INTERNATIONAL JOURNAL OF CONSERVATION SCIENCE

ISSN: 2067-533X Volume 6, Issue 1, January-March 2015: 51-62 www.ijcs.uaic.ro

IN SITU PRESERVATION AND RESTORATION OF ARCHITECTURAL TILES, MATERIALS AND PROCEDURES: RESULTS OF AN INTERNATIONAL SURVEY

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Abstract

In order to aid research, improve preservation actions and develop better options for future interventions it is important to know the preservation materials and procedures adopted throughout the past and especially the ones being adopted nowadays. A survey to specialists working in situ in preservation and restoration of glazed decorative tiles has been performed aiming at getting insight on their type of training, work portfolio, opinions, the current materials and procedures used in the diverse phases of a preservation intervention (diagnosis, cleaning, consolidation, bonding fragments and fixing of glazed layer, volumetric and chromatic reintegration, final coating, resetting of tiles and manufacture of replicas) and the criteria/factors that support the specialists choices.

Keywords: *Architectural tiles; Azulejo; In situ preservation; Online survey; Treatment phases*

Introduction

In situ preservation of architectural tiles is a constant concern in Portugal, but also in many other countries. Although the use of tiles does not constitute an exclusive Portuguese artistic expression, Portuguese glazed tiles (azulejo) are unique due to the form, quantity and diversity that can be found in the country for the last five centuries.

In the field of conservation, the architectural tiles remain often associated with other working areas such as architectural structures, stone materials or non-architectural ceramics. Some papers and other type of information specific for this field have been published [1-16] but far from the large amount existent in the other areas. The restricted number of technical and scientific information about the materials and procedures used hinder the task on research of the

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methodologies and materials used in preservation of architectural tiles being, consequently, a motivation to the approach adopted in this article.

An extensive multiplicity of materials and procedures is known to have been applied in preservation of architectural tiles, many times in an empirical way, without much knowledge of their properties and behaviour throughout the time. The understanding of the past and especially present applied solutions (materials and procedures) is crucial to optimize and develop better treatments for future interventions. In order to obtain this knowledge a dedicated survey [17] was envisaged where information provided by specialists, integrating the working field of conservation and restoration (C&R) of *in situ* tiles, was collected. Together with technical reports from actual interventions, this type of data provides relevant information regarding the different procedures and materials used on site which will aid to monitor and identify the quality and success of the interventions made in architectural tiles.

Technical survey design and methodology

An online technical survey (accessed and answered online at www.questionpro.com), was elaborated based on other surveys from related fields [18] and specialized technical literature [10, 12] in order to pre-select the most common materials/products and procedures used on each phase of treatment and other specificities in the field of preservation of architectural tiles. The survey was composed by 65 questions, some close-ended and others open-ended (allowing to present some alternative options) with single and multiple choice selection.

The first part of the survey intended to know the profile of each respondent in the target population, type of training and work, as well as some general considerations on the practice of preservation and restoration. As to the remaining questions, the purpose was to know the materials and procedures used from diagnosis to the different phases of treatment – cleaning (including disinfection and desalination processes), consolidation, bonding fragments and fixing of glazed layer, volumetric and chromatic reintegration, final coating, resetting of tiles and manufacture of replicas. At the same time, this survey sought to understand the criteria/factors that support the decisions of the specialists and influences the selection of materials, products and procedures of treatment.

The results presented in this work consider all the responses to each question, whether the respondent has finished the entire survey or not. Being so, it is expressed the number of respondents to each question (*n*).

Sampling

The universe of specialists engaged in preservation and restoration of tiles and *in situ*, was unknown. The survey was available online in three languages: English, Portuguese and Spanish to try to reach as many specialists as possible. The dissemination of the survey was done through direct contact and social and professional networks, such as Facebook and LinkedIn.

Results and discussion

The target population

The survey was seen by over a thousand individuals. 51 were totally completed and 400 partially. The maximum number of responses to a question was 130.

Specialists from 35 countries answered: mostly from Portugal (39%), Spain (22%), Brazil (19%), USA and Italy (3% each), Greece and UK (2% each), Austria, Belgium, Bulgaria and Iran (1% each). The remaining percentage corresponds to scattered answers obtained in several European countries (Netherlands, Germany, Switzerland, France, Ireland, Bulgaria, Croatia, Hungary, and Georgia), Asia (Turkey, China, India, Bangladesh, Jordan, Lebanon and Albania) South America (Mexico, Peru, Argentina, Chile) and Africa (Egypt, Nigeria and Tanzania).

