IV - VALUATION AND EVOLUTION OF THE QUALITY OF CERAMIC TILES IN SPAIN

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1.— INTRODUCTION

With the objective of narrow down the subject to be handled, that of evolution and evaluation of the quality of ceramic tiles and paving, we will first define what we understand by quality, given its general nature, so as not to place obstacles in the way of development of this talk along a logical path. According to norm UNE 66-011-88, "QUALITY, vocabulary", this is defined as "collection of properties and characteristics of a product or service which confers upon it it suitability for fulfilling expressed or implicit needs". We will therefore study the evolution of the properties and characteristics which I consider to be most important in Spanish ceramic tiles from 1975 onwards. Information on this is available in the files of results of the "Sebastian Carpi" Ceramics Laboratory; that evolution can then be linked with satisfaction of expressed or implicit product needs.

2.— CHARACTERISTICS OF CERAMIC TILES

These are defined in table 1 below, and are established in norm UNE 87 (UNE 67087).

TABLE 1

	Floors		Walls	
	interior	exterior	interior	exterior
Dimensional characteristics and surface appearance				
a) Length and width	•	•	•	•
b) Thickness	•	•	•	•
c) Straightness of sides	•	•	•	•
d) Orthogonality	•	•	•	•
e) Surface planeness (curvature and warping)	•	•	•	•
f) Surface appearance	•	•	•	•
Physical properties				
g) Water absorption	•	•	•	•
h) Flexion resistance	•	•	•	•
j) Surface hardness to scratch	•	•	•	•
k) Resistance to deep abrasion of non-glazed tiles.	•	•		
l) Resistance to surface abrasion of glazed tiles	•	•		
m) Lineal thermal expansion (1)	•	•	•	•
n) Thermal shock resistance	•	•	•	•
p) Resistance to crazing of glazed tiles	•	•	•	•
q) Reistance to freezing (2)	•	•	•	•
r) Expansion by humidity of non-glazed tiles with absorption of water E 6%	•	•	•	•
Chemical properties				
s) Resistance of glazed tiles to stains	•	•	•	•
t) Resistance to household cleaning products and water for swimming pools	•	•	•	•
u) Resistance to acids	•	•	•	•
v) Reistance to alkalis	•	•	•	•

(1) Only where special conditions are required.
(2) For tiles destined to be used in placed where they may be subjected to freezing.

We can group these into:

— Instrinsic needs. Physical and chemical characteristics which the tiles must meet in general in accordance with their product norms.

— Expressed needs. Dimensional and surface appearance characteristics in accordance with their product norms, in addition to physical properties: lineal thermal expansion and resistance to freezing and chemicals; resistance to acids and alkalis.

3.- QUALITY OF CERAMIC TILES IN SPAIN IN THE YEAR 1975

In our country in 1975 glazed ceramic tiles were manufactured for cladding walls and floors, with porous red pâte for the most part, and manufactured by the tradition system known as "double firing", in line with European norm EN 87, products belonging to group BIII. We can subdivide this group

into two parts — tiles destined to wall cladding and tiles destined to floor paving.

Wall tiles were mainly to be found in the 15 x 15cm, 10 x 20 cm and 20 x 20 cm formats, glazed, with a predominance of zirconium whites, there existing some special pieces in 10 x 20 format, marine water and titanium matt types.

In order to provide us with a clear idea of the implicit quality of the material, the values for the average trial characteristics in the year 1975 were as follows:

Water absorption	13.1	
Flexion resistance (in N/mm2)	17.6	
Scratch hardness of surface	4.6	
Lineal thermal expansion (x 10-6/°C)..	6.5	
Thermal shock resistance	100% resistant	
Resistance to crazing (%)	40 resistant	60 non— resistant
Resistant to acids and bases (%)	75 resistant	25 non— resistant

Floor paving tiles were pieces of the 10 x 20 and 20 x 20 cm formats, basically, glazed, with predominance of reactive glazes, leather glazes and hard corundum-based glazes. The values for the average trial characteristics in the year 1975 were as follows:

