CLEANABILITY AND HYGIENE OF CERAMIC TILE SURFACES

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ABSTRACT

The role and importance of cleanability and hygiene in the framework of the technical performance and durability of ceramic tile surfaces (floors and walls) are outlined.

The methodological problems associated to the measurement of cleanability of ceramic tiles are discussed, and the methods developed and experienced by the Italian Ceramic Center are presented and critically analysed. Attention is focused, in particular, on the evolution of cleanability with the progressive wear of the ceramic surfaces, as well as on the representativity of the staining agents used, with respect to the real working conditions of ceramic tile surfaces. The role and interactions of staining and cleaning procedu43ty are analysed and justified.

The results of measures carried out on a significant sample of glazed and unglazed ceramic tiles are discussed, and correlated to the microstructural features and to the chemical and mechanical properties of the proper surface. A general picture of cleanability performances of various types of ceramic tiles is presented.

The results achieved are finally elaborated, in order to develop tile choice criteria for the designer and specifier of ceramic tiled floors and walls.

1. INTRODUCTION: THE PROBLEM

Cleanability, together with ease of maintaining hygienic conditions, represents one of the main acknowledged advantages of ceramic tiles with respect to most of the alternative materials, of different nature, for floor and wall coverings.

Until around two or three decades ago, when tiles were produced and used mainly for floor and walls of kitchens and bathrooms, the statement "*ceramic tilings are the floors and walls with the easiest upkeep, and with the best possibilities of maintaining their aesthetic and functional characteristics all over their lifetime in working conditions*" was true without reserve.

Now the situation is more complex, and the statement above, still valid in general terms, is no longer sufficient as choice criterion for the material for floor and wall coverings.

In fact, the last two decades have been characterised by the following aspects:

- an important progress in tile manufacturing technologies, and a consequent large increase of ceramic tile types available on the market: products designed and produced with the purpose of meeting the more and more severe requirements of the users, as regards both aesthetic solutions, and technical characteristics and performance;
- the environments in which ceramic tiles can be used now - and are effectively used - have had a significant increase: in fact, ceramic tiles are now widely used, in domestic environments, not only in kitchen and bathrooms, but also in the other rooms; and not only in domestic applications, but also in public and industrial environments.

From the user - or architect - point of view, the present situation is certainly positive and "rich": he can identify and select tiles for his purpose in an exceptionally wide choice. And, for a given environment, with its specific aesthetic and technical requirements, he can always find suitable tiles, conforming with those requirements. This was not true some decades ago.

But, in front of this advantage, the user/architect should take this fact into consideration: **that no tile exists** which can be suitable - i.e. complying with all the specific technical and aesthetic requirements - **for all the environments** in which ceramic tiles may be used [1].

In other words, today the identification, among the tiles available on the market, of the product (or products) which, as stated above, ensure the easiest upkeep, as well as the best possibilities of maintaining their aesthetic and functional characteristics all over their lifetime in specified working conditions, is no longer so easy, as it was in the past: since several present "working conditions" of ceramic tilings are quite different from the past.

This is the problem on which this paper is focused. And this is why "cleanability", i.e. the facility and efficiency with which dirt, stains and other materials which come into contact with the floor and wall surfaces can be removed, thus restoring the surface to its previous aesthetic and functional characteristics [2], can no longer be accepted as an "intrinsic" property of the ceramic tiles, but needs to be measured and characterised.

Today the user, the designer, the architect, the tile specifier need a deeper and more detailed knowledge of surface characteristics and performance of ceramic tiles, in order to select the suitable product for any given environment, as well as to carry out the most correct upkeep operations on the ceramic tiling.

In order to meet these needs, in the last years the Italian Ceramic Center has carried out an extensive research activity, aimed to the development of measurements methods for cleanability, giving results enabling a reasonably reliable prevision of tile performance in working conditions. Some of the results achieved have been taken into consideration also in the new international standards on ceramic tiles.

In the following sections, a critical analysis will be carried out of the standardised methods for the surface characterisation of ceramic tiles, as well as of the methods related to cleanability assessment, developed or under study at the Italian Ceramic Center. Some results will be presented, and their use will be discussed, as a tool for a correct selection of tiles for given applications and working conditions.