About 60% of the respondents (n = 127) have more than 10 years of working experience, 15% claim to have between 5 and 10 years of experience in preservation and almost 25% have less than 5 years of experience in *in situ* preservation and restoration of architectural tiles.

The results obtained in the survey indicate that there is a lack of specific training in architectural tile preservation, reflected by the number of persons that have acquired their skills in a working context, i.e. the skills were obtained during the professional exercise and not before, in an academic context (Fig. 1).

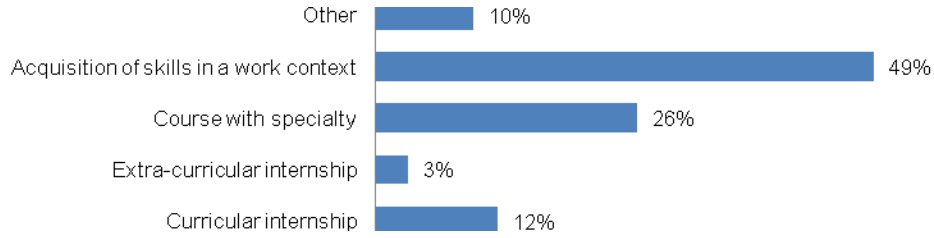

Fig. 1 Specialty acquisition in architectural tiles C&R (n = 108).

Another sign of this situation, and probably also due to the absence of enough work, lead to the fact that people are scattered in distinct working fields, contributing, at the same manner, to a lack of specialisation on this area. Beyond the work on architectural tiles, during the last five years, the respondents have been mostly active with other ceramics and glass but also stone materials, sculptures and archaeological materials.

The architectural tiles

The type of architectural tiles that respondents have been intervening are (n = 105): hispano - moresque (pre-majolica techniques, 15%); majolica type (all tiles manufactured with majolica technique, 37%); semi-industrial (produced with mixed industrial and handmade techniques, 32%) and the industrial ones (16%). The tile panels located indoors represented 58 % and 42% the ones located outdoors (n = 110).

Tile diagnosis, intervention reporting and effectiveness monitoring

When asked about the kind of methods used for identification of materials or deterioration patterns and diagnosis, the answers (n = 98) indicate a predominance of visual observation (39%); 22% do *in situ* analysis; 19% perform sampling for later laboratory analysis and 18% use diagnosis through microscopic observation. About 2% do not make any diagnosis and auxiliary diagnostic methods using simple analysis methods are the ones used on a large scale. The factors that influence the most the choice of a certain treatment material or product were ranked by the specialists from 1 to 5 (where 1 does not influence and 5 greatly influence), (Fig. 2), the prevailing factor being the characteristics of the material/product.

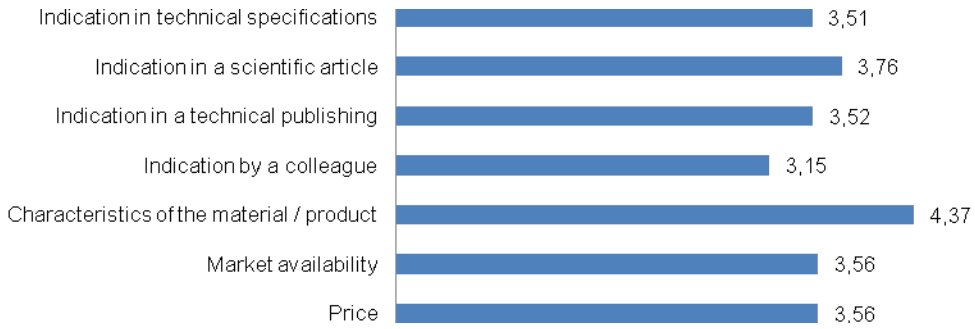

Fig. 2 Factors that influence the most the choice of a material/product (1-does not influences; 5- greatly influences) (n = 89).

More than 90% of the specialists perform a final technical report of the interventions. However, the preservation treatment effectiveness is predominantly monitored by the specialists (n = 88) just after its execution (Fig. 3) and visual observation is the preferential method (85%).