Water absorption	12.7	
Flexion resistance (in N/mm2)	14.7	
Scratch hardness of surface	5.5	
Lineal thermal expansion (x 10-6/°C)	6.4	
Thermal shock resistance	100% resistant	
Resistance to crazing (%)	83 resistant	17 non— resistant
Resistant to acids and bases (%)	35 resistant	65 non— resistant
Resistance to abrasion wear (rev.)	450 (PEI II)	

Another of the types of tile manufactured were those of vitreous base by the single firing system, though mainly with tunnel kilns. Tiles of the 10 x 20 and 20 x 20 formats were the ones mostly manufactured, and glazes of a type similar to those used in the manufacture of porous floor tiling were used.

The average characteristics of trials carried out in that year were:

Water absorption	2.0	
Flexion resistance (in N/mm2)	28.9	
Scratch hardness of surface	7.4	
Lineal thermal expansion (x 10-6/°C)	5.5	
Thermal shock resistance	100% resistant	
Resistance to crazing (%)	100% resistant	
Resistant to acids and bases (%)	87resistant	13 non— resistant
Resistance to abrasion wear (rev.)	300 REV (PEI II)	

These values all complied with the product norms required for EN 159 porous products (B III) with vitreous base (BI) EN 176. In short, we could say that they complied with the implicit needs of the material.

Nevertheless, compliance with the needs expressed was no longer quite so satisfactory. Product classification with respect to appearance characteristics was not very rigorous, and the same occurred in control of measurements, thickness orthogonality, straightness of sides and planeness of vitrified products.

4.- EVOLUTION OF THE INTRINSIC NEEDS OF CERAMIC TILES.

Having defined under point 2 the intrinsic needs of ceramic tiles, we shall now outline in tables 2, 3, 4 and 5 the evolution from 1975 to 1989 of the characteristics considered to be most important with respect to porous products (BIII) destined to cladding of wall and floor paving and vitrified base (BI and BII), red pâte and white pâte.

TABLE 2.— CERAMIC TILES

Group BIII. Destination: wall cladding

Year	Water abs..(%)	Flexion R.(N/m2)	Scratch Resist. (as per Mohs)	Abr.Surface	R.Ag.Chemical (%)
1975	13'1	17'6	4'6	—	R=75 / NR=25
1976	12'1	15'0	4'8	—	R=63 / NR=37
1977	12'5	17'0	4'4	—	R=64 / NR=36
1978	11'4	17'0	4'6	—	R=90 / NR=10
1979	13'6	16'1	5'0	—	R=73 / NR=27
1980	11'5	19'1	4'6	—	R=55 / NR=45
1981	11'6	19'4	4'6	—	R=57 / NR=43
1982	12'0	17'5	3'8	—	R=100 / NR=0
1983	13'3	16'7	4'6	—	R=83 / NR=17
1984	13'8	17'4	3'6	—	R=60 / NR=40
1985	13'4	18'0	4'0	—	R=86 / NR=14
1986	12'1	20'2	4'5	—	R=46 / NR=54
1987	12'6	22'7	4'0	—	R=89 / NR=11
1988	13'1	21'2	3'8	—	R=63 / NR=37
1989	13'4	21'0	3'8	—	R=71 / NR=39

TABLE 3.— CERAMIC TILES

Group BIII. Destination: floor paving

Year	Water abs.(%)	Flexion R.(N/m2)	Scratch Resist. (as per Mohs)	Abr.Surface	R.Ag.Chemical (%)
1975	12'7	14'7	5'5	450 (PEI II)	R=35 / NR=65
1976	11'7	14'3	5'5	450 (PEI II)	R=43 / NR=57
1977	12'6	13'5	5'2	450 (PEI II)	R=37 / NR=63
1978	12'9	13'2	4'7	450 (PEI II)	R=45 / NR=55
1979	12'7	15'3	6'0	450 (PEI II)	R=34 / NR=66
1980	13'0	13'6	6'0	600 (PEI II)	R=35 / NR=65
1981	12'8	13'7	6'0	600 (PEI II)	R=38 / NR=62
1982	12'0	14'7	5'5	600 (PEI II)	R=64 / NR=36

