

INNOVATIVE CERAMIC APPLICATIONS IN CASTELLÓN DE LA PLANA IN THE 20TH AND 21ST CENTURIES

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1. ABSTRACT

According to the ranking of *Acimac Survey dept.* “World Production and consumption of ceramic tiles” in 2016, Spain was in 4th place on the global ranking with 440 million square metre ceramic tile production. As far as exports are concerned, it was in 2nd place with a total of 448 million square metres. The main companies in the wall and floor tile manufacturing sector are to be found in the province of Castellón.

The joint work of different sectors such as ASCER (the Spanish Ceramic Tile Manufacturers’ Association), Castellón City Council, Castellón County Council, ITC (the Spanish Ceramic Technology Institute), IPC (the Spanish Institute for the Promotion of Ceramics), among others, has turned the city into a European reference in ceramic innovation, pursuing the CityLab concept, where the latest advances in ceramic products in urban spaces are showcased.

This new route for ceramics attempts to show, both to society and to the experts, buildings and places of interest where both the traditional application of ceramics and technological innovation have left their mark on history, taking the ceramic industry in Castellón to maturity.

In this paper, a synthesis of a Bachelor’s Degree Final Project in Technical Architecture, a compilation has been carried out of buildings and urban spaces where innovative ceramics have been used, which at the time were milestones in ceramic innovation. In addition, the behaviour over time of these applications and their current conservation and maintenance needs have been analysed.

2. INTRODUCTION

Ceramics in Castellón fulfil a very important role both on a national and international level. The La Plana district may be considered an international ceramic industry cluster.

The industry's economic growth has been possible thanks to natural conditions and the human capacity for making the most of them, from the use of raw materials characterised by the quality and quantity that production pursued, to the ease of communication via the port and by land transport.

Production capacity has increased with the passage of time due to innovation and the implementation of the latest technology. Companies have committed to boosting the image of their products, technology and own advanced designs.

The aim of this paper has been to make a compilation of the ceramics used in Castellón in the 20th and 21st centuries, taking as a starting point the leaflet "The Ceramic Route" published by the Castellón de la Plana City Council.

A compilation has been made of the ceramic coverings in buildings and public spaces in the city of Castellón, which have been milestones in ceramic innovation. Beyond the compilation of these works, a study has been made of the materials used, construction solutions and innovations contributed in each case.

Subsequently, the behaviour over time of each covering has been analysed, paying particular attention to the maintenance and conservation measures that have been taken. Based on our observations, proposals have been put forward for improvements to the materials and construction solutions used.

The paper concludes with a communication strategy for society, publicising the development and innovation of ceramics in Castellón, via a mobile application simulation displaying on a map the places of interest, their location and relevant information.

3. CERAMICS

Ceramics are made from a series of raw materials, essentially clays which are mixed with water to allow them to be shaped, dried and after firing acquire resistance and stability in the face of most types of environmental aggression.

3.1. THE ORIGINS OF CERAMICS IN CASTELLÓN

In the vicinity of Castellón, the beginnings were marked by the installation of the Conde de Aranda factory in the municipality of Alcora in 1727, which, under the guidance of Don Buenaventura Pedro de Alcántara Ximénez de Urrea y Abarca de Bolea, marked the national heyday of ceramics. (Cabrera 2012)

3.2. CERAMIC TILE

There are extensive regulatory standards on ceramics, such as the *ISO 13006* *UNE-EN 14411* production standards, which classify tiles according to their method of manufacture and their water absorption.

There are also documents such as the Ceramic Tile Guide of the Valencian Regional Government, which although not international in scope, is of particular interest for the correct use of ceramics as a rigid modular covering.

This guide provides an interesting classification of uses in which it establishes indicators such as mechanical requirements, slip resistance and additional characteristics, which allow definition of the use requirements for any ceramic covering, based on which the appropriate tile can be chosen, Table 1.

