CERAMIC CLADDING SYSTEMS IN SOLAR DECATHLON COMPETITION PROTOTYPES

USE TO DATE AND FUTURE POTENTIAL

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ABSTRACT

The current tendency in building construction is to try to promote sustainable construction projects. This trend is reflected in various European directives and, increasingly, in the environmental certifications of buildings.

The Solar Decathlon Europe competition also encourages the use of environmentally friendly materials and systems. This is why we have an ever-increasing number of ceramic products that respond to these demands, which enables us to compare and select materials and products from the entire European market, as well as analysing their use in the immediate future.

This study is based on an analysis of ceramic products used for interior and exterior cladding purposes in the prototypes presented at the Solar Decathlon competition during its 2010 and 2012 exhibitions. It was conducted with the aim of determining the attributes that justify their use in these "sustainable" buildings and as a way of analysing their potential uses in the future.

It is also important to know the direct competitors of ceramic products for these applications and the options the ceramics sector can offer in response to environmental demands.

The final objective of this study is to provide an analysis of the materials and applications that were used and the products which are available on the market, so that we know what ceramic options there are and can respond to the requirements of sustainable buildings.

1. INTRODUCTION

Solar Decathlon is a competition in which universities design and build energy-efficient and eco-friendly homes, which function exclusively by means of solar energy. In this study, we analyse the use of ceramic materials in these prototypes, as well as the products manufacturers offer in response to environmental demands.

In the study, the materials and products which are used, the way they are perceived and the technical specifications of each of the materials are analysed, so that the future use of these new materials can be estimated.

2. INTRODUCTION TO SOLAR DECATHLON EUROPE

Solar Decathlon Europe is an international university competition which promotes research on the development of energy-efficient homes. The aim of the teams that take part is the design and construction of houses which consume as few natural resources as possible and produce the least possible waste during their life cycle. A particular emphasis is placed on reducing energy consumption and obtaining everything that is required from the sun.

With the financial and technical collaboration of institutions and companies, each team acquires training and research experience which are relevant to the challenges posed by building in the future, and they develop innovative solutions and support scientific research in their field.

Together with these institutions and companies, the teams act as drivers of change, enabling the general public to discover the options for themselves and raising their awareness of the real possibilities of combining a reduction in environmental impact with the maintenance of comfort and quality in the design of their homes.

For their part, the Universities, companies and public organizations have entered into a new form of collaboration, testing scientific projects, for example, in real conditions so they can later be transferred to the market, or improving and applying existing products creatively.

Fig. 1. Solar Decathlon Europe 2012 in Madrid. Source: http://solardecathlon.ch/

Currently, Universitat Jaume I and the Danish University, VIA University College, are developing their project so they can present their prototype at the next Solar Decathlon Europe competition, which will be held in Versailles (France) in 2014.

3. MATERIALS USED AT SOLAR DECATHLON

In the previous Solar Decathlon Europe competitions held in Madrid in 2010 and 2012, there was limited use of ceramic materials which are adaptable to this new type of building. As can be seen in Table 1, these ceramic materials compete with other materials, some of which have a reputation for being environmentally friendly, but there are other synthetic materials whose environmental qualities might be more questionable.

SDE PROTOTYPE	EXTERIOR	INTERIOR	BATHROOMS
01 FLORIDA 	Trespa panels, Wood	Flooring: pine wood	**Ceramic tiling** Fittings: ceramic bathroom fittings
02 UPC 	Polycarbonate, OSB	Flooring: varnished OSB	ZICLA (recycled plastic) Fittings: dry fibreglass toilet, shower tray and washbasin possibly **ceramic**

