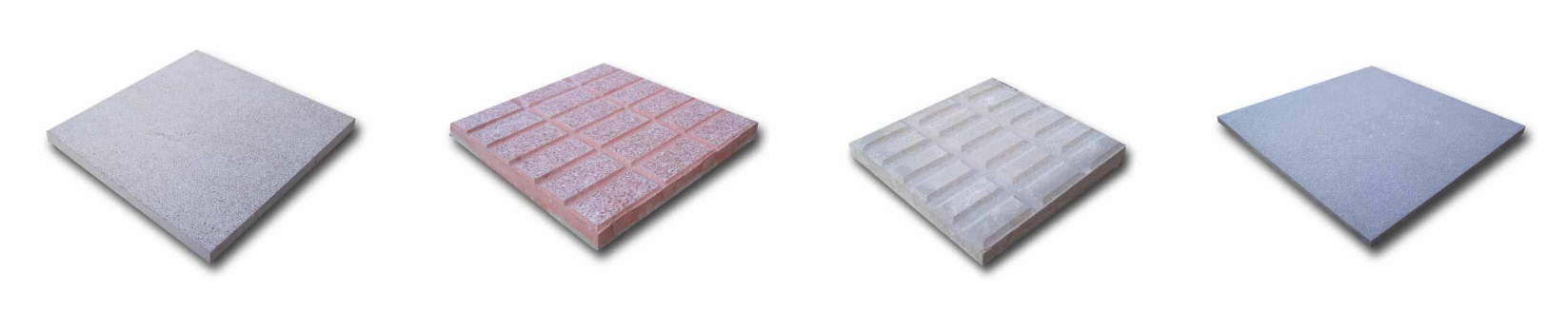

**Figure 2. Appearance of tiles currently being used in urban flooring: a) natural stone, b) polished red terrazzo, c) concrete, and d) porcelain stoneware tile.**

**Figure 3. LIFECERAM tile.**

## Tests conducted to characterize the products

The following tests were conducted to characterise the products:

- Modulus of rupture and breaking load (UNE EN ISO 10545-4: 2012 "Ceramic tiles - Part 4: Determination of modulus of rupture and breaking strength").
- Resistance to deep abrasion (UNE EN ISO 10545-6: 2012 "Ceramic tiles - Part 6: Determination of resistance to deep abrasion for unglazed tiles" and EN ISO 10545-7: 2012 "Ceramic tiles - Part 7: Determination of resistance to surface abrasion for glazed tiles"
- Resistance to hard impact (described in Annex 6 of Cahier 3735 of the Centre Scientifique et Technique du Bâtiment "Détermination de la tenue au choc lourd des carreaux céramiques non émaillés-choc à la bille de 510 g").
- Slip resistance (UNE-ENV 12633:2003 "Method of determination of unpolished and polished slip/skid resistance value").
- Frost resistance (UNE EN ISO 10545-12: 1997 "Ceramic tiles - Part 12: Determination of frost resistance").

- Water absorption (UNE-EN 13748-2:2005 Point 5.8 "Terrazzo tiles - Part 2: Terrazzo tiles for external use").
- Moisture expansion (UNE EN ISO 10545-10: 1997 "Ceramic tiles - Part 10: Determination of moisture expansion").
- Linear thermal expansion (UNE EN ISO 10545-8: 1997 "Ceramic tiles - Part 8: Determination of linear thermal expansion").
- Dirt retention capability.
- Cleanability (method C described in standard UNE-EN ISO 10545-14: 1998 "Ceramic tiles - Part 14: Determination of resistance to stains").

