UNIVERSAL DESIGN APPLIED TO CERAMIC TILES FOR ACCESSIBILITY

[1]ZURBA, Nadia Khaled; [2]DISCHINGER, Marta; [3]ALARCON, Orestes Estevam.

E-mail: [1]nadiazurba@bol.com.br ; [2]mdisch@arq.ufsc.br ; [3]orestes@materiais.ufsc.br.
Universidade Federal de Santa Catarina, Florianópolis, Santa Catarina, BRAZIL.

ABSTRACT

The study and development of ceramic tiles based on an interdisciplinary programme that includes the fields of architecture, industrial design and materials engineering are intended to support the creation of ***ceramic flooring for accessibility****, prioritising sustainable design, and attending to social, cultural, environmental and economic needs. The application of the principles of Universal Design in the development of new ceramic tile products for pedestrian flooring, considering accessibility to be an essential attribute of the project, is intended to provide comfort and safety for handicapped users and contribute to their social integration.*

At the same time, requirements concerning production, quality and maintenance are considered, with a view to achieving sustainable design. The flooring at issue has texture, profiles, colour contrast and sound characteristics that enable people with a visual handicap to perceive tactile, sound and visual stimuli, thus contributing to their autonomy and independence in spatial orientation, providing accessibility on pedestrian paths. In addition, ceramics is a high-performance basis material due to its physical and mechanical properties and tribological system, as well as its means of application, enabling greater durability and maintenance of its physical and functional characteristics.

To better understand the point at issue requires awareness of the dimension of the problem in a global context. According to the UN World Action Program, as a result of mental, physical or sensorial handicaps there are at present over 500 million handicapped people worldwide, who should have the same rights and opportunities as other human beings. These people are very often forced to live in disadvantageous conditions because of physical and social barriers that prevent their access and participation. In this context, Universal Design acts as a design process that ranges in its search from conception to the creation of spaces and products with potential use and adaptation for all users, taking into account their abilities and limitations, thus promoting accessibility and integration.

This research is based on a Design Process Methodology and Classification of Flooring for Accessibility – MECLAPA, in which the principles of Universal Design have been applied to the creation of new products. The stages of product design, prototype development, pre-industrial tests, technical certification and industrial production have been planned and are currently being carried out. In the field of architecture, formal studies have been conducted on combining floorings and treating pedestrian paths, in which accessibility is the pivotal factor of the project. In the field of materials, in-depth studies are being conducted of ***Porcelain Tile*** *as a basic material for Ceramic Flooring for Accessibility – CFA.*

Regarding the results to date, products have already been manufactured on a semi-industrial scale. This will be followed by the creation of pilot areas in internal and external environments, with application of ceramic flooring for accessibility, with testing on use by groups of handicapped persons. It is hoped that the present study will help disseminate the principles of Universal Design applied to the development of new products, particularly ceramic materials, and contribute to future research.

Keywords: *Universal Design; ceramic tile; accesibility.*

1. INTRODUCTION

Spatial accessibility can be understood as the set of environment conditions that allows locomotion, reaching and undertaking activities in urban spaces in a comfortable, individual and safe way[5], which can be favoured by the flooring of pedestrian routes. Individuals with limitations relating to mobility, perception, cognition, and lack of appropriate environmental conditions can be seriously restricted in their accessibility, adversely affecting their conditions of access to citizenship. To better understand this point, according to the UN World Action Program[9], as a result of mental, physical or sensorial handicaps there are at present over 500 million handicapped people worldwide, who should have the same rights and opportunities as other human beings. These people are very often forced to live in disadvantageous conditions because of physical and social barriers that prevent their access and participation. Considering this global reality, in Brazil alone an estimated 24,600,256 inhabitants have some type of handicap according to the IBGE[7], which corresponds to approximately 5% of the world population of handicapped persons, according to the above UN data.

In this context, dealing with accessibility in pedestrian walkways is desirable for all the user population, and particularly essential for bearers of some handicap, as they are most affected owing to their special needs, which restrict their full access. Thus the principles of Universal Design were applied in this study[10], which can be defined as the design of products and environments to be used by the greatest possible number of people of all ages and abilities. Universal Design is consistent with human diversity and promotes social integration of all people in all walks of life.