2. THE BACKGROUND

2.1. Cleanability, surface characteristics and working conditions of ceramic tiles

The working conditions of ceramic tile surfaces are schematically represented in Figure 1. The ceramic tile surface (of a floor, in this scheme), is exposed:

• **to chemical actions**, by dirt, staining agents, substances of different chemical nature which can come into contact with the floor surface (for example, food, ink, etc. in domestic environment; processing liquids in an industrial environment, such as milk in a milk and cheese plant, grease and oil in a garage, etc.);

• **to chemical actions** by the detergents used in the upkeep activities;

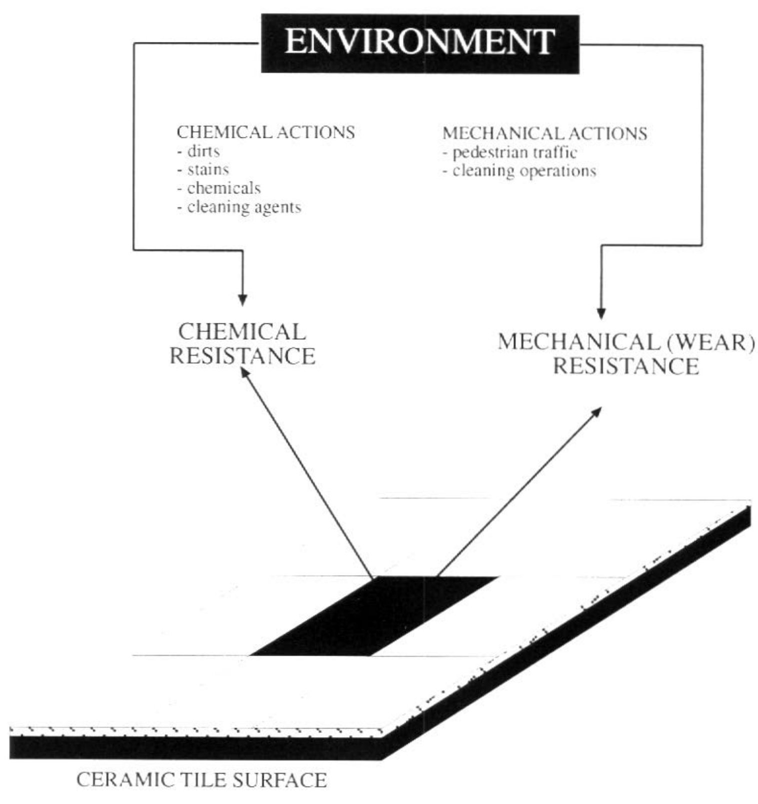

Figure 1 - Working conditions and surface performance characteristics of ceramic tiles.

• **to mechanical actions** (scratches, wear) due to both the movement of bodies or materials in contact with the surface (e.g. people walking on the floor, trolleys and other vehicles, chairs and furniture, etc.), and to the cleaning operations, when carried out with detergents containing abrasive materials, or with abrasive tools.

The ceramic surface must withstand these chemical and mechanical attacks. To do this, the ceramic surface must have suitable levels of chemical resistance (resistance to chemical attack) and mechanical resistance (wear resistance, scratch hardness). These properties represent the "reactions" of the ceramic surface to the environmental actions, and depend on the nature and state of the surface, on the composition and microstructural features, in turn determined by the manufacturing technology.

The designer of the ceramic tile floor should, in principle, identify the intensity level of the chemical and mechanical actions, associated to the given environment, and select tiles having correspondingly suitable levels of mechanical and chemical characteristics. Otherwise there is the risk that tiles, after a rather short period of use, lose definitively their aesthetic and/or functional characteristics, which cannot be restored, with any upkeep procedure. Cleanability can be considered as one of the functional characteristics - having however also an aesthetic impact - which would be lost in this case.

The scheme reported in Figure 1 suggests some further considerations:

• the chemical and mechanical actions discussed above are applied simultaneously on the ceramic tile surface, both in the ìdirtyingî process (i.e., in normal use conditions of a tiled surface), and in the ìcleaningî process (i.e. in the upkeep conditions);

• both chemical and mechanical actions are associated to cleaning operations, which, in turn, are intended to remove the effects of both chemical and mechanical actions on the ceramic surface by the environment. Therefore cleanability, in the sense of performance characteristic of tiles, as defined above, is a function of both chemical and mechanical (wear) resistance of the ceramic tile surface;

• cleanability is strongly influenced by the actual state (structure) of the ceramic surface, which may vary with use and wear [3˜5]. Consider the porosity structure in the thickness of the tile: an example for a glazed tile is reported in Figure 2. These pores are associated to the