The following table provides a comparative analysis of the main characteristics of the product developed in the project and those of products currently being used in urban flooring**.**

**Table 1. Measured technical characteristics of different types of urban flooring.**

| Technical characteristics | LIFECERAM tile | Natural stone | Terrazzo | Concrete | Porcelain stoneware tile |
|---|---|---|---|---|---|
| **Breaking load. (N) EN ISO 10545-4 (min thickness, mm)** | **6060 (15)** | **9680 (30)** | **4707 (40)** | **2590 (30)** | **6710 (13.5)** |
| **Mechanical strength. ($N/mm^2$) EN ISO 10545-4** | **38** | **15** | **6** | **5** | **52** |
| **Abrasion resistance. ($mm^3$) EN ISO 10545-6 EN ISO 10545-7** | **175** **Class 4** | **299** **-** | **414** **-** | **361** **-** | **109** **-** |
| **Impact resistance. Cahier CSTB 3735** | **Resistant** | **Resistant** | **Resistant** | **Resistant** | **Resistant** |
| **Slip resistance. ENV 12633. USRV** | **> 45** | **> 45** | **> 45*** | **> 45** | **> 45** |
| **Frost/thaw resistance EN ISO 10545-12** | **Resistant** | **Resistant** | **Resistant** | **Resistant** | **Resistant** |

| | | | | | |
|---|---|---|---|---|---|
| **Water absorption by capillarity. ($g/cm^2$) EN 13748-2** | **< 0.01** | **0.01** | **0.47** | **0.28** | **< 0.01** |
| **Total water absorption. (%) EN 13748-2** | **2.8** | **0.5** | **6.3** | **6.6** | **0.1** |
| **Moisture expansion. (mm/m) EN ISO 10545-10** | **0.1** | **0.8** | **1.2** | **1.3** | **< 0.1** |
| **Thermal expansion. EN ISO 10545-8 ($K^{-1}$)** | **$6.4 \times 10^{-6}$** | **$5.0 \times 10^{-6}$** | **$4.6 \times 10^{-6}$** | **$5.3 \times 10^{-6}$** | **$5.7 \times 10^{-6}$** |
| **Dirt retention.** | **Low** | **Low** | **Medium** | **Medium** | **Very low** |

*** Polished terrazzo yielded a value of 35>USRV≥45**

**Conclusions: the LIFECERAM tile exhibits technical characteristics that make it appropriate for outdoor use.**

The results obtained allow the following conclusions to be drawn:

- Ceramic tiles, both the one developed in the LIFECERAM project and porcelain stoneware tile, were the products that displayed the best mechanical properties. The LIFECERAM tile properties were not as good as those of the porcelain stoneware tile owing to the LIFECERAM tile's greater porosity.
- The deep abrasion test exhibited the same trend as the mechanical strength test: both ceramic tiles displayed much less wear than the other materials. The greater porosity of the LIFECERAM tile led to greater deep abrasion than in the porcelain stoneware tile. As the LIFECERAM tile was glazed, a surface abrasion test was also performed to determine glaze resistance. The tested model yielded a value corresponding to class 4 because the design was a light colour. When the same glaze composition was a dark colour, this was class 5. The latter value is appropriate for outdoor use.
- With respect to the impact resistance test, all materials behaved satisfactorily under appropriate installation conditions owing to their high thickness.
- The developed glaze exhibited a slip resistance of 54, this being higher than the value of 45 required for outdoor use.
- All tested materials passed the frost resistance test.
- The LIFECERAM tile exhibited low moisture expansion. The values obtained in the linear thermal expansion test were very low, all tested materials exhibiting similar values.

- Dirt retention and cleanability are related to tile surface porosity and type of surface roughness. The developed glaze exhibited excellent slip resistance and low dirt retention.

The above results indicate that the body granulate obtained in the industrial trials with the operating variables used, as well as the developed engobe and glaze, provided appropriate characteristics for the manufacture of ceramic tiles in existing industrial facilities. The process conditions used allow ceramic tiles to be fabricated with appropriate properties for use in urban flooring. These properties were often better than those of the studied non-ceramic products (concrete flags, terrazzo, and natural stone). With regard to natural porcelain stoneware tile, the LIFECERAM tile exhibited a slightly lower mechanical strength owing to its lower degree of densification, caused by the use of fired tile scrap with a coarse particle size.

The above results yielded the technical data sheet of the new product, shown in Figure 4.