The present study is based on two researches conducted between 1996 and 1998, through a co-operative agreement between Universidade Federal de Santa Catarina (UFSC) and the Instituto de Planejamento Urbano de Florianópolis (IPUF), co-ordinated by professor Marta Dischinger of the Department of Architecture and Town Planning, in which I participated with scholarship of scientific initiation. The first study, entitled *"Acessibilidade no Centro de Florianópolis"*[4], was designed to evaluate the accessibility conditions in the historical centre district of the city of Florianópolis, focusing on use by handicapped persons, particularly those with visual and motor disabilities. In 1998, a second work was initiated in the form of Technical Consultancy, aimed at establishing and projecting a pilot area for intervention to increase accessibility in the pedestrian pathways of a pilot area. The project, entitled *"Projeto de Revitalização das Ruas Esteves Júnior e Álvaro de Carvalho"*, led to the elaboration of an experimental project for the reconstruction of the public walkways of two streets in the centre of Florianópolis.

Figure 1. View of a street with alerting flooring in concrete next to the kerb.

Figure 2.
Alerting flooring in concrete, broken piece with cuts, surface stains and irregular setting.

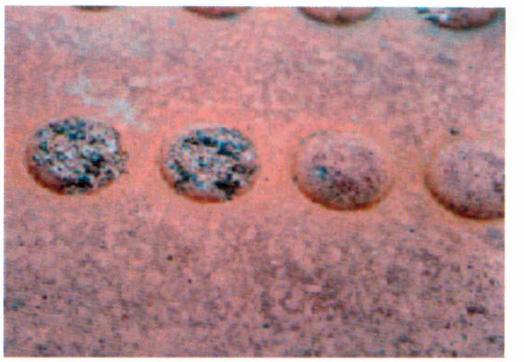

Figure 3.
Alerting flooring in concrete: broken profiles stains and loss of colour.

The proposed technical solutions gave rise to the paging of the walkways with the use of the profiled red alerting walk, set out along the kerb of the street to delimit zones of architectural barriers and urban danger, focusing on use by bearers of a visual handicap. The execution of the IPUF project initiated in 1999 brought to the city a new urban landscape, illustrated in Figure 1, resulting in increased legibility and spatial qualification of pedestrian walks by the use of alerting flooring.

Despite the landscaping improvements caused by the use of the alerting strip, and despite its dissemination in other parts of Florianópolis by a spontaneous process of acceptance by the community, we questioned its application with regard to the material used -concrete slabs- for the present context, as this did not fully satisfy the recommendations of the original project. This is because the flooring does not offer sound contrast as a mechanism of strip identification, which alerts the visually handicapped, since it is made of the same material as the rest of the flooring used in the road. Moreover, the physical and mechanical properties of concrete have exhibited service in urban environments with regard to durability, as shown the illustrations of Figure 2 and Figure 3 This led to the search for a new material that could meet the requirements of accessibility on pedestrian paths.

In view of the problems encountered, new flooring was developed in ceramic material, that satisfied all the aspirations and requirements of accessibility, aiming to achieve superior performance to that of concrete. Ceramic Flooring for Accessibility -CFA[11]– was thus developed in the frame of an interdisciplinary Materials Science and Engineering, Architecture and Design programme. In this context, our objective is to present the application of Universal Design in the conception, materialisation and application stages of CFA, attempting to achieve a greater understanding in the possible use of ceramic tile.

2. DESIGN PROCESS METHODOLOGY AND CLASSIFICATION OF FLOORING FOR ACCESSIBILITY - MECLAPA

The research conducted used the Design Process Methodology and Classification of Flooring for Accessibility MECLAPA[11] -in the development of Ceramic Flooring for Accessibility- CFA. This is based on the lifecycle stages of products, i.e., the understanding that products go through stages like birth, life and death[8]. The design stages of the flooring for accessibility proposed by the MECLAPA include: conception, materialisation, application, evaluation, classification, information, production, distribution, use, certification and rejection, as shown in

Figure 4. The conception, materialisation and application stages proposed by the MECLAPA are discussed below.