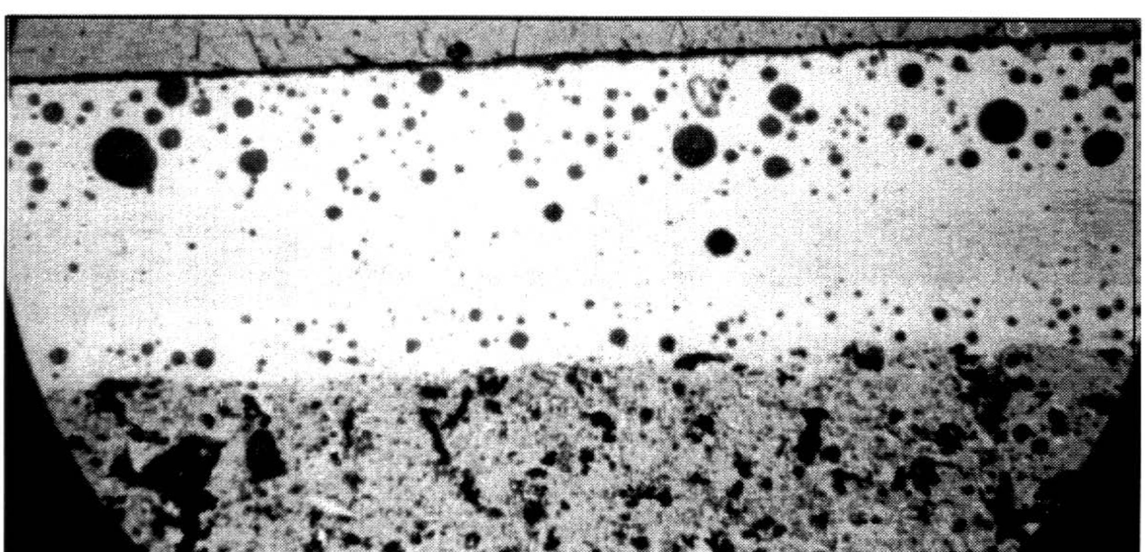

Figure 2 - Cross section of a glazed tile: porosity in the thickness of the glaze.

manufacturing technology (raw materials used, glazing technology, firing schedule, etc.)[5]. The progress of wear in working conditions is expected to modify - in particular, increase - surface porosity, and consequently affect both ìdirtyabilityî and cleanability;

• the characteristics and performance of the detergent, and the cleaning methods adopted, strongly influence the cleaning possibility of a ceramic surface. The detergent acts on both dirt, stains, etc., and on ceramic tile surface, which may be chemically attacked by some cleaning agents. A possible progress in the field of detergents for hard surfaces (in particular, ceramic surfaces) is therefore expected to give a significant contribution to the solution of some cleaning problems of ceramic tiles. And, in effect, such a progress is now in course: some producers of detergents have asked the Italian Ceramic Center cooperation for the development of new and more efficient detergents for ceramic surfaces, compatible with the ceramic surface characteristics and performances.

2.2 Chemical and mechanical surface characteristics of ceramic tiles in the international standards (EN and ISO)

The preceding discussion has shown the importance of the chemical and mechanical surface characteristics of ceramic tiles, in order to assess the quality and performance levels of the products, and therefore their suitability for specific destined environments and applications. For this reason the international standards - both the EN standards, at present in force in Europe [6], and the new ISO standards, which are in the final approval phase [7] - include these characteristics in the technical specification of both glazed and unglazed ceramic tiles. The characteristics considered, and the respective norm describing the testing method, are reported in Table 1.

Table 1 - Chemical and mechanical surface characteristics of ceramic tiles in the EN and ISO Norms [6,7].

Surface characteristics	Glazed tiles		Unglazed tiles	
	EN	ISO	EN	ISO
• **Mechanical**				
- Scratch hardness	EN 101		EN 101	
- Surface abrasion (PEI Method)	EN 154	ISO 10545-7		
- Deep abrasion			EN 102	ISO 10545-6
• **Chemical**				
- Resistance to stains	EN 122	ISO 10545-14		ISO 10545-14
- Resistance to household chemicals and swimming pool salts	EN 122	ISO 10545-13	EN 106	ISO 10545-13
- Resistance to acids and alkalis	EN 122	ISO 10545-13	EN 106	ISO 10545-13

The following aspects are worth of mention, in the framework of this discussion on cleanability:

• for unglazed tiles, stain resistance - i.e. the chemical resistance aspect more directly related to cleanability - is not taken into consideration by EN standards. This reflects the considerations made in the introduction: in the past stain resistance of unglazed ceramic tiles was not considered as a basic property, with respect to the available types of tiles and their main applications fields. Now, mainly after the progress in porcelain stoneware production and application, stain resistance has been acknowledged as a relevant characteristic also for unglazed tiles, and in effect the new ISO standards have included it among the standardised properties. The Italian Ceramic Center has given an important contribution to this, as it will be discussed in the next section;

• all the test methods, in both EN and ISO standards, are based on a "simulation" of the respective action considered. The principle can be summarised as follows: a particular and precisely defined attack condition is reproduced in laboratory on the tile surface (for example: some specified chemical agents are put and maintained in contact with the ceramic surface with a defined procedure, for a defined time and in defined conditions; a defined abrasive charge is moved in contact with the surface, in defined conditions). The test conditions are selected taking into account, as far as it is possible, both the real working conditions, and the needs of technical and economical acceptability of the test (repeatability, time required, cost, etc.). Successively, the test pieces are examined, with a defined procedure, in order to assess the effects of the attack applied. It is quite evident that such a test procedure allows only a very general (and abstract) representation of what can occur in real working conditions;