CERAMIC TILE GUIDE CODE		
FIRST IDENTIFIER	SECOND IDENTIFIER	THIRD IDENTIFIER
MECHANICAL CHARACTERISTICS	SLIP RESISTANCE	ADDITIONAL CHARACTERISTICS
1, 2, 3, 4, 5, 6, 7, 8	Class 0,1, 2, 3	H/E Hygienic Exterior

Table 1: Ceramic Tile Guide identifiers

3.3. BONDING MATERIAL, TECHNIQUE AND TILE INSTALLATION SYSTEMS

Bonding materials may be considered the link between the fixing background and the covering.

The choice of one or other material will depend on the type of application. Tile installation was traditionally performed using a thick layer of mortar, whereas nowadays tiles are mainly installed in a thin bed with adhesives.

There are several characteristics which condition the materials and installation techniques, such as tile water absorption and size, the characteristics of the fixing background, and environmental conditions.

Standard *UNE 138002:2017 General rules for the installation of ceramic tiles with bonding material* has recently been published in Spain, which defines the materials, techniques and installation systems for fixing ceramic tiles by direct bonding. For the drafting of this standard, the prior experience in using ceramic tiles has been very useful, both in traditional solutions and in innovative solutions such as those set out in this paper.

4. CATALOGUE

The work consisted of making up a catalogue covering a total of 30 architectural applications located in the city of Castellón, Table 2.

The catalogue is based on the leaflet entitled "The Ceramic Route" published by the Castellón City Council in 2012. This information has been completed with a search for complementary information on these works, consulting experts, visits and in situ data collection at each studied place.

The following table shows that most of the places studied date from the 21st century.

20th CENTURY	BUILDINGS AND URBAN SPACES	21st CENTURY	BUILDINGS AND URBAN SPACES
1912	Casa de las Cigueñas	2001	ITC flooring
1927	Ribalta Park furniture	2009	UJI assembly hall façade
Start of 20th century	Façade of the former Diago factory	2006	Espaibar cafeteria
1963	Diago building mural	2007	Españec flooring
1991	UJI Ágora flooring	2008	Grao Goose Game
1995	Grao Fish Sculpture	2009	Palau de la Fiesta
1995	Grado Tower-Lookout	2010	Plaza Santa Clara flooring
1999	Renfe In-Contrast Sculpture	2010	Calle Arrufat Alonso, Joaquín Acosta, Ronda Mijares, Ronda Magdalena flooring.
1999	Renfe fountain	2010	Plaza Maestrat children's interactive and direct activity games
1999	Sant Pere church mural	2010	Plaza Huertos Sogueros Goose Game
End of 20th century	Plaza Fadrell ceramic mural	2010	Plaza Huertos Sogueros children's game: Blackboard
2000	Plaza Violant D'Hongria ceramic mural	2010	Plaza Huertos Sogueros children's game: Zambori
		2010	Plaza Fadrell children's interactive and direct activity games
		2010	Heated shelter
		2010	Smart traffic lights
		2011	Castellón Paddle tennis facility
		2016	Plaza Real public toilets
		2017	UJI Faculty of Medicine façade

Table 2. Chronology of the studied buildings and urban spaces.

An example of the information compiled for each studied application is shown in Figure 1, in which the ceramic application, materials and construction system used are identified, together with the requirements and state of conservation in which the covering is to be found.

	
LOCATION	Universidad Jaume I
DESCRIPTION	The UJI Ágora designed by artist Manuel Sáez depicts a white glove on a blue background. It is a circular open public space where the service areas leading to the various buildings, such as the Faculty of Human and Social Sciences, the Library, the Vice-Chancellor's office, among others, are located. This has a surface area of 48.5 metres in diameter and 1,848 m ² . It comprises 27,930 non-slip porcelain stoneware tile (9,716 blue tiles and 8,214 light beige ones).
YEAR	1991
IDENTIFICATION	Porcelain stoneware tile
INSTALLATION SYSTEM	Thin bed
CONSTRUCTION SYSTEM	1.Compact terrain 2. Concrete slab 3.Layer of levelling mortar 4.Decoupling layer 5. Bonding material: Special deformable ceramic adhesive for outside use 6.Covering: Porcelain stoneware tiles 32x32 cm and 16x16 cm, with non-slip treatment, in two different colours in matte finish, 5 mm tile-to-tile joints with waterproof mortar and flooring expansion joints every 5.5m
USE REQUIREMENTS	In accordance with SUA1-CTE the flooring belongs to class 3, for outside areas. According to the Ceramic Tile Guide it is a type 8 flooring (mechanical characteristics), type 3 (slip resistance) and EH exterior hygienic (additional characteristics)
STATE OF CONSERVATION	 fair

Figure 1: Covering identification data sheet.