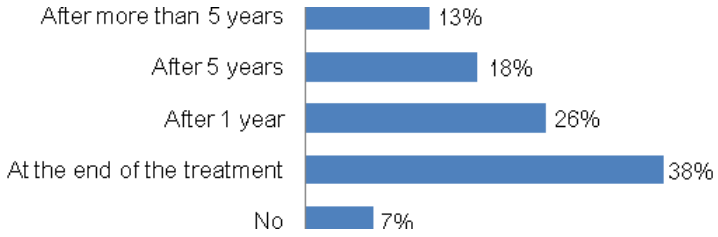

Fig. 3. Evaluation of the effectiveness of the treatment provided (n = 88)

The decrease of effectiveness monitoring through time has a practical explanation since usually is not provided the budget for this type of monitoring, but represents a counter-productive practice from the standpoint of the tile panel/treatments maintenance and study of materials weathering.

Cleaning - Materials and Procedures

Table 1 resumes the options of cleaning procedures the specialists choose to use in relation to the type of substance to remove (n = 72), and displays the disadvantages of the procedures (n = 56).

When soluble salts are present, the respondents (n = 61) have mostly chosen to remove the tiles from the architectural support and afterwards hold an aqueous soaking treatment (36%), closely followed by *in situ* desalination with poultices (35%), and by superficial cleaning of efflorescence (29%).

In the presence of biological colonisation, 16% of the specialists didn't perform any type of identification of the microorganisms, 49% held only *in situ* observation and 35% held a "scientific" identification, including microscopic observation and species and/or genera identification through culturing (n = 60). The respondents (n = 47) considered that for the treatment of biological colonisation, the use of biocides is the most suitable method for several types of biological colonisation, such as the presence of brownish or black stains/biofilm, green stains/biofilm, as well as for the elimination of incrustations (lichens). Mechanical procedures

are preferred for removing whitish/coloured efflorescence and vegetation, such as plants and mosses, and for the removal of incrustations (lichens).

Table 1. Possible cleaning procedures for different types of substances and its disadvantages.

CLEANING PROCEDURES	DISADVANTAGES	TYPE OF SUBSTANCE TO REMOVE					
		Superficial deposits (%)	Coherent materials (concre-tions) (%)	Residues of paints, mortars, adhesives, etc. (%)	Soluble salts (%)	Stains (%)	Biological colonisation (%)
Mechanical (micro-tools)	Time consuming	27	23	27	8	5	10
Sprayed water	Non effective	25	11	13	18	17	14
Solvents (including water)	Dangerous to the operator	18	15	29	9	20	10
Detergents	No disadvantage	27	6	21	3	30	13
Poultices	Difficult to apply	11	15	22	15	31	8
Air abrasion (water and inert)	Causes reactions with/in the original materials	19	27	13	8	15	15
LASER	Very expensive	19	31	0	13	31	6
0-14%		15-24%		≥25%			

Regarding the treatment of biological colonisation with biocide, 26% of the respondents (n = 28) believe that it is dangerous for the operator and can cause colour change in the original substrate (23%). 19% consider that this kind of treatment is not effective and 13% admit that there is physical damage to the substrate or reaction with the substrate materials (11%). The remaining answers correspond to other situations that were reported (in the *other* option) such as glaze detachment when the biological colonisation occurs between the glaze and the ceramic body and the short duration of such treatment, since new colonization can occur again after 5 years or less.

Bonding fragments

For bonding tile fragments the respondents (n = 45) have chosen from the adhesives presented – cellulose nitrate, polyester, epoxy, vinylic, acrylic and inorganic ones, the acrylics, as the more often used ones (Fig. 4).

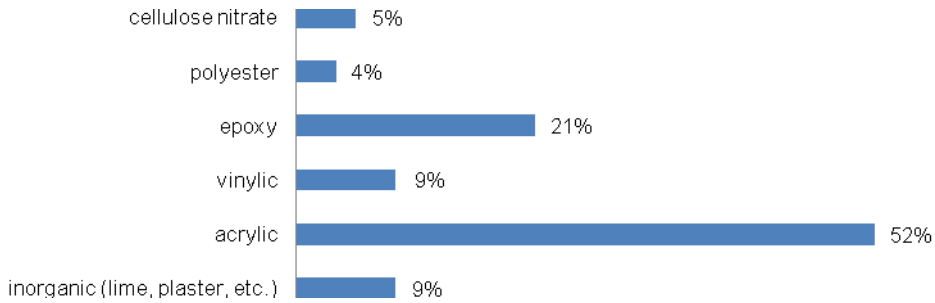

Fig. 4. Adhesives used for bonding fragments (n = 45).