03 SEVILLA 	Formica cladding	Flooring: steel tiles with PCM (Phase Change Material) and vinyl finish	Formica cladding Fittings: ceramic sink, stainless steel toilet, shower base consisting of wooden slats
04 IAAC 	Laminated wood	Flooring: flexible wooden slats	Interior formica or vinyl (not clearly specified) Fittings: **ceramic bathroom fittings**
05 ROSENHEIM 	Synthetic wood, glass, metal	Flooring: beech-wood parquet	Beech-wood parquet, **mosaic tile mesh** in shower Fittings: **ceramic toilet and washbasin**
06 BERGISCHE 	Wood, glass, solar curtain	Flooring: Trespa panels, thermowood floor	Bathrooms: wood, synthetic materials Fittings: Corian-type fittings
07AALTO 	Wood	Flooring: wood	Wood Fittings: ceramic bathroom fittings, except shower
08 TIANJIN 	SIP (structural insulated panels) sandwich panels	Flooring: SIP sandwich panels (structural insulated panels)	Prefabricated SMC (sheet moulding compound) Module Fittings: prefabricated SMC (sheet moulding compound) Module
09 NOTTINGHAM 	Wood, glass	Flooring: wood	Bathrooms: prefabricated unit Fittings: **ceramic toilet and washbasin**

10 ARTSetMETIERS 	Wood, green façade	Flooring: clay tiles	Bathrooms: wood, synthetic materials Fittings: **ceramic washbasin, wooden shower**
11 STUTTGART 	Wood, lacquered steel, glass	Flooring: wood	Bathrooms: wood, melamine Ceramic bathroom fittings, shower fitted into the floor
12 VIRGINIA 	Laminated zinc, stainless steel, glass, polycarbonate	Flooring: floated / polished cement	Bathrooms: floated cement, wood Fittings: **ceramic toilet and washbasin**
13 CEU UCH 	Corian, wood, glass	Flooring: **7 mm tiles (Saloni)**	Bathrooms: **tiled floors, walls (Saloni)** Fittings: ceramic toilet, washbasin, shower
14 VALLADOLID 	Wood, glass, metal	Flooring: wood	Bathrooms: wood, vinyl materials Fittings: **ceramic toilet, washbasin, shower**
15.LIVINGEQUIA-BERLIN 	Wood flamed to a black colour	Flooring: 3.5 mm natural rubber tiles	Fittings: **ceramic toilet, washbasin, shower**

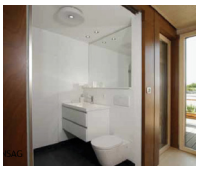
16. TONGJI 	Bamboo	Bamboo floors Cladding: plaster panels fixed to phase change materials	**Ceramic** fittings 
17 ARMADILLO BOX-GRENOBLE 	Wood, metal 15 mm OSB panels	10 mm OSB panels Floating floor, cork strips	Fittings: **ceramic toilet, washbasin, shower** 

Table 1. Table 1: Exterior and Interior Cladding, and Bathroom Materials Used in the SD-2010 Prototypes. Source: http://www.sdeurope.org/

4. CERAMICS USED IN SOLAR DECATHLON COMPETITIONS

On the webpage of the organization, we can obtain information about the prototypes presented at previous competitions and we can analyse the ceramic materials that were used in detail. Other non-ceramic materials, such as Corian, the characteristics of which we can regard as being similar to ceramic materials, are also included.

SML HOUSE- CEU SDE 2010		
EXTERIOR	12.5 cm white Corian (Dupont) + photovoltaic panel. 175x300 cm; wood, glass	
INTERIOR	30x80 cm ultra-thin, 7 mm-thick, stoneware floor tiles reinforced with fibreglass (Saloni) Solar floor, enabling the absorption of solar radiation and functioning as a heat collector	
BATHROOM	Flooring: interior ceramic cladding (Saloni) Fittings: ceramic toilet, washbasin, shower	

ROSENHEIM (SDE 2010)		
BATHROOM	Bathrooms: beech-wood parquet, **ceramic mosaic mesh in shower** Fittings: ceramic toilet and washbasin	

MED IN ITALY (SDE 2012)		
INTERIOR	**Ceramics**: they are used in the lighting design project for the creation of **biomorphic lamps**	 

SOLAR KIT SEVILLA (SDE 2010)		
EXTERIOR	Formica cladding Exterior cladding of the solar-power towers, built using striated U-shaped tiles	

CASA PATIO 2.12 (SDE 2012)		
EXTERIOR	800x800x18 mm ventilated façade finished with ceramic tiles which are porous on the outside and fixed with metallic profiles to the columns of the structure (Cerámica Decorativa)	
BATHROOM	The bathroom island has CORIAN cladding, 13% of which consists of recycled materials	