5. STUDY OF THE STATE OF CONSERVATION

To determine the state of conservation of each studied covering, these were analysed, verifying the existence of the following defects or changes in each covering, Table 3:

Dimensional deteriorations	• Deficient flatness
	• Irregularities in modulation
Surface deteriorations	• Chipping
	• Stains
	• Lack of homogeneity in appearance
	• Cracks in glazed tiles
	• Lack of safety for walking
Detachment of wall tiling	• Individually or in small surface areas
Debonding or lifting of floor tiling	• Isolated or in small surface areas
Cracking in floor or wall tiling	• In wall tiling
	• In longitudinal and isolated floor tiling
Tile-to-tile joints	• With craters or piercing
	• Stains, discolouration
	• Non-uniform colour
	• Filling, crazing / cracking
	• Longitudinal lifting of material
	• With efflorescence

Table 3. List of detected deteriorations.

5.1. IDENTIFICATION OF THE DETERIORATIONS

The above was used to generate a deterioration matrix in which the presence of each defect was evaluated with a score of 0 to 3, 0 being no apparent defect and 3 being a very significant manifestation of the defect.

BUILDINGS AND URBAN SPACES	DEFECTS																		VALUE*
	DIMENSIONAL DETERIORATIONS		SURFACE DETERIORATIONS				DETACHMENT OF WALL TILING	DEBONDING AND LIFTING OF FLOOR TILING	CRACKING IN FLOOR AND WALL TILING	TILE-TO-TILE JOINTS									
	Deficient flatness	Irregularities in modulation	Chipping	Stains	Lack of homogeneity in appearance	Cracks in glazed tiles	Lack of safety in walking	Individually or in small surface areas	Isolated or in small surface areas	In wall tiling	In longitudinal and isolated floor tiling	Low filling	With craters or piercing	Stains, discolouration and low stain resistance	Non-uniform colour	Filling, crazing / chipping	Longitudinal lifting of material	With efflorescence	
Renfe In-Contrast Sculpture				1	1														2
Renfe fountain		3		3	3	2		1	2			1	3	3				3	24
Diago building mural																			0
Sant Perre church mural																			0
Diago factory façade			3			2		1		2									8
Plaza Violant D'Hongria ceramic mural			1	1	1														3
Plaza Fadrell mural														2					2
Ribalta Park furniture			2			1		3			1	1		3					11
Casa de las Cigüeñas			1	1									1	1		1			5
Palau de la Festa			1	1				1											3
Plaza Santa Clara flooring			1	3							1		1	2		1	1		10
Ronda Mijares, Ronda Magdalena, Arrufat Alonso and Joaquin Acosta flooring	1		1	3							1		1	1	1	1			10
Plaza Maestra children's games			1	1							1		1	2		1			7
Plaza Hort children's games				1															1
Plaza Hort children's games (zambori)				1															1
Plaza Hort Goose Game			1			1			1		1								4
Plaza Fadrell children's games														2					2
Puerta del Sol public toilet													1	1					2
Espalbar Café			1																1
Paddle tennis facility				2						1				2					5
Smart traffic lights			1											2					3
Heated shelter				1										1	1				3
Grao Castellón Goose Game			3	1							1			2					7
Grao Fish Sculpture				3	3	1		1		3			1	3				3	18
Grao Tower-Lookout			1	3				2		3				3	3			3	18
UJI Àgora flooring			1	3	2						3	1	3	3		3	2		21
Espaltec UJI														1			1		2
UJI assembly hall			1	1	1					1									4
UJI Faculty of Medicine																			0
ITC														3					3
Total		4			68			9	3		19			77					180
TOTAL DEFECTS (%)		2%			38%			5%	2%		11%			43%					

* Each covering result has been obtained from the addition of the defects.