Fecha / Date: 11-12-2015 | Modelo / Model: LIFECERAM | Formato / Size: 33 x 33

| ENSAYO / TEST | RESULTADO / SCORE | NORMA DE ENSAYO STANDARDS OF TEST |
|---|---|---|
| DIMENSIONES Y ASPECTO SUPERFICIAL<br>SIZES AND SURFACE APPEARANCE | Cumple con los requisitos aplicables a cada modelo definidos en la norma UNE-EN 14411 para el Grupo BIb<br>All products meets the requirements applied to the standards of UNE EN 14411 for the type BIb. | UNE-EN-ISO 10545-2:1996 |
| ABSORCIÓN DE AGUA / WATER ABSORTION | 0,5 % < E ≤ 3% | UNE-EN-ISO 10545-3:1997 |
| FUERZA DE ROTURA (N) / BREAKING STRENGH | > 5.000 N | UNE-EN-ISO 10545-4:1997 |
| RESISTENCIA A LA FLEXIÓN / MODULUS OF RUPTURE | > 35 N/mm² | UNE-EN-ISO 10545-4:1997 |
| DUREZA AL RAYADO / SCRATCH RESISTANCE ESCALA MOHS | 6 | UNE-67-101-1992 |
| RESISTENCIA A LA ABRASIÓN<br>ABRASION RESISTANCE PEI | Type 3 | UNE-EN-ISO 10545-7:1996 |
| RESISTENCIA A LA HELADA / FROST ENDURANCE TEST | Pass the test | UNE-EN-ISO 10545-12:1997 |
| RESISTENCIA A LAS MANCHAS / STAIN RESISTANCE | Type 5 | UNE-EN-ISO 10545-14:1998 |
| RESISTENCIA A LOS PRODUCTOS DOMÉSTICOS DE LIMPIEZA Y ADITIVOS PARA AGUA DE PISCINAS / CHEMICAL RESISTANCE DOMESTIC CLEANING PRODUCTS & SWIMMING POOL WATER ADDITIVES | Type GA | UNE-EN-ISO 10545-13:1998 |
| RESISTENCIA A LOS ÁLCALIS Y ÁCIDOS DÉBILES Y FUERTES / CHEMICAL RESISTANCE (ACIDS AND ALCALIS LOW & HIGH CONCENTRATION | Type GLA, GHA | UNE-EN-ISO 10545-13:1998 |

Nules, 18 de Diciembre de 2015

Responsable / Responsible:

Pedro Castejón Segarra
Director de Calidad / Quality Manager

**Figure 4. Technical data sheet of the tile developed in the LIFECERAM project.**

**Environmental characteristics: the LIFECERAM tile's environmental performance is the same as or better than that of products currently being used for the same purpose.**

The results of actions B3 and B4A were used to perform a Life Cycle Assessment (LCA) of the new product. This was then compared with those of the studied existing products. The LCA study was conducted considering the environmental aspects of the tile manufacturing process and of the overall environmental impact. This action demonstrated that the environmental performance of the product developed in the LIFECERAM project was as good as or better than that of products currently being used for the same purpose.

The LCA was conducted in accordance with the recommendations and requirements of international standards ISO 14040:2006 and ISO 14044:2006, as well as European standard UNE EN 15804:2012, which sets out the basic Product Category Rules for construction products. For the modelling of the Life Cycle Assessment in the GaBi software, the Annex C recommendations: *Modelling reuse, recycling, and energy recovery of the ILCD Handbook,* and related methodologies applied in published articles, such as Bala Gala et al., 2015; Gentil et al., 2010; and Silvestre et al., 2014, were followed.