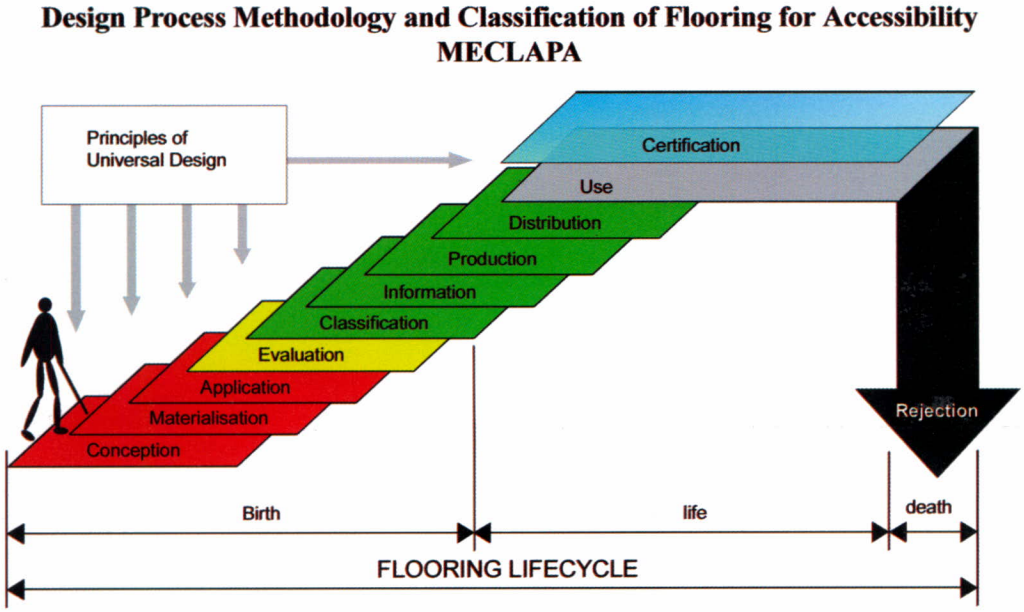

Figure 4. Design Process Methodology and Classification of Flooring for Accessibility – MECLAPA[11].

2.1. CONCEPTION

The conception stage proposed by MECLAPA is based on monitoring the attributes of the idea[6] and consists of defining the language, need for use, cultural assimilation, aesthetic forms and values, and manufacturing feasibility of the products to be developed. This stage has been applied in the development of coverings for accessibility, as described in Table 1.

Attributes of the idea	Ceramic Flooring for Accessibility
LANGUAGE	Ceramic tile as a system of artificial communication for signalling conditions of access
CONTEXT	Application context: external and internal environments of common and private use.
	Scientific context: Brazilian universities with research in ceramic tile and renovation for bearers of handicaps.
	Technological context: Brazil and its industrial ceramic districts.
NEED FOR USE	Accessibility for all users, particularly bearers of handicaps, in harmony with **Universal Design** relating to the reality of bearers of handicaps.
CULTURAL ACCEPTANCE	Worldwide awareness of the reality of bearers of handicaps.
AESTHETIC FORMS AND VALUES	Simple shapes that facilitate understanding by the user. Aesthetic value of **porcelain tile** superior to that of concrete.
MANUFACTURING FEASIBILITY	Compensation by social benefits. Global demand by 500 million bearers of handicaps. New commercial typology of **porcelain tile** for the industrial ceramic sector.

Table 1. Conception stage of MECLAPA: CFA attributes of the idea[11].

After satisfying each attribute of the idea in the ceramic FLOORING for accessibility conception, we proceeded with flooring design through virtual modelling. We began by elaborating the technical design with AutoCAD® 2000i in 2D and 3D, Figure 5 and Figure 6, with a view to setting out the dimensions established by the standard and simulating a three-dimensional idea for paging studies. After

concluding the virtual modelling in a CAD language, a file conversion was made [cdr] using CorelDRAW® 11 software (Figure 7), which was subsequently altered using ADOBE PHOTOSHOP® 7.0 software (Figure 8). The ADOBE programme was an important tool in the conception to materialisation stages of the flooring, due to the similarity of the reading through the numerical command (CNC) for 3D milling with the general programme files, as illustrated in Table 2.