TABLE 4.— CERAMIC TILES

Groups BI and BIIa Red Pâte

Year	Water abs.(%)	Flexion R.(N/m2)	Scratch Resist. (as per Mohs)	A.Resist.Surf. (rev.)	Chemical Ag.R. (%)
1975	2'0	28'9	7'4	300 rev.(PEI II)	R=87 / NR=13
1976	1'4	28'8	6'7	600 rev.(PEI II)	R=40 / NR=60
1977	1'6	32'9	6'2	450 rev. (PEI II)	R=69 / NR=31
1978	1'8	31'2	5'7	450 rev. (PEI II)	R=68 / NR=32
1979	2'4	30'0	6'2	300 rev.(PEI II)	R=73 / NR=27
1980	1'6	32'9	6'4	600 rev.(PEI II)	R=62 / NR=38
1981	1'6	33'0	7'0	900 rev.(PEI II)	R=62 / NR=38
1982	2'4	31'8	5'7	600 rev.(PEI II)	R=46 / NR=54
1983	2'9	35'8	6'0	600 rev.(PEI II)	R=62 / NR=38
1984	3'1	32'1	6'0	750 rev.(PEI II)	R=42 / NR=58
1985	3'7	33'0	6'0	1.200 rev.(PEI II)	R=46 / NR=54
1986	3'9	35'0	5'5	1.200 rev.(PEI II)	R=39 / NR=61
1987	3'1	37'1	5'1	1.200 rev.(PEI II) PEI IV = 19'6 %	R=45 / NR=55
1988	3'6	33'8	5'1	1.200 rev.(PEI II) PEI IV = 31'4 %	R=53 / NR=47
1989	3'1	33'9	5'4	1.200 rev.(PEI II) PEI IV = 33'3 %	R=53 / NR=47

TABLE 5.— CERAMIC TILES

Group BI White Pâte

Year	Water abs.(%)	Flexion R.(N/m2)	Scratch Resist.	A.Resist.Surface (as per Mosh)	Chemical Ag.R. (%)
1980	1'5	32'5	6'2	600 rev.(PEI II)	R=100 / RN=0
1981	1'6	33'3	6'7	900 rev.(PEI III)	R=100 / NR=0
1982	1'9	33'9	6'2	600 rev.(PEI II)	R=78 / NR=22
1983	1'9	34'1	6'1	600 rev.(PEI II)	

1984	3'0	32'8	6'0	750 rev.(PEI III)
1985	4'8	33'6	6'3	1.200 rev.(PEI III)R=100 / NR=0
1986	2'8	34'7	6'0	1.200 rev.(PEI III)R=62 / NR=38
1987	2'8	36'5	5'0	1.200 rev.(PEI III)R=33 /NR=67 PEI IV = 35'3 %
1988	2'1	36'4	6'1	1.200 rev.(PEI III)R=100 / NR=0 PEI IV = 41'5 %
1989	2'3	31'2	6'1	1.200 rev.(PEI III)R=50 / NR=50 PEI IV = 28'6 %

4.1.- Porous products (BIII) destined to all cladding

Observation of table 2 permits us to make the following comments:

a) That variation in values with respect to water absorption are not significant, in all cases meeting the specification of product norm BIII, of water absorption value greater than 10%.

b) The flexion resistance values show a reduction of these values over the years 1976 — 1979, produced by Geldo clay being replaced by Chulilla clay when deposits became exhausted. This was compensated by means of increased pressing force and installation of hydraulic presses.

A considerable increase of the values can also be noted from 1986 onwards, the product of utilization of spray clay in the manufacture of both biscuit and single firing ceramic tiles, the use of hydraulic presses of greater power and the type of glazes used.

c) The scratching hardness values show a progress fall in the average value, this being due to the majority use of soft crystalline-type glazes and to more widespread achievement of special effects.

d) Few conclusions can be drawn from the column on resistance to chemical agents, given that the results are very dispersed and without relationship between them. This is a result of the different glazes used in different years, in function of demand, fashion, economic reasons, etc.