When asked about the brand names of the adhesives usually used, the most indicated products are Paraloid® B72, followed by Primal® AC33 and UHU® Art and with minor importance Paraloid® B42, B74, B60, Hxtal Nyl 1®, Epo150®, Mowihal®, Mowilith®, Flexi Weld 520T® and Flexi Fill 530®, UHU® Plus 24h, Ledan® TA1, Ledan® C30 and Bicomponent Araldite®. The referenced solvents used to dilute the adhesives for bonding fragments were: acetone, methylethylketone, isopropanol, ethanol, ethyl acetate, toluene and xylene.

Fixing the glazed layer

For fixing the glazed layer, the answers of the specialists (n = 39) are presented (Fig. 5), being similar to the bonding fragments operation, where acrylics the most commonly used adhesives, by a large extent.

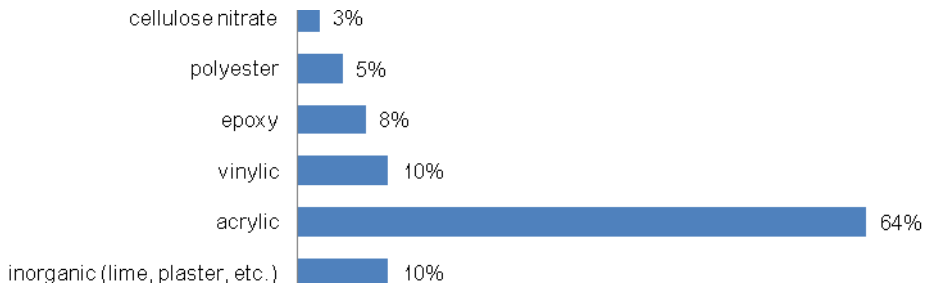

Fig. 5. Adhesives used for fixing the glazed layer (n = 39).

The most commonly used commercial materials are Paraloid® B72 and Primal®AC33. There are references to the use of Paraloid® B42, Nanorestore®, Golden MAS® and Avalure®. The solvents referred are acetone, ethanol, isopropanol and water.

Consolidation

The privileged method to consolidate the ceramic body is by brushing (57%) followed by immersion (20%) and spraying (17%) and finally immersion using vacuum with 7% of the responses of the specialists (n = 40). For this treatment phase the specialists chose acrylics and ethyl silicate as the most used materials (Fig. 6). The most commonly used products remain the Paraloid® B72 followed by Tegovakon® and WackerOH100®, Nanolime and Nanosilica. The solvents, depending on the products chosen, are acetone, ethanol, white spirit, diacetone alcohol, water and isopropilic alcohol.

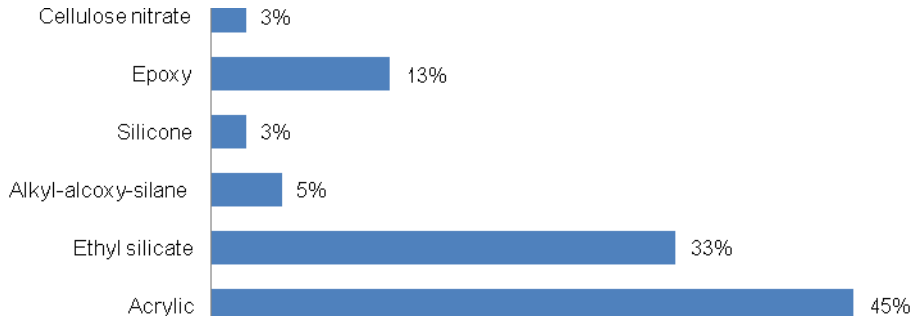

Fig. 6. Materials more often used by specialists for consolidation of the ceramic body (n = 39).

Volumetric Reintegration

For volumetric reintegration the specialists were asked to choose from different solutions presented accordingly to where the tiles are located – indoors or outdoors. The results are in Table 2. Before filling the lacunae, 41% of the respondents (n = 41) apply a barrier layer of a reversible resin on the lacuna surface, 32% just clean the surface, 20% did not specify any treatment while 7% do not perform any treatment on the lacuna surface.