The calculated environmental impact parameters were those recommended by the ILCD and those considered in the work of committee CEN 350 on sustainability of construction works:

- Global Warming Potential, GWP; expressed in kg $CO_2$ equivalents
- Acidification Potential, AP, expressed in kg $SO_2$ equivalents
- Eutrophication Potential, EP, expressed in kg $PO_4^{-3}$ equivalents
- Photochemical Ozone Creation Potential, POCP, expressed in kg $C_2H_4$ equivalents
- Ozone Depletion Potential, ODP, expressed in kg CFC-11 equivalents
- Abiotic Depletion Potential – elements, ADP–Elements, expressed in kg Sb equivalents
- Abiotic Depletion Potential – fossil fuels, ADP–Fossil, expressed in MJ

The results of the environmental impact parameters relating to the manufacturing process of the different studied products are shown in Figure 5, while the value of these parameters in the whole life cycle is shown in Figure 6.

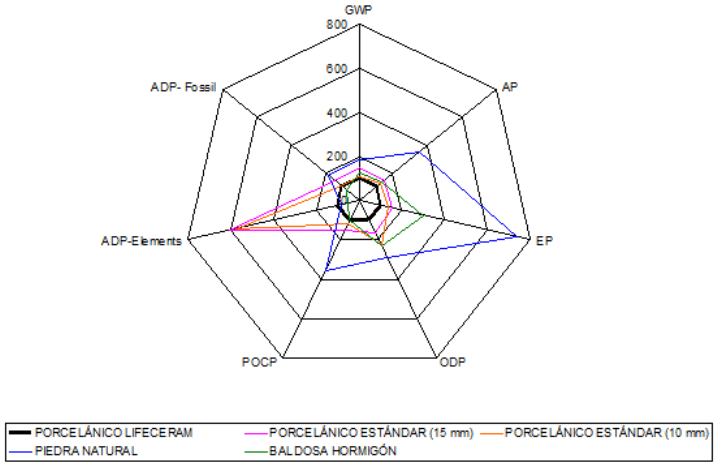


**Figure 5. Environmental impacts of the manufacturing stage of the studied urban flooring.**

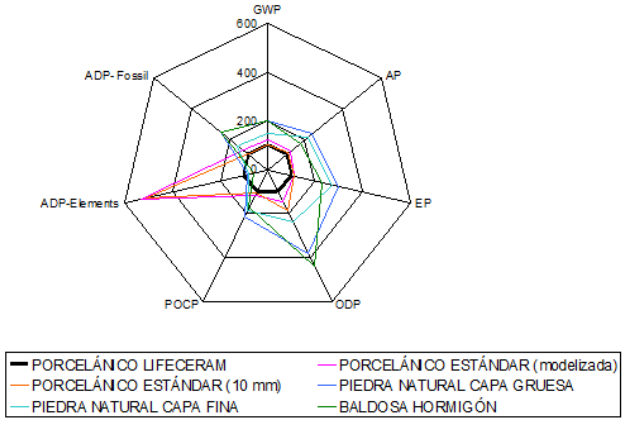


**Figure 6. Environmental impacts of the whole life cycle of the studied urban flooring.**

As may be observed from the data on the product manufacturing stage (Figure 5) – that is, raw materials extraction, transport and manufacture of the studied products – the new LIFECERAM tile performed better in all but two flooring impact categories. This was because concrete flags generated a lower Abiotic Depletion Potential – fossil fuels (ADP–Fossil) than the LIFECERAM tile owing to their lower energy consumption. In addition, concrete flags and natural stone had a lower Abiotic Depletion Potential of non-fossil resources (ADP–Elements) than the LIFECERAM tile owing to the absence of glaze, whose composition contains raw materials deemed critical by the European Union, such as the boron-introducing raw materials in the composition (http://ec.europa.eu/growth/sectors/raw-materials/specific-interest/critical/index_en.htm).

With regard to the whole Life Cycle Assessment (Figure 6), only the concrete flags and natural stone performed better than the LIFECERAM tile in the environmental impact category of Abiotic Depletion Potential of non-fossil resources (ADP-Elements). In the other impact categories, the LIFECERAM tile exhibited better environmental performance.