ARTSetMETIERS (SDE 2010)		
INTERIOR	Flooring: wood, clay tiles	 

SML SYSTEM CEU VALENCIA (SDE 2012)		
INTERIOR	Techno floor tiles (Butech, Cemento Manhattan) Walls: plasterboard 	
BATHROOM	Ceramic fittings Flooring: Techno floor made with ceramic tiles (Saloni)	

Tables 2: SDE Prototypes 2010 & 2012 which have used Ceramic or Similar Materials and Their Characteristics. Source: http://www.sdeurope.org/

5. CHARACTERISTICS OF ALTERNATIVE MATERIALS

In the summary of materials used in the prototypes for these two Solar Decathlon Europe competitions we can define five general groups of materials that were employed for interior and exterior cladding:

- **Woods** and wood derivatives: for example, different kinds of natural wood, laminated wood, chipboard or even synthetic woods.
- **Ceramics** used in ventilated façades or indoor floors.
- **Composite materials**, in the form of cement flooring or plaster panels for cladding systems.

- **Metals** like steel, zinc or aluminium, which take the form of interior panels or tiles.
- **Polymers** which are translucent or opaque.
- **Thermal materials**: these include materials which are used primarily for their thermal properties, for example phase change or structural insulated panels.

In Fig. 2 we can see a graph showing the number of times we find each of them in the prototypes included in the analysis

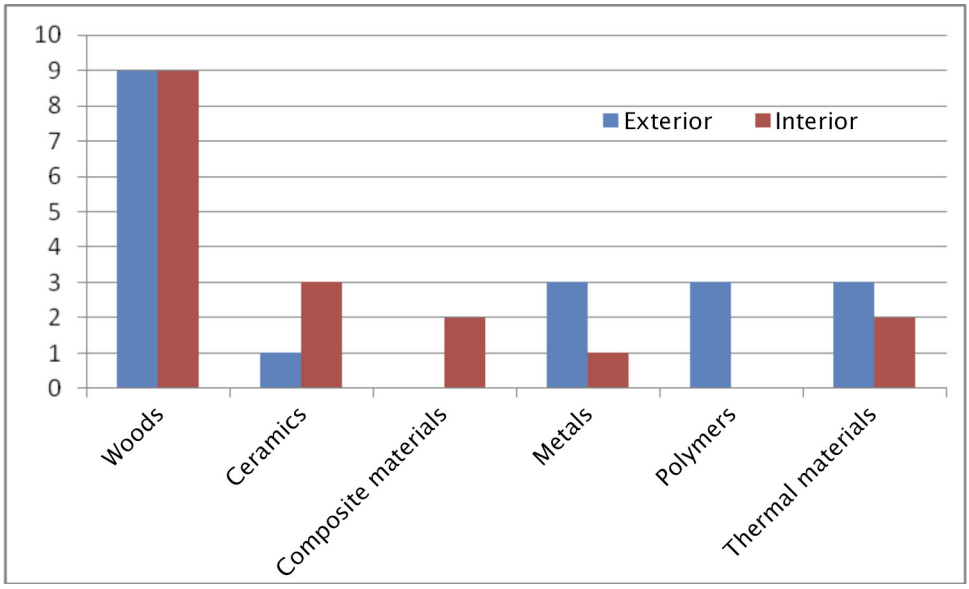


Fig. 2. Distribution of materials used in the studied prototypes.

5.1. WOOD AND WOOD DERIVATIVES

- NATURAL WOOD
- LAMINATED WOODS
- OSB (Oriented Strand Boards)
- BAMBOO
- TRESPA PANELS, SYNTHETIC WOOD

General Characteristics:

Natural materials have considerable ecological advantages, owing to their retention of atmospheric CO_2, low cost, excellent physico-mechanical properties and range of uses in construction, where they are used extensively to clad walls and floors.

It is easy to work with these materials and they are suitable for earthquake-resistant buildings. They can be finished with paint, varnish, lacquers and transparent oils, and are quickly incorporated into a building because they are dry-assembled, adaptable and resistant, and they provide good thermal, electrical and acoustic insulation.

Main Disadvantages:

They are susceptible to attack by wood-boring insects and require special treatments; they are also inflammable and are not recommended where there is constant exposure to moisture.

5.2. COMPOSITE MATERIALS

- FLOATED CEMENT

- PLASTER PANELS

General Characteristics:

These are artificial materials, which can be moulded. They have lower than average energy costs, enabling them to be mixed with recycled materials.