Table 2. Types of volumetric reintegration depending on the location of the tiles (indoors or outdoors).

Types of volumetric reintegration	Indoors (n = 33) (%)	Outdoors (n = 34) (%)
Manufactured ceramic replacement fragments	10	19
Commercial filling materials ("ready to use")	40	25
Fillers formulated by the professional (binder + aggregate)	46	46
Other	4	10

The type of tile also affects the selection of the fillers to be used. In general, the most used fillers are the ones formulated on site, but for industrial and semi-industrial tiles the choice is in favour of commercial ones and the manufactured replacement fragments were reported to be most used in hispano - mouresque type, reflecting a highest concern with more ancient tiles.

Regarding the kind of binders and aggregates used for preparation of fillers on site, aerial lime is the prevailing followed by hydraulic lime, epoxy and acrylic resins (Table 3).

Table 3. Binders used to formulate fillers on site and distribution of the aggregates chosen by the specialists accordingly to the type of binder and expressed by preference order.

Type of binder	(n = 27) %	Aggregates
Aerial lime	29	fine grained sand, followed by silica powder, calcium carbonate powder and marble powder
Epoxy resin	19	silica powder, calcium carbonate powder, titanium oxide powder and marble powder
Hydraulic lime	18	fine grained sand, marble, calcium carbonate powder and silica powder
Acrylic resin	17	silica, calcium carbonated powder and fine grained sand
Plaster	9	calcium carbonated powder and marble powder
Vinylic resin	4	silica powder and glass microspheres
Polyester resin	4	calcium carbonated powder and silica powder

The commercial fillers mostly referred are Miliput®, Aquaplast® Universal and Hantek®. There were also references to the use of Aquaplast®Cima and Exterior, Ledan® C30, Polifilla®, Altek®, Rasostuc®, Modostuc®, Araldite®, Esoduro®, Thin Fill 55® and Costum System 45®, DAP® and Vicat prompt cement®.

Chromatic Reintegration

In relation to chromatic reintegration, 57%, of the respondents (n = 37) have chosen mimetic reintegration and 43% differentiated chromatic reintegration. Regarding the techniques of chromatic reintegration (n = 37), the sub-tone is the most used (34%), followed by *trattegio* with 20% and then free hand (18%), *velatura* and *pontillism* (both with 14%).

Regarding materials for the chromatic reintegration, commercially available acrylic paints and prepared resin-bonded pigments are the most commonly used (Fig. 7).

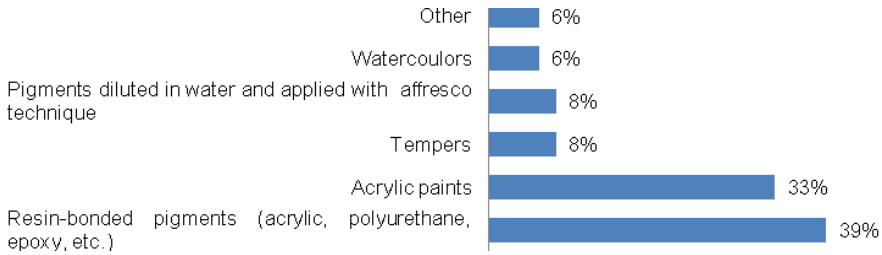

Fig. 7. Materials used to perform chromatic reintegration (n = 37).

Some examples of materials used for chromatic reintegration were named by the specialists: Rembrandt® acrylic paints, silicate paints, mineral pigments agglutinated in Paraloid® B72, Incralac®, Graniver®, Hxtal Nyl 1® and copaiba oil.

Final Coating

The materials most commonly used to protect the chromatic reintegration with a final coat are acrylic resins (Fig. 8). Within the brand names of products used for the final coating are Paraloid®B72, Hxtal Nyl 1®, and Microcrystalline wax, Primal® AC33, Wacker 290®, Bluesil 224®, Golden MAS® and Avalure®. Acetone, white spirit, water, ethyl silicate, xylene and toluene are the solvents referred, depending on the products chosen.