• each kind of attack (for example, individual stains, individual chemical agents, wear, etc.) is applied alone, always on the original surface of the tile. Therefore the resistance measured by each test method should be intended as the resistance of the original surface of a new, never used tile, to a single attack. In this case the difference from the real working conditions is more evident and important than in the preceding case. In fact, in real working conditions all the actions considered in Figure 1 are applied simultaneously, on a surface which is progressively modified by the effects of such actions.

Unfortunately, specific experiences carried out and observations made have demonstrated that the effects of chemical and mechanical actions of defined level or intensity, applied simultaneously on the surface of a given tile are different from the effects due to the same actions applied separately. For example, a good chemical resistance and a good abrasion resistance, measured according to the standard test methods under discussion, are not necessarily associated to a good resistance, or to an acceptable behaviour of the tile surface, when both chemical and abrasive actions of the same intensity are applied simultaneously. The two kinds of actions are synergetic, not additive.

This fact represents the main limit of such "simulation" test methods, and raises some hard metrological problems.

First of all, it should be clearly stated that the results of the tests under consideration must be considered as data for quality assessment of the tiles, and not directly as an assessment of performance and durability in every working conditions. Prudence is necessary in the use of these results, and their meaning should not be over-estimated [8].

From a metrological point of view, some difficulties arise when trying to simulate in an acceptably simple, cheap and reproducible way the "superimposition of the effects" that occurs in real working conditions of ceramic tilings.

This problem has been faced with a "step-by-step" approach.

The first step has been the application of two actions (for example, mechanical and chemical actions) in sequence on the same surface. This is the approach on which the cleanability method developed by Centro Ceramico, and discussed in the next section, is based: a method in which a further objective has been pursued, that of improving the representativeness of the results and the knowledge of the staining and cleaning mechanisms, through a wider selection of both staining and cleaning operative conditions.

This approach has been accepted and introduced also in the new ISO standards. See, for example, ISO 10545.7 (Draft), reporting the test method for abrasion resistance of glazed ceramic tiles [7]: the maximum level of abrasion resistance (Class PEI V) is assigned to tiles complying with both the following conditions:

- no abrasion failure is visible after 12000 revolutions;
- the abraded surface is stain resistant (according to ISO 10545.14).

This last condition is verified just subjecting the abraded surface (i.e., the surface previously subjected to a mechanical action) to a chemical (staining) action, in sequence.

The second step has been the simultaneous application of both mechanical and chemical actions, in order to simulate in a closer way what happens in real working conditions. This approach will be discussed in the section 4.

3. A MORE DETAILED ASSESSMENT OF CLEANABILITY: THE CENTRO CERAMICO METHOD

3.1 Objectives and procedures

As stated above, the term "cleanability" is intended as a performance characteristic of the surface of floor and wall tile, which can be defined by the following two aspects:

- the **efficiency** with which stains produced by various substances can be removed;
- the **ease** with which complete removal of the stains can be achieved.

Moreover, cleanability is expected to change during the working life of the tiling, due to the surface modifications induced by the mechanical wear effects.

The cleanability method developed by the Italian Ceramic Center was intended to characterise all these aspects. It is once again a "simulation" method - as it is, for example, the method for the measurement of resistance to stains reported in the EN 122 Norm [6]. But, compared to this method, the Centro Ceramico Method, with the purpose of achieving a more detailed description of the tile surface behaviour, as well as a higher sensitivity and selectivity with respect to the different performance levels of different products, has significantly enlarged the range of test conditions, increasing the numbers and kinds of both the staining agents and the cleaning procedures and conditions scheduled (it can be considered, for example, that stain resistance tests carried out according to the EN 122 procedure, but on abraded surfaces, would have given almost always a stain resistance class 3, for any product tested).

The **staining agents** chosen are listed in Table 2; they also cover the main types of action or mechanisms of staining:

- *chemical action,* when the stain performs a true chemical attack on the surface (red wine vinegar and/or lemon juice, olive oil). This chemical action is in general negligible on unabraded and impervious surfaces, but can become important on abraded, more porous surfaces;

• *penetrating and colouring action*, when the stain has the ability to penetrate into the material through the surface porosity (methylene blue solution, blue and red inks, lighted cigarette);

• *oxidising action*, when the staining agent is also an oxidant (potassium permanganate solution, lighted cigarette, carbonated cola beverage);

Table 2 - Staining agents chosen for the "Centro Ceramico Cleanability Test Method".