1= Fair
2= Poor
3= Very poor

Table 4. Deterioration matrix in each covering.

The state of conservation of the ceramic flooring or wall tiling was obtained as a result of the sum of the evaluations of each type of defect detected.

Three levels of deterioration were defined for the coverings as a function of the sum of the evaluations of each defect: good state of conservation (in green) for coverings with a score between 0 and 7, fair (in orange) for applications with scores between 8 and 15, and bad (in red) for applications with scores between 16 and 24.

5.2. DETERIORATION ANALYSIS

The results obtained in the study on the state of conservation were used to detail the defects present in the coverings, evaluating the degree to which each was present and their possible causes

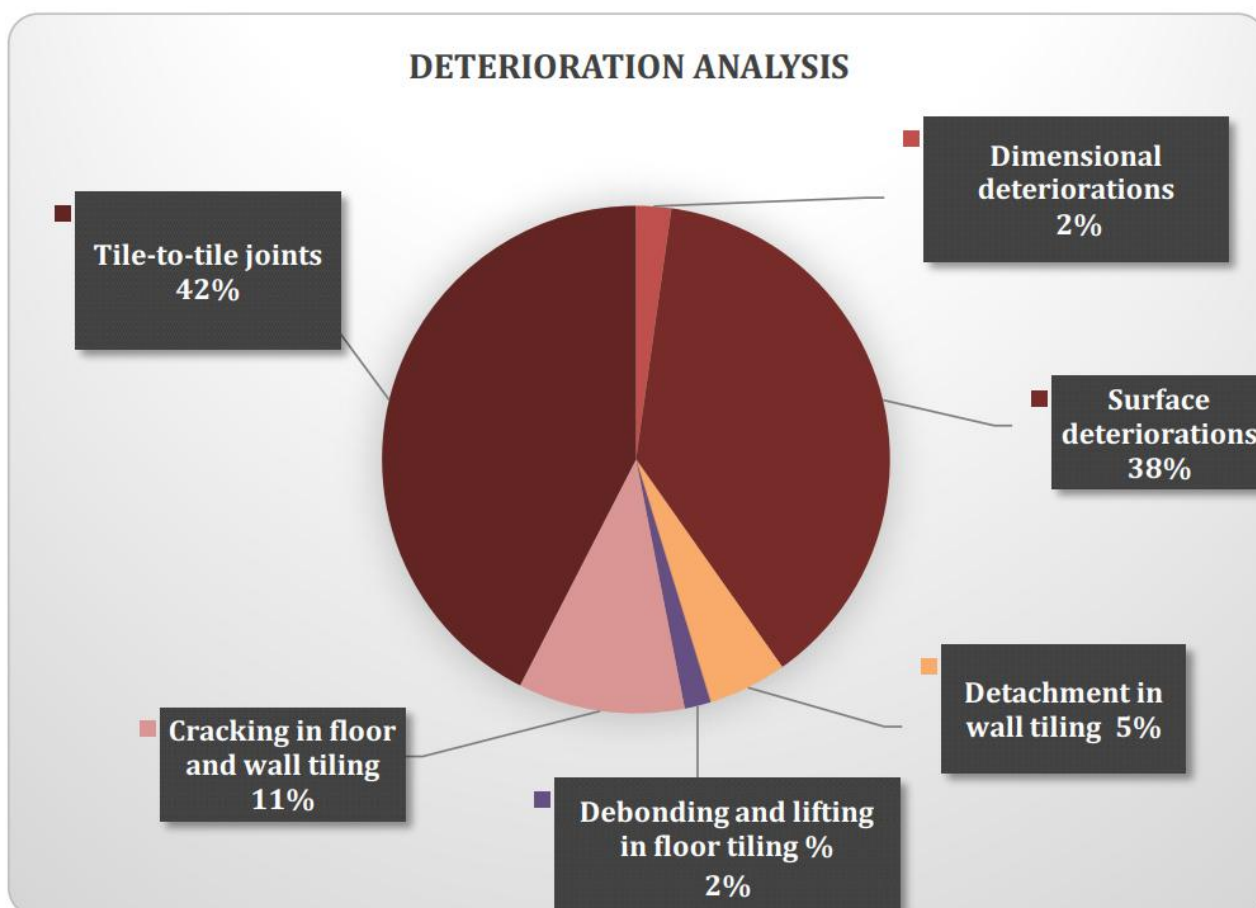


Figure 2. Analysis of defects.