They contain inert materials, which can show high durability when exposed to atmospheric and biotic agents.

They can perform well as thermal accumulators, facilitating the retention of heat and stabilizing the temperature of a building.

Main Disadvantages:

Their energy consumption may be moderate and their durability not particularly high. Depending on how they are installed, they may be difficult to reuse or recycle.

5.3. METALS

- STAINLESS OR LACQUERED STEEL

- STEEL TILES WITH PCM (Phase Change Material)

General Characteristics:

Artificial materials with many structural possibilities and optimal mechanical performance.

Combined with other materials and building systems, they can demonstrate thermal properties which are beneficial to the building as a whole.

They are completely recyclable.

Main Disadvantages:

They consume a lot of energy, although this can be compensated by their excellent thermal performance.

5.4. POLYMERIC MATERIALS

- RECYCLED RUBBER TILES
- TRESPA PANELS
- SYNTHETIC WOOD
- ZICLA-RECYCLED PLASTIC
- FORMICA CLADDING

General Characteristics:

These are compound materials. They are generally formed from natural products or artificial products agglutinated by means of resins.

They are generally easy to install, reliable, flexible and resistant to the elements, and their volume is highly stable.

They may be eco-friendly, given that recycled materials or waste from other production processes are used during their manufacture.

Main Disadvantages:

In some cases there may be durability problems, depending on their composition.

Some of them also require moderate energy consumption.

Some of these materials require certain treatments and constant maintenance.

5.5. THERMAL MATERIALS

- SANDWICH PANELS
- SOLAR-ABSORPTION TILES
- PHASE CHANGE MATERIALS (PCM)

General Characteristics:

This group includes materials which enable the thermal performance of a building to be controlled by regulating properties, such as the heat resistance of building envelopes, or thermal inertia, thereby conferring significant environmental benefits to the building during its useful life.

Main Disadvantages:

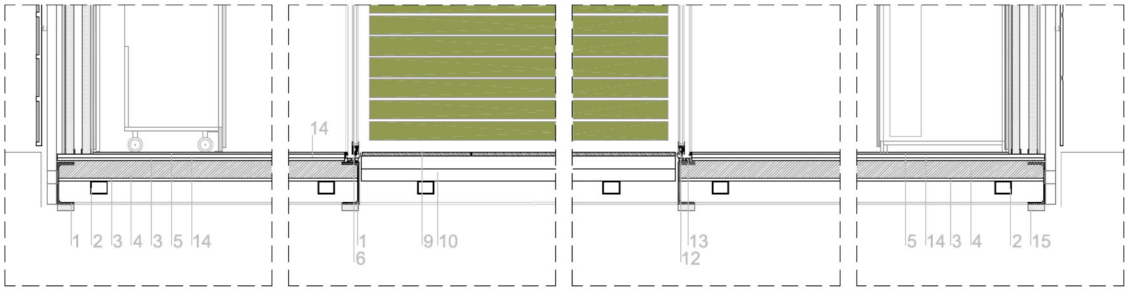
They are generally artificial materials with a significant environmental impact during their manufacturing phase, which, in some cases, is compensated during their useful phase.

6. CHARACTERISTICS OF THE CERAMIC MATERIALS USED

The advantages we can attribute to each of them can be gleaned from the information supplied by the manufacturers and the technical specifications of the prototypes, and some of their disadvantages or weaknesses can be inferred from a critical analysis.

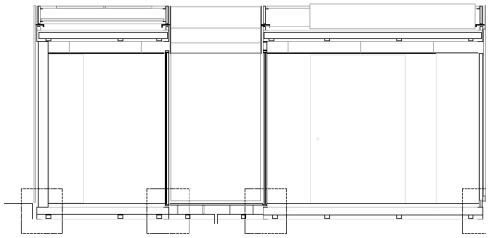
ULTRA-THIN STONEWARE PANELS

Manufacturer: SALONI



Cross Section of Floor

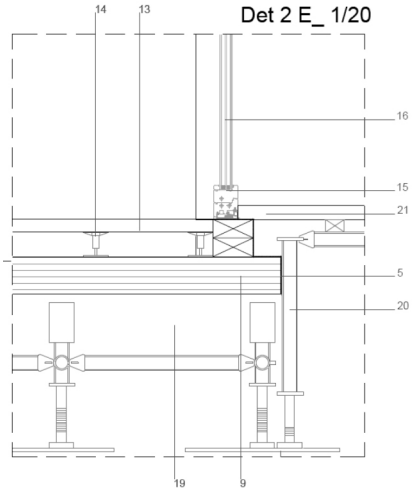
1. ;
2. Tubular 60 x80 mm laminated steel crossbar;
3. ;
4. ;
5. Ceramic flooring e=7mm (Saloni);