Staining agent	Contact time
A. Red wine vinegar and/or lemon juice	24 h
B. Coffee	24 h
C. Olive oil (*)	24 h
D. Cola	24 h
E. Lighted cigarette	15 min
F. Methylene blue (10 g/l)	24 h
G. Potassium permanganate (10 g/l)	24 h
H. Blue ink (*)	24 h
I. Red ink (*)	24 h

(*) Commercial products conforming to defined specifications.

• *coating action*, when the stain has the ability to form a persistent and continuous film on the surface (olive oil, coffee, carbonated cola beverage).

Also indicated in Table 2 are the times of contact between the staining agent and the tile surface being tested. A contact time of 24 hours was established for all the stains selected, the only exception being the lighted cigarette, for which the contact time is 15 minutes (the cigarette is kept lighted by means of a vacuum pump).

Several **cleaning methods** are specified, as listed in Table 3 in order of increasing intensity. Each procedure is defined by:
• the type of cleaning agent;
• the time length of the cleaning intervention;
• the cleaning tool adopted.

Some cleaning methods involve the use of a brush, in order to apply the cleaning agent on the stained area. This is a rigid, vegetable bristle brush, 8 cm diameter, rotating at a velocity of 480 rpm with the detergent solution continuously flowing at the centre of the brush for the entire duration of the treatment.

Table 3 - Cleaning procedures adopted in the "Centro Ceramico Cleanability Test Method".

No.	Cleaning agent	Time	Cleaning tool
I	Hot water (60 ∞C)	5 min	--
II	Commercial detergent pH 6.5˜7.5 not containing abrasive	3 min	Soft sponge
III	a. Commercial detergent pH 9˜10 not containing abrasive	3 min	Soft sponge
	b.		Rotating brush
IV	a. Commercial detergent pH 3˜4 not containing abrasive	3 min	Soft sponge
	b.		Rotating brush
V	a. Commercial detergent containing abrasive	3 min	Soft sponge
	b.		Rotating brush
VI	Suitable solvents	3 min	Rotating brush
	a. HCl solution 3% b. KOH solution 200 g/l c. Sodium hypochlorite, 20 g/l d. Trichloroethylene e. Hydrogen peroxide, 110 vol.	24 h	Immersion of tile into the solvent

Table 4 - Classification of results in the "Centro Ceramico Cleanability Test Method".

Result of the cleanability test	Cleanability class
Surface permanently damaged	0
Stain not removed at all	1
Stain weakened	2
Very evident halos	3
Not very evident halos	4
Spots on a clean background	5
Stain completely removed	6

The **test procedure** is, schematically, the following:

• each staining agent is applied on the surface to be tested (the application method is specified in detail);

• the cleaning trials are carried out in sequence, according to the list reported in Table 3;

• after each cleaning trial, the test pieces are dried and subjected to visual examination (in specified conditions). For each stain and each cleaning trial, a **cleanability class** is assigned, according to the specification reported in Table 4;

• the test can be carried out on both whole, new tiles, or on tile surfaces previously subjected to abrasion (in general, 600 revolution according to the PEI method; but various abrasion stages can be adopted, with the aim, for example, of characterising the stain resistance behaviour with the progress of wear phenomena).

Therefore, at the end of the cleaning test, for each state of the ceramic tile surface (whole or abraded), it is possible to obtain a "*cleanability sheet*", such as reported in Table 5, containing all the results of individual cleaning trials carried out on each individual stain.

Table 5 - Cleanability sheet.

Product:	State of	• Whole
	the surface:	• Abraded (no. .... rev.; PEI Method)

CLEANABILITY CLASS FOR THE STAINING AGENT

Cleaning procedure	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**
I									
II									
III a									
III b									
IV a									
IV b									
V a									
V b									
VI (a÷e)									

3.2 Experiences carried out

This test method has been experienced first of all on unglazed tiles, for which no previous experiences or reliable data on stain resistance existed (as stated before, the EN Standards did not included stain resistance among the standardised properties of unglazed ceramic tiles). In the meanwhile experiences have been brought about also on glazed surfaces. This work has been carried out in cooperation with the ISO T.C. 189 "Ceramic Tiles" [7]. And, in effect, the new stain resistance method included in the ISO Standards is a somewhat simplified version of the "Centro Ceramico Cleanability Test Method".

It is worth discussing now in more detail on "how" this test method characterises a ceramic tile surface from the cleanability point of view, and "how" it enables to compare different products, giving also suitable indications on their performance levels in specified working conditions. Several results obtained on both glazed and unglazed tiles of the different types are reviewed in the following.