4.2.— Porous products (BIII) destined to floor paving

From observation of table 3, the following may be deduced:

a) The factor explained in point 4.1. is applicable to the values of the first column, water absorption capacity. It is similarly applicable for resistance to flexion and resistance to chemical agents values.

b) The average values for resistance to wear by abrasion are relatively low, even though there is tendency to improvement in this respect.

We make no further comment here, for the product was practically manufactured no longer, on being displaced by vitrified products which made a massive appearance in this period, with harder glazes and better characteristics encouraged by their poor performance in use.

4.3.— Products of low water absorption (BI, BIIa), red pâte base

Looking at table 4, we may observe that:

a) In 1984 there is a shift from from BI to BIIa group products, with water absorption figures higher than 3%. This is due to a reduction of manufacturing problems (calibre, deformation, etc.) in obtaining these products with the same pâte and to increased production obtained.

b) A certain regularity may be observed in the flexion resistance values obtained.

c) For scratch hardness of the surface it can also be seen that there has been a certain gradual decrease, due to manufacturing with softer granular-type glazes, marbles, sheens and various applications.

d) From 1984 onwards, there was a strong increase in the resistance to wear by abrasion, this due to market requirements and use over the last few years of glazes which, although softer, have better performance in the resistance to surface wear trial.

4.4.— Products of low water absorption (B I), white pâte base

The observations of the preceding paragraph are applicable here too, with the exception of water absorption capacity, for which we can see that these products continue to belong to group BI and that the scratch hardness value of the surface does not reduce the values mentioned under red pâte.

4.5.— Summary

We may conclude this point by saying that the products, Spanish glazed ceramic tiles destined to the covering of walls and floors, have over the course of the 15 years studied, generally complied with a greater or lesser margin with the specifications required by the corresponding European product norm.

Only in recent years have some types of tile used as ceramic paving as lustres, marbles or grittiness failed to comply with the scratch hardness required by the product norm.

5.— EVOLUTION OF THE EXPRESSED NEEDS OF SPANISH CERAMIC TILES

Tables 2, 3, 4 and 5, seen above, show the evolution of glaze resistance to acids and bases, so we will not mention these under this point.

With respect to the other two physical properties included as expressed needs in point 2 — lineal thermal expansion and resistance to freezing — these may be said to have been met, as were generally the specifications required by the European product norms over these years, by Spanish ceramic tiles.

Where there has been a really major evolution over these years, however, and one which is difficult to quantify, is in product classification both in control of appearance characteristics and dimensional characteristics.

We are all aware of the problems of placing low water absorption material during its first years of manufacturing, put right by utilization of automatic classification machines which control all the variables included as dimensional characteristics.

The unification of criteria for identification of manufacturing defects established in norm, linked to higher market requirements, evolution in the outlook of the business sector, etc., have also helped towards classification of the product with greater strictness and stringency regarding appearance characteristics, the achievements reached in this field being spectacular.

6.- OTHER VARIABLES.

Utilization of these products is not only a consequence of their being applied for their properties; there are also other factors which explain their use, amongst which are ease of cleaning, aesthetic consideration, design regarding both shape and motif, etc.

The evolution undergone in the field of design has been very great, an example of which is the great diversity of formats currently existing on the market and the progressive increase in sizes of same.

In view of it not being possible to make available any publication showing percentages by format manufactured at present, and with the aim of demonstrating the above statement, we shall show two comparative tables (tables 6 and 7) on the number of factories producing various formats corresponding to ceramic tiles for facing and paving in the years 1985 and 1988.

These tables show a reduction in the number of factories producing smaller formats and an increase in those producing larger formats.

TABLE 6. CERAMIC TILES

Classification by formats of ceramic product (surfacing) and number of companies manufacturing it.