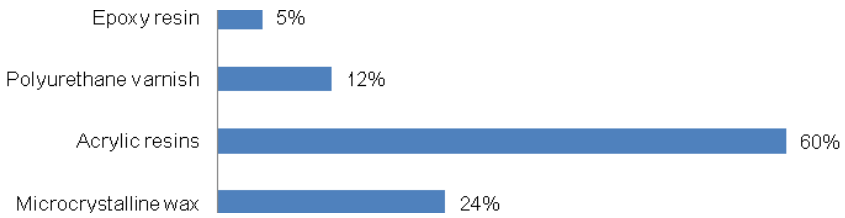

Fig. 8. Materials used to final coating (n = 42).

Replicas

When there is a need to replace original missing tiles with replicas, about half of the specialists require the support of a ceramicist and the other half do their own replicas (n = 36). Specialists (n = 36) give preference to replicas with similar appearance to the original tiles, when it comes to tone, brightness and defects (68%) and just 32% prefer replicas with approximate composition to the original (glazed layer and ceramic body). In relation to the reintegration criteria used in the replicas (n = 34), 59% prefer a mimetic reintegration and 41% differentiated. Regarding replicas production the choice of the specialists are expressed in Fig. 9.

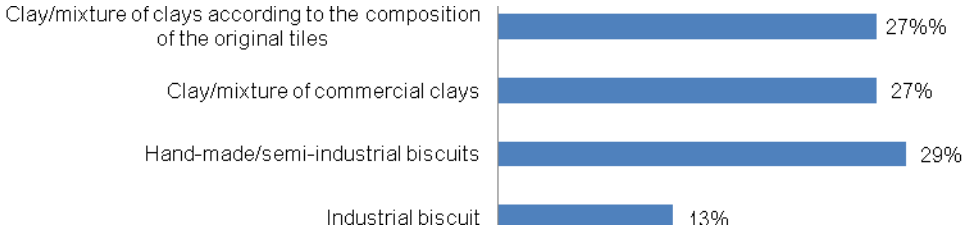

Fig. 9. Different kinds of replicas production (n = 34).

Resetting Mortars and architectural support treatments

50% of the respondents reveal that joints between the tiles are preferably always repointed and 47% depending on the case, but 3% of the respondents (n = 38) never repoint the joints between the tiles. The most commonly used binders for resetting mortars are aerial lime, with 40% of the answers followed by the mixture of aerial and hydraulic limes (33 %) and just hydraulic binders (27 %) (n = 32). Considering treatments on the architectural support the respondents (n = 28) refer desalination (21%) and treatments against bio colonisation (22%), 29% report situations of consolidation of original mortars and the treatment of loss of adhesion between the setting mortar and the roughcast mortar (29%).

Influential factors on material/product choices

In order to know how certain factors influence the choice of materials/products for some treatments and how their importance depends on the type of treatment, the specialists were asked to rank from 1 to 5 (where 1 means less important and 5, more important) the various factors that can influence that choice. Table 4 presents these results.

Table 4. Influential factors that affect the material selection for each phase of treatment and its ranking from 1- less important; to 5 - more important.

		In selecting materials for:					
Influential Factors	Ranking Average	Consolidation	Bonding fragments	Volumetric Reintegration	Chromatic Reintegration	(Re)Setting Mortars	Final Coating
Compatibility	4,8	4,8	4,8	4,8	4,6	4,7	4,8
Durability	4,6	4,6	4,5	4,7	4,7	4,6	4,8
Location (indoors/outdoors)	4,4	4,2	4,5	4,5	4,6	4,3	4,5
Reversibility	4,2	3,7	4,4	4,4	4,2	4,4	4,3
Aspect	4,1	3,9	3,8	4,4	4,6	3,7	4,5
Easy application/product characteristics	3,7	3,6	3,5	4,1	3,9	3,6	3,9
Type of tile	3,7	3,8	3,7	3,9	3,6	3,7	3,5
Toxicity	3,5	3,5	3,6	3,6	3,4	3,3	3,5
Availability	3,4	3,3	3,4	3,4	3,5	3,4	3,5
Price	2,8	2,7	2,6	2,9	2,8	2,8	3,0
2,5 - 3		3,1 - 3,5		3,6 - 4		4,1 - 4,5	4,6 - 5

Although the *Durability* (efficacy retention with time) has been identified as one of the most influential factors, when selecting materials/products for distinct treatment phases, in practice it is not, actively checked as denoted by the lack of treatment monitoring with time (Fig. 3). Both *Reversibility* and *Compatibility* are basal concepts of preservation and restoration; however, both theoretical principles are subjective, difficult to operationalise and to quantify. The *Reversibility* factor implies some degree of reversibility and, at the same time, the possibility of future treatment when, and if it becomes necessary. The *Toxicity* factor got low values, even, if it is increasingly considered to be one that most affect the choice of any material or method of C&R. This is particularly meaningful if we consider the increase of occupational diseases due to excessive use of materials and products with high toxicity.