The graph shows:

- The most important defects were superficial and at the tile-to-tile joints.
- Detachments, lifting, cracks and dimensional defects were present, but to a lesser degree, in most cases being only occasionally found.

5.3. CONCLUSION REGARDING THE STATE OF CONSERVATION

Based on the evaluation of the defects and the period to which each application belonged, the following table allows a series of conclusions to be drawn about the state of conservation of the coverings in relation to the defects they display.

COVERINGS	STATE OF CONSERVATION			
	Bad	Fair	Good	TOTAL
20th century	4	2	6	12
	33%	17%	50%	
21st century	0	2	16	18
		10%	90%	
TOTAL	13%	13%	74%	30

Table 8. Analysis results.

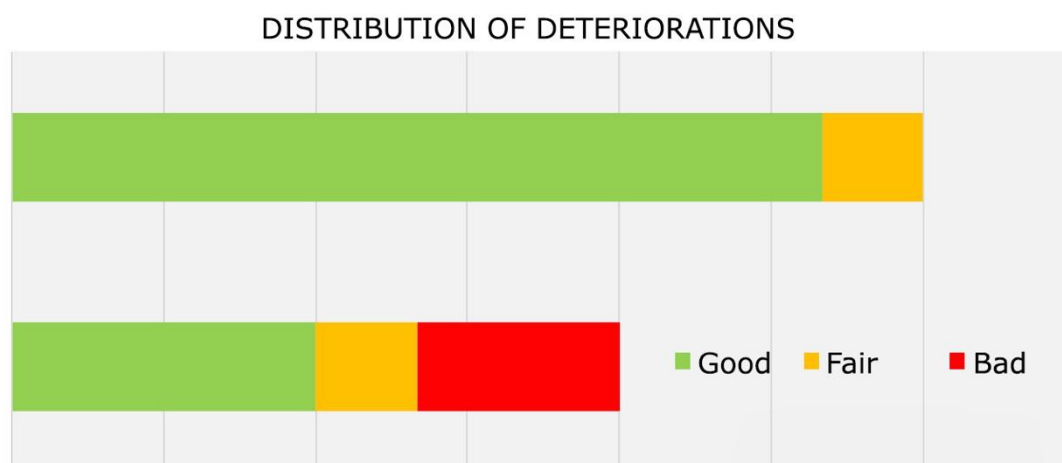


Figure 3. State of conservation of the 21st century coverings

The coverings with the highest score, i.e. with the greatest presence of defects were found in the **20th century**. Nevertheless, half the studied coverings belonging to that century were in a good state of conservation.

The existing malfunctions were related to the incompatibility of the material in respect of its fixing background, the bonding material, weather conditions and the use to which they had been exposed throughout their useful life, which had probably not been fully foreseen.

Concerning the **21st century** ceramic coverings, most exhibited a good state of conservation. The deteriorations were mostly due to lack of maintenance and the presence of external agents.

As shown in the state-of-conservation analysis in general, the state of preservation of the studied coverings was good. Only 25% of these exhibited a bad or fair state.

It may be concluded from the analysis that the divergences associated with the defects, quality and poor performance of the ceramic materials with the passage of time were a result of the appearance of a wide range of ceramic tiles made of not very porous materials, new tile installation techniques, shorter execution times and the lack of a well-regulated technical framework for intended tile use. The development of the sector has overcome these inadequacies, and the appearance of new technical documentation and updates of standards have clarified these discrepancies, ensuring the quality and durability of ceramic coverings.