3.2.1 Efficiency of cleaning and stain removal

From the "cleanability sheets" it is possible to assess immediately if someone of the stains experienced cannot be completely removed, in either the whole or the previously abraded surfaces. This occurs when - or for those stains for which - the cleanability Class 6 (completely restored surface) is not reached, for none of the cleaning methods. In this way the efficiency of cleaning and stain removal can be immediately evaluated.

As far as cleaning efficiency is concerned, the results achieved in the characterisation campaign carried out show that:

• **glazed tiles**: all the stains can be removed from the whole surfaces. Therefore, in general, "new" glazed tiles have an *efficient* cleanability with respect to all the stains. But, for abraded surfaces, a very wide range of results is achieved. And, in around half of the tiles tested, some stains (in particular, cigarette, inks, potassium permanganate) could not be removed with none of the cleaning procedure experienced. For some products the recourse to the strongest cleaning procedures has led to a definitive damage of the proper surface. Therefore for glazed tiles there is the risk that cleaning efficiency may be appreciably decreased by the progress of wear, and that tiles become not cleanable in real working conditions. On the other hand, glazed products are available for which this cleaning efficiency decrease does not occur. But it is worth noting that tiles with the highest resistance levels to both chemical and mechanical actions according to EN standards (for example, Class 1 of stain resistance and Class PEI IV of abrasion resistance) are represented among both the tiles which lose their cleaning efficiency and tiles which maintain their cleaning efficiency after wear. This is a further demonstration that the EN results alone cannot give a reliable assessment of the expected performances of tile surfaces in real working conditions, as discussed above;

• **unglazed tiles**: some stains are hardly removed by the surface of particular types of tiles, even in the whole, new state. "Cotto" tiles (with the impregnation treatment ordinarily performed on such type of material) are in general definitively altered by cigarette (which "burns out" the treatment). Some types of porcelain stoneware have presented, in the not abraded state, a not completely efficient cleanability (with cigarette and inks being the more problematic stains). Among these less cleanable products, types of porcelain stoneware with polished surface are rather often represented. This fact can be associated to two circumstances: i) polishing is substantially a controlled removal of the surface layer: the consequence is the generation of a new surface, generally characterised by more diffused micropores, which can increase the penetration and retention of the stains (i.e. dirtyability); ii) the polished surface can be negatively affected by the strongest cleaning procedures, which may be required for the reason above. In particular, the surface gloss may be changed.

The abraded surface, in general, has shown cleaning efficiency levels not so different from those of the new, unabraded surface. In most products no increase of stains not removable with any cleaning method has been observed, passing from unabraded to abraded surfaces.

In conclusion, as far as the cleaning efficiency is concerned (i.e., the actual possibility of restoring the tile surface, after complete removal of all the applied stains), generally glazed tiles can be considered as superior to unglazed tiles in the unabraded state, but very often inferior after abrasion. Therefore, when specifying glazed tiles for environments in which high wear levels are expected, the architect should ask the tile producer a more detailed technical specification, according to the concepts and testing methods here discussed.

3.2.2 Ease of cleaning and stain removal

From the "cleanability sheets" an indicator of the ease of cleaning and stain removal is represented by the less strong cleaning procedure which leads to the complete restoration of the surface (i.e., to a Class 6 result). The lowest is the intensity of the cleaning methods required to a full efficiency stain removal (i.e. for Class 6), the highest the ease of cleaning is.

The results achieved in the characterisation campaign carried out lead to very similar conclusions, compared to the above discussion on cleaning efficiency: glazed tiles are in general superior to all unglazed tiles in the unabraded state, but lose most of their advantage after abrasion. And, among unglazed tiles, porcelain stoneware tiles with polished surface, compared to the corresponding product with untreated surface, are characterised by a more pronounced decrease in ease of cleaning, when passing from the whole surface to the abraded surface.

3.3 Discussion

The main advantages of the Centro Ceramico method, compared to the EN test methods, are associated to the possibility of a more detailed characterisation of ceramic tile surface cleanability in working conditions.

The wider range of stains and cleaning procedures, and their closer relation with stains occurring and procedures adopted in real work conditions, as well as the possibility of taking into account and verifying the effects of wear on cleanability, are the most qualifying aspects of this method. Another important aspect is that this method can be applied to both glazed and unglazed ceramic tiles.

With this method, it has been possible to verify that products with the same quality level, according to the EN standards, may have very different expected behaviours and performance in certain working conditions. Thus, the results of this test can give the user/architect/tiling specifier a more reliable tool in view of a correct selection of tiles with defined performance levels, as a function of the destined environment. This is why this method, as already stated, has been substantially accepted by the ISO TC 189, and included (although in a somewhat simplified form) in the new ISO standards.

The main limits are associated to the very high number of conditions which are reproduced, controlled and measured, as well as to the still imperfect way in which working conditions are simulated.