The *location (outdoor or indoor) of the tiles* may influence the choice from the standpoint that the materials exhibit different behaviours in the presence of different weathering

conditions that will influence their durability. The *Type of tiles* can also influence the behaviour of the different materials used in C&R interventions because different compositions and production techniques of the ceramic body and of the glaze, lead to specific tile properties such as different porosities, thermal and hydric expansions, water absorption and water vapour permeability and consequently to different environment behaviour and mechanical resistance that should be considered when choosing the treatment materials.

Considerations about the survey

In relation to the survey itself there are some considerations that might influence the final results: the close-ended questions facilitate the processing of the collected data but may limit the "freedom" of the respondent and, on the other hand, the open-ended ones allow the specialists to express their specificities but also to diverge from the scope of the question; it has the risk of free interpretation of the questions different from the original intention; terminology problems, and its extent may have led some specialists to quit before completing the questionnaire.

Conclusions

The survey reached a significant amount of specialists engaged in *in situ* preservation and restoration of tiles, being answered by over 400 persons (51 completed all questions) from different countries. The specialists contributed with their knowledge and know-how in order to gather information about the materials and procedures currently used in preservation and restoration of architectural tiles.

From the information collected through the survey it was revealed that the choice of certain material or product, to perform a specific preservation treatment is nowadays more influenced by the characteristics of the product or materials than by for instance a peer recommendation. Compatibility and durability are the factors that most influence their choice, followed by the location of the tiles (indoors or outdoors) and reversibility. Basic analytical resources are usually used on the characterization and diagnosis of architectural tiles prior to intervention, as well as for identification of microorganisms.

With regard to cleaning treatments, different procedures are chosen depending on the materials to clean: for superficial deposits mechanical processes, detergents and sprayed water are usually used; for coherent materials (concretions) LASER is the chosen method; for residues of paints, mortars, adhesives, etc., the use of solvents (including water) and mechanical procedures are preferred; stains are usually cleaned with poultices and LASER; and for biological colonization cleaning air abrasion (with water and inert particles) are usually applied.

When bonding tile fragments and fixing the glazed layer is necessary, acrylic resins (mainly Paraloid® B72) are by far the most commonly used. For tile matrix consolidation these resins are also commonly applied (followed shortly by ethyl silicates derivatives) and brushing is the preferred application method. For volumetric reintegration of tile lacunae fillers are usually formulated, in situ, by specialists. The filler binder most currently used is aerial lime, mixed with different kinds of aggregates. The chromatic reintegration is claimed by the specialists to be performed in both mimetic and discernible manner with prevalence on the first technique, using commercial acrylic paints or resin bonded pigments followed by an acrylic coating protection. And, when replicas are needed specialists also give preference to a mimetic appearance to the original ones.

The survey revealed a lack of specific training in this field of conservation. The amount, diversity and specificities of azulejo, especially in Portugal, justify an investment in particular training in preservation and restoration of architectural tiles, but this has not been yet achieved. The preservation of this heritage needs specific knowledge and forms of action to mitigate their particular decay factors including their linkage to the architectural support. The knowledge obtained from C&R of general ceramics (such as tiles in a museum context) or stone materials integrated in built heritage is useful and important but not sufficient to be directly applied to the C&R of architectural tiles. The preservation and restoration of architectural tiles should, therefore, be constituted as a field of intervention with defined terminology and specific methodologies for diagnosis and intervention. The benchmarking of what materials and procedures specialists are actually using in the field is crucial to aid research on this field and optimize - develop better treatments for future interventions.

Acknowledgements

The authors wish to acknowledge Fundação para a Ciência e Tecnologia for financial support: Doctoral Grant (SFRH/BD/65824/2009) and CerAZUL Research Project (PTDC/CTM-CER/119085/2010) and also to all the participants, since without their contribution this study would not have been possible.

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Received: May, 05, 2014
Accepted: January, 30, 2015