FORMAT (in cm)	YEAR 1985	YEAR 1988
15 x 15	69	46
15 x20	49	46
20 x 20	37	36
15 x 25	22	12
10 x 20	18	8
15 x 22'5	19	10
20 x 30	13	37
20 x 25	12	13
17 x 28	6	7
11 x 11	5	4
15 x 30	3	1
20 x 36	3	3
20 x 40	2	2
16 x 24	2	1
Otros.	9	44

TABLE 7. CERAMIC TILES

Classification by formats of ceramic product (paving) and number of companies manufacturing it.

FORMAT (in cm)	YEAR 1985	YEAR 1988
20 x 20	42	38
20 x 30	19	11
10 x 20	19	7

31 x 31	11	16
15 x 20	9	6
30 x 30	8	12
15 x 15	7	3
23 x 31	6	2
20 x 25	6	5
15 x 25	5	2
30 x 40	4	4
15 x 22'5	3	3
31'6 x 31'6	3	23
33 x 33	3	15
25 x 25	3	2
Otros.	31	69

7. EVALUATION

The way of evaluating the evolution of the quality of ceramic tiles is that of checking if the product satisfies expressed or implicit needs.

7.1.Intrinsic needs

As we saw in the summary on the comments relating to tables 2, 3, 4 and 5, Spanish glazed ceramic tiles for covering walls and floors comfortably comply with the characteristics and specifications required for ceramic tiles by European norms.

The demand for glossy products over the last few years for floor paving has made it difficult to comply with norms relating to scratch hardness of surface for this type of glazes.

7.2.Expressed needs

A large range of production is available, capable of satisfying expressed needs with respect to resistance to acids and bases, given that fulfilment of specifications regarding lineal thermal expansion is general.

With the new classification techniques used for control of both size and appearance characteristics, the evolution of quality experienced also allows us to guarantee all-round compliance with specifications required by European product norms.

7.3.Other needs

Market requirements with respect to fashion and design have also been taken up by the industry, which can be demonstrated (rather than evaluated) in the increased demand for these products on domestic and foreign markets, which has permitted strong expansion of this industry over recent years. We can see the figures for this below.

7.4.Evolution of production capacity

The annual production capacity of the tile industry can be observed in the following table:

YEAR	MILLIONS OF M2	ANNUAL VARIATION (%)
1980	116	—
1981	117	0'86

1982	119	1'70
1983	123	3'36
1984	128	4'06
1985	150	17'18
1986	154'5	3'00
1987	158	2'33
1988	185	17'09
1989	210	8'11

7.5.Evolution of domestic sales

YEAR	MILLIONS OF M2	ANNUAL VARIATION (%)
1984	54'6	—
1985	63'2	15'75
1986	66'5	5'22
1987	94'6	42'25
1988	114'3	20'82

7.6.Exports

YEAR	MILLIONS OF M2	ANNUAL VARIATION (%)	VALUE (THOUS. PTS.)
1985	55.279	—	32.072.562
1986	49.141	11'10	31.310.664
1987	56.089	14'14	38.287.916
1988	66.692	18'19	48.490.792

7.7.Principal clients of the tile sector

COUNTRY	YEAR /POSITION			
	1985	1986	1987	1988
Saudi Arabia	1.º	5.º	4.º	5.º
France	2.º	1.º	1.º	2.º
United Kingdom	3.º	2.º	2.º	1.º
United States	4.º	3.º	3.º	3.º
Egypt	5.º	4.º	8.º	—
West Germany	6.º	6.º	6.º	7.º
Canada	7.º	7.º	7.º	8.º
Hong Kong	8.º	8.º	9.º	9.º
Algeria	9.º	9.º	—	11.º
Singapore	10.º	10.º	10.º	6.º

7.8 Summary

As a summary of the evaluation made so far, we can state:

1.— That Spanish ceramic tiles and paving in general comply with specifications required by European norms.

2.— They are capable of satisfying the needs required by consumers.

3.— The level of quality achieved and the acceptance of the product has permitted strong development of the industry in recent years.

4.— Evaluation as a result of quality is demonstrated in increased consumption inside and outside our country, and in a shift towards countries with higher standards of living.

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