As far as the first aspect is concerned, it is clear that such a method involves rather long execution times and high costs. The ISO version (ISO Draft 10545.14 [7]) is simpler, cheaper and less expensive, although, of course, less detailed. In any case, the application of this method may be technically and also economically justified in the case of some problematic environments (for example, for "heavy duty" applications, such as particular public environments, etc.).

For the second aspect, this method is not yet able to reproduce the simultaneous application of the mechanical and chemical actions, which occurs in real working conditions. The reliability of the results achieved (in terms of representation of the real behaviour in working conditions), as well as of the tiling design implications which can be deduced from these results, is not yet at optimum levels. However, a significant progress has been made, with respect to the EN standards.

The simultaneous application of both chemical and mechanical actions is now discussed in the next section.

4. A NEW APPROACH: THE SIMULTANEOUS APPLICATION OF CHEMICAL AND MECHANICAL ACTIONS

4.1 Introductory remarks

As discussed in the preceding section 2, in real working conditions both dirtying and cleaning processes of a tiled surface (for example, of a floor) involve the simultaneous application of both mechanical and chemical actions. And, for a given intensity level of each action, the effects are different from those which would be expected if these actions would have been applied separately. Thus, a testing method (once again, a ìsimulationî method, like those considered so far) involving the simultaneous application of both the actions under consideration is expected to enable a better representation of the effective behaviour of the tile surface in real working conditions.

Such a testing method has been developed and experienced at the Italian Ceramic Center, by now for a particular purpose: that of qualifying some commercial and experimental detergents for hard surfaces (more specifically, for ceramic surfaces).

In the preceding discussion it has been outlined that detergents are used, in usual cleaning procedures, together with abrasive tools (or may contain abrasives). Thus any cleaning procedure involves the simultaneous application of a wear action (due to the abrasive) and a chemical action (due to the chemical active components of the detergent). It is obvious that a detergent can be assessed as suitable for a given type of surface, if this surface is not damaged by it, in the normal application conditions (of course, this is one of the requisites for an acceptable detergent: not the only one, but in any case a basic requisite).

The new testing method based on the simultaneous application of chemical and mechanical actions has been applied just to assess the acceptability of detergents from the above mentioned point of view. This study has been carried out in cooperation with some producers of detergents, who are developing new products suitable for the more severe cleaning conditions now required for tiles, in the different environments in which tiles are now widely used.

An extension of the use of this new method, also for the assessment of the cleanability of a given ceramic surface (i.e., as an improvement of the cleanability method presented in the preceding section) is at present under study.

4.2 Objectives and procedures

Only a general overview is proposed here, since the method is still in the development phase.

The evaluation of a detergent is made carrying out the following tests, and then comparing and analysing the results achieved:

• A reference material (for example, glazed ceramic tile) is chosen. This tile is fully characterised according to the EN standards. In particular, resistance to acids, alkalis, stains and other chemicals is determined, according to EN 122 [6].
Both tiles with high chemical resistance and tiles with low chemical resistance should be selected as reference materials for this test.

• The resistance of the tile selected to the chemical attack by the detergent to be evaluated is then measured, using, in principle, the same procedure reported in EN 122.

• Successively, various abrasion steps are performed, according to the PEI method (EN 154)[6]: i.e., using an abrasive charge containing steel spheres of defined diameters, alumina powder and distilled water. The following effects are assessed after abrasion:
- the occurrence of visible effects, according to the classification criteria reported in EN 154;
- the modification of surface gloss (expressed as ratio of the surface gloss after each abrasion test to the surface gloss of the original, untreated sample);
- the cleanability of the abraded surface, measured according to the Centro Ceramico method reported in the preceding section.

• Finally, the same abrasion steps are performed, as indicated above, but using an abrasive charge in which distilled water is replaced by the detergent to be evaluated. According to the objective of the test method under consideration, this procedure ensures the simultaneous application of mechanical actions (due to the abrasive charge) and chemical action (due to the detergent). On the treated surfaces the same observations and measurements listed above are performed.

Table 6 - Example of results from the new testing method: Assessment of the detergent «A» behaviour with a tile having low chemical resistance.

Materials:	• Tile: glazed tile marked «GLC» • Detergent: «A»

I. Chemical resistance		
Resistance to acids and alkalis (EN 122)		*Resistance to detergent «A» (procedure as in EN 122)*
Class of resistance		**Class of resistance**
HCl	KOH	
C	AA	AA

II. Resistance to surface abrasion (1500 rev. PEI charge - Abrasive charge + water, as in EN 154)		
Visual examination	*Gloss reduction ratio (%)*	*Cleanability class according to CCB method (Stain: F; cleaning proc.: VI.c, 3 min)*
No visible effect	33.4	6

III. Resistance to surface abrasion and chemical attack (1500 rev. PEI charge - Abrasive charge + detergent «A»)		
Visual examination	*Gloss reduction ratio (%)*	*Cleanability class according to CCB method (Stain: F; cleaning proc.: VI.c, 3 min)*
Some visible effect	33.0	6

4.3 Some results

With the purpose of showing the type of results and information achievable with the test method under consideration, two exemplifying (and partial) sets of results, corresponding to two different detergents (marked «A»and «B»), are reported in Tables 6 and 7, respectively. Each of these tables refer to an individual type of tile used for the characterisation of the detergent: in particular, for detergent «A» (Table 6) to a glazed tile with low chemical resistance, and for detergent «B» (Table 7) to a glazed tile with high chemical resistance.