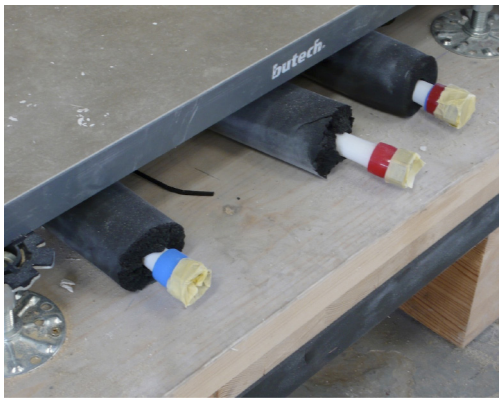
ADVANTAGES	DISADVANTAGES
· **Scratch-proof** · **Uniform appearance** · **Low porosity** · **Very resistant** · **Easy to clean** · **Resistance to temperature changes** · **Resistance to chemical products** · **It can be installed in any part of the house** · **Reduced thickness**	· Low contact temperature at certain times of the year

TECHNO FLOOR: Ceramic tiles Cemento Manhattan

Manufacturer: BUTECH (Porcelanosa)



Cross Section of Techno Floor



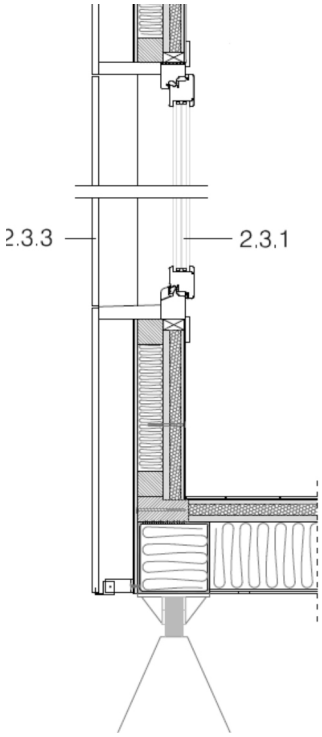
Techno Floor or SML System

TYVEK Mod waterproof membrane;
13. Grupo Butech 600 mm x 600 mm floor;
14. Grupo BUTEK adjustable pedestals;
15. Oak exterior carpentry;
16. Triple glazing unit with cavity;
19. IPE 200 profile;
20. Structure;
21. Outer wooden floor

ADVANTAGES	DISADVANTAGES
· **Aesthetic Enhancement** · **Greater performance in terms of installation than traditional tiling** · **Possibility of including any ceramic finish** · **Excellent fire resistance** · **High mechanical load capacity: 4.100kg/m²**	· Not recommended for wet zones · It can be affected by moisture

TILES ON VENTILATED BREATHABLE ECO FAÇADE

Manufacturer: CERÁMICA DECORATIVA

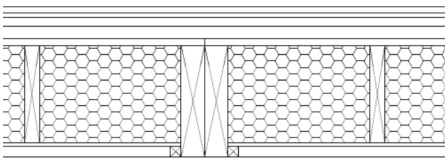


Detail of the Façade of Casa Patio 2.12

2.3.1 Solid pine wood frame. Casement windows;
2.3.3 Shutters with an identical finish to the porous ceramic panels

ADVANTAGES	DISADVANTAGES
· The porosity of this type of ceramic tile is responsible for the so-called "botijo" effect (evaporative cooling) **· When the water on a façade evaporates, it causes the ceramic tiling to cool and, as a result, the temperature of the air cavity is lowered, reducing the thermal load of the house. When the façade is dry in winter, it helps to conserve the heat inside the house** **· Low density and low thermal conductivity** **· Good resistance** **· Good chemical resistance**	· Absorption of moisture · Maintenance required