To facilitate comparison of the above results, the set of environmental indicators has been reduced to a single value by applying Normalisation Factors. The normalisation method set out in CML2001 – Apr. 2015, EU25+3, which provides information on the environmental situation in 2001–2015 of the 25 countries in the European Union plus Iceland, Norway, and Switzerland (EU 25+3), was used. The results are shown in Figures 7 and 8. It may be observed that the tile developed in the LIFECERAM project exhibited the lowest environmental impact, both in the manufacturing stage and in the product's whole life cycle.

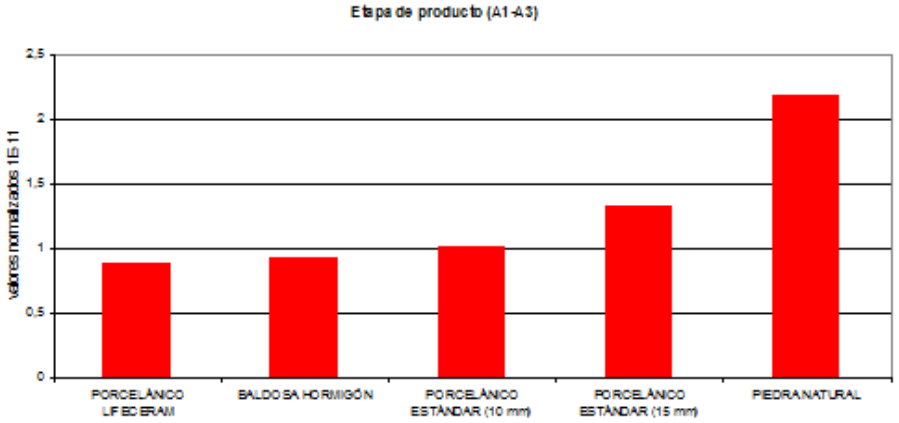


**Figure 7 Comparative analysis of the normalised environmental impact of the studied urban flooring. Scope: cradle to gate.**

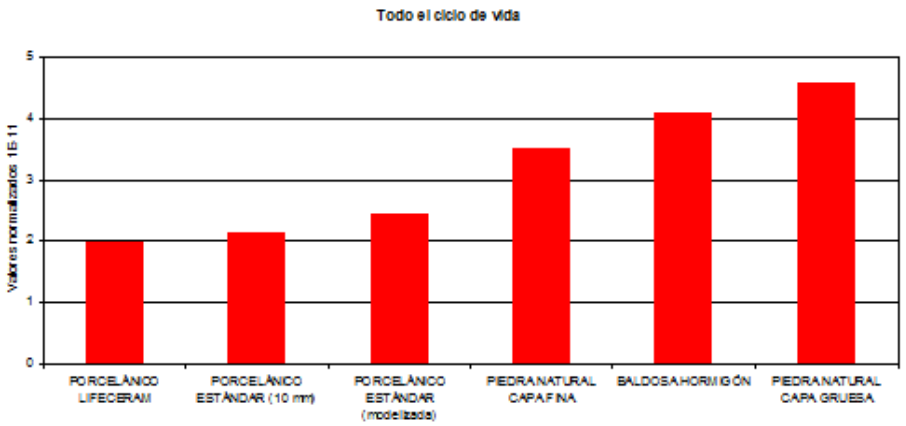


**Figure 8 Comparative analysis of the normalised environmental impact of the studied urban flooring. Scope: cradle to grave.**

**LIFECERAM tile presented to the ceramic companies on 29/05/2016**

## About LIFECERAM

LIFECERAM is a LIFE+ project, coordinated by the Instituto de Tecnología Cerámica (ITC), with the participation of the Spanish Ceramic Tile Manufacturers' Association (ASCER) and the companies CHUMILLAS TARONGI, S.A., KEROS, S.A., and VERNÍS, S.A., which manufacture ceramic machinery; ceramic tiles; and frits, glazes, and ceramic colours, respectively. The project seeks to achieve zero waste throughout the ceramic tile manufacturing process. For further information on LIFECERAM+, please check out: http://www.lifeceram.eu

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