6. REFURBISHMENT PROPOSAL

Based on the analysis carried out regarding the state of conservation of the coverings and on the results obtained, an intervention proposal will be made for each covering which has a fair or bad state of conservation.

The intervention criteria and work methods to be followed for correct refurbishment have been defined, respecting the original and its structural characteristics to the greatest possible extent, and intervening according to the needs of the material.

7. DISSEMINATION PROPOSAL

Another of the aims envisaged in this paper was the definition of communication strategies towards society. To do this, a mobile application simulation has been designed, aimed at making citizens aware of the development and innovations in ceramics in the city of Castellón. This section was developed using the APP FLUIDUI.

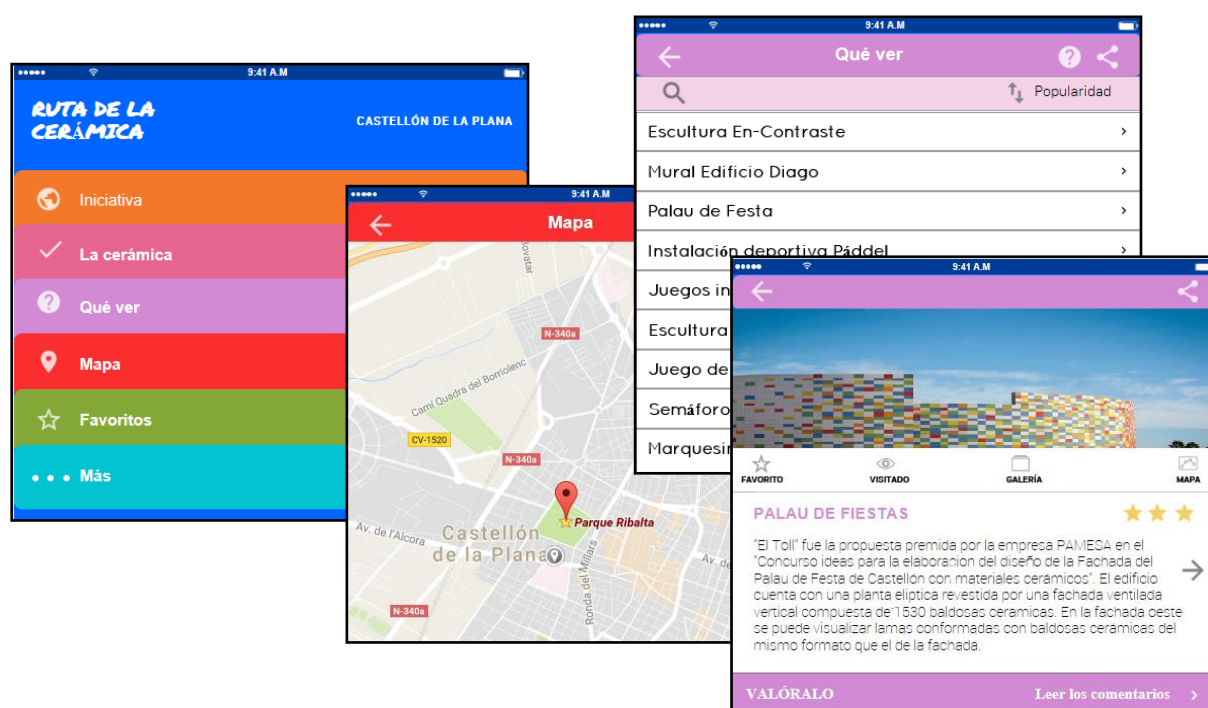


Figure 4. Pictures of the APP simulation.

8. CONCLUSION

Ceramics are very valuable materials with multiple possibilities, which have adapted to the passage of time and adjusted to their surroundings. Besides undergoing constant technological development, they offer users excellent performance features.

Ceramic activity in the province dates back to antiquity, ceramics currently being one of the region's most important economic engines. For this reason, development and innovation are vital to the progress of the ceramic sector.

This study has helped better understand how valuable these materials are and how important the commitment is to technological innovation and development of the sectors involved, widely present in the province of Castellón, considered an international ceramic industry cluster.

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