CLAY FLOOR TILES



Detail of Floor

Fired clay tiles
Solid wood
Plywood
Vapour barrier
Insulation
Plywood
Laminated wood

ADVANTAGES	DISADVANTAGES
· **Porous material, which ensures a constant room temperature** · **Breaking load 2300-3200 N** · **Easy to clean** · **High durability**	· Material sensitive to abrasion · Its low mechanical resistance has to be compensated by increasing tile thickness · Its high porosity means its use is not recommended for exteriors in cold climates · Not resistant to frost

CORIAN

Manufacturer: DUPONT

Solid surface material; non-porous material with low maintenance

ADVANTAGES	DISADVANTAGES
· **Very resistant material** · **Thermoformable** · **Non-porous (making it easy to clean)** · **Inert material, no toxic gases** · **Monolithic appearance** · **Repairable using abrasive agents** · **It is translucent (can be used in lamps)**	· Expensive · Sensitive to some chemical products · Resists temperatures of up to 205ºC · Approximate duration: 10 years · Non-sustainable material

7. CERAMIC PRODUCTS AND SYSTEMS AVAILABLE ON THE MARKET

Currently, the repercussions of this type of competition and of new buildings based on more sustainable architecture demand materials that meet their requirements from the market. Following our research on the availability of more sustainable ceramic products, some of the solutions offered by the market are shown below.

7.1. CERAMICS WITH REDUCED THICKNESS

Ceramic tiles destined to be used for flooring/cladding systems and designed to have a thickness of only 3 to 6mm.

Various manufacturers offer thin tiles or thin, large-sized ceramic panels. Whatever the case, the main advantage is a reduction in the use of raw materials, energy consumption and CO_2 emissions of approximately 50% compared to a traditional tiling solution.

http://www.thesize.es

7.2. CERAMICS CONTAINING RECYCLED MATERIALS

Tiles made with recycled material obtained from the tile production process.

One of these products is STON-KER®. It avoids the generation of waste, which would need to be treated and processed.

They have good technical properties and, at the same time, they save energy consumption during the tile production process.

7.3. PHOTOCATALYTIC TILES

Ceramic tiles which absorb NOx and convert them, by photocatalytic processes, into harmless water-soluble nitrogen compounds and volatile organic compounds (VOC), thereby protecting the environment.

Some ceramic products, such as BIONICTILE® or LIFEKER®, have these properties, which facilitate the elimination of pollutants and clean façades naturally.

According to the manufacturers of these products, an urban centre, which has 200 buildings with a surface area of 3000 m^2 clad with this material, would remove approximately 82 Tn of N0x a year from the atmosphere, meaning 17m^2 tiling is approximately equivalent to one tree.

7.4. HEAT ACCUMULATOR TILES

Tiles which are capable of accumulating energy and slowly releasing it as a result of the presence of phase change materials in their composition.

The first ceramic product with these properties is ECOM4TILE®, which achieves a reduction in the consumption of energy used to regulate room temperature by curtailing the emission or absorption of heat, depending on the temperature of the environment.

8. CONCLUSIONS

Having completed this study on the interior and exterior materials used in the Solar Decathlon prototypes, we can see that there has been an increase in the use of ceramic materials, especially those used in the prototypes presented by the Spanish universities, whereas the countries in the north of Europe tend to opt in favour of wood.

The use of ceramics in this type of international competition, based on sustainability and energy efficiency, may help to boost the use of ceramics in new forms of sustainable architecture. The repercussions of this kind of competition also increase awareness of this kind of ceramic product both nationally and internationally.

From the analysis of the attributes of the materials employed in these prototypes, there is no clear justification for environmental preferences of certain materials rather than others; there are environmental arguments that can justify the use of ceramic materials in this type of building in which sustainability is at a premium.

Market research on innovative ceramic products with environmental benefits can enable us to obtain a range of ceramic materials which are very appropriate for this type of competition, in which ecological and environmental issues are a primary concern. And we can see that the ceramics sector continues to pursue this line of research in order meet all the expectations of sustainable architecture in the future.

This is why we believe that this new innovative trend must continue to gather pace in the future, so we can develop new materials that comply with the environmental requirements which are increasingly demanded in new buildings and for the renovation of existing buildings.

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