Two aspects are worth of mention here from these tables:

• it is confirmed that, as discussed above, the simultaneous application of both chemical and mechanical actions may lead to effects that are different (in particular, more severe) compared to those associated to each individual action. See the case of detergent «A», Table 6. The test tile used has the highest resistance to detergent «A»(Class AA), and has also a good abrasion resistance (no visible effect is detected at 1500 revolutions, what means that the tile under consideration has a PEI Class IV). However, the simultaneous application of both wear and chemical attack by the detergent leads to the occurrence of visible effects after 1500 revolutions: in other words, an early surface deterioration occurs in these conditions. We can conclude that detergent «A», which does not attack the surface when applied alone, may be somewhat hazardous for the surface when applied together an abrasive action;

• on the contrary, some detergents have been found which seem to accomplish a sort of protection of the surface against the possible wear effects. Detergent «B», Table 7, is a clear example. Note that the effects of a given wear action, when applied alone, are rather severe: i) visible effects are detected after 1500 revolutions of the PEI charge, ii) gloss is remarkably decreased, and iii) the abraded surface has a limited cleanability, at least for the stain and the cleaning procedure considered (see Table 4 for the cleanability class). When the detergent «B» is used together with the same abrasive action, all the effects are improved: i) no visible effect is detected, ii) a lower decrease in surface gloss is observed, and iii) the treated surface is fully cleanable (for the same stain and cleaning procedure considered above).

Table 7 - Example of results from the new testing method: Assessment of the detergent «B» behaviour with a tile having high chemical resistance.

Materials:	• Tile: glazed tile marked «GLA» • Detergent: «B»

I. Chemical resistance		
Resistance to acids and alkalis (EN 122) **Class of resistance**		*Resistance to detergent «B» (procedure as in EN 122)* **Class of resistance**
HCl	KOH	
AA	AA	AA

II. Resistance to surface abrasion (1500 rev. PEI charge - Abrasive charge + water, as in EN 154)		
Visual examination	*Gloss reduction ratio (%)*	*Cleanability class according to CCB method (Stain: F; cleaning proc.: VI.c, 3 min)*
Some visible effect	23.7	4

III. Resistance to surface abrasion and chemical attack (1500 rev. PEI charge - Abrasive charge + detergent «B»)		
Visual examination	*Gloss reduction ratio (%)*	*Cleanability class according to CCB method (Stain: F; cleaning proc.: VI.c, 3 min)*
No visible effect	73.4	6

These results are very interesting for the producers of cleaning agents for hard surfaces. And they can find, in the test method here discussed, a good tool in order to assess the quality of their products, as well as to envisage their behaviour and performance in real working conditions.

A quite similar approach, based on the simultaneous application of mechanical and chemical actions, can be adopted to simulate also the dirtying process, in a more reliable way, compared with the separate application of the actions which characterises the Centro Ceramico cleanability test method discussed above. This extensions is at present under study.

5. CONCLUSIONS - FUTURE PROSPECTS

The behaviour of ceramic tile surfaces in real working conditions, when both chemical and mechanical, wear actions are applied simultaneously, has been studied in detail, and new test methods have been developed, which are intended to supply a more reliable simulation and representation of what actually occurs in those working conditions.

It has been shown that the new ISO standards on ceramic tiles have taken some results of these studies into account. Therefore these studies have contributed to the improvement of quality control and quality assessment of ceramic tiles, according to the standards. Moreover, these studies have given the architect or tile specifier more reliable tools for the identification of suitable tiles for a given destined environment. This is an important result, in view of a more correct use of ceramic tiles.

These studies - and the methods developed as well - can also assist tile manufacturers in the design and development of new products, improved from the «dirtyability» and «cleanability» points of view: surfaces able to «repulse» dirt, and in any case to maintain good cleanability performance all over their service time, also in heavy duty applications.

Finally, these studies are sought with increasing interest also by the producers of detergents for hard surfaces, who aim to develop new and improved cleaning agents for ceramic tiles, which are not only efficient in dirt and stains removal, without damaging the ceramic surface, but also effective in the protection of the ceramic surface itself.

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