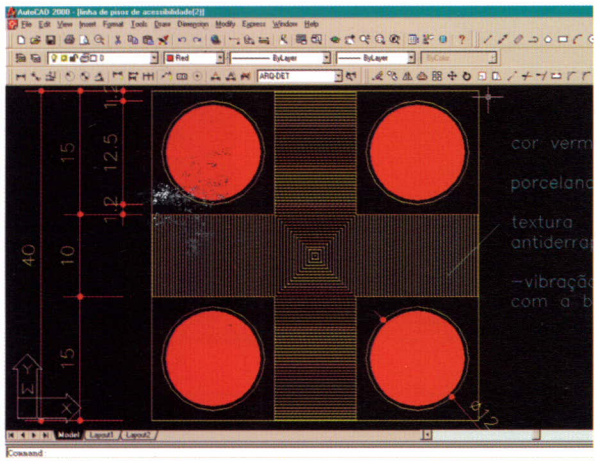

Figure 5. Simulation of cross CFA with AutoCAD® 2000i en 2D.

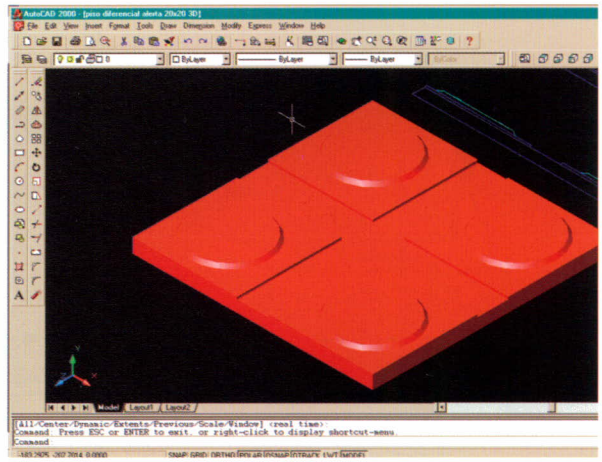

Figure 6. Simulation of CFA with AutoCAD® 2000i en 3D.

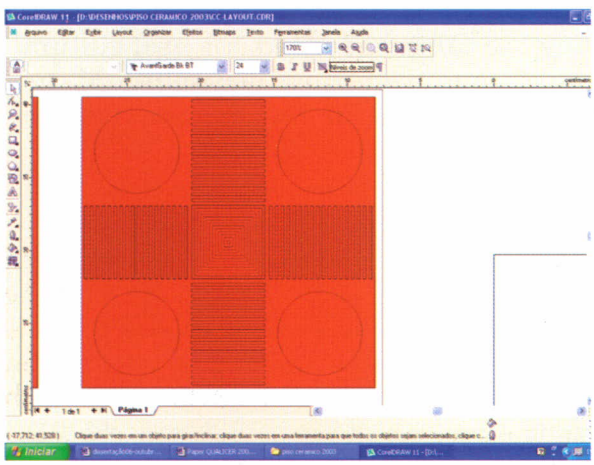

Figure 7. Simulation of cross CFA with CorelDRAW® 11.

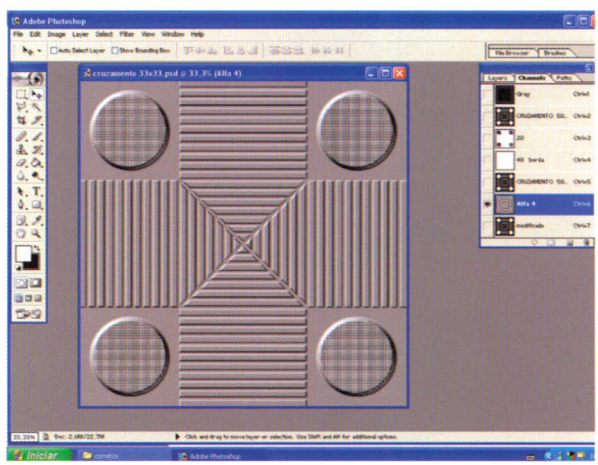

Figure 8. Simulation of cross CFA with ADOBE PHOTOSHOP® 7.0.

Table 2. MECLAPA conception stage: virtual modelling in 2D and 3D[11].

2.2. MATERIALISATION

The materialisation stage proposed by MECLAPA focuses on the **formal properties** of the flooring for accessibility, which includes a group of external structural and functional characteristics that are intended to ensure the flooring meets the requirements of use for the user with comfort and safety, favouring the opening of accessible spaces in which these are to be applied (Table 3).

Formal properties	Ceramic Flooring for Accessibility
SIGNALLING	This informs the pedestrian of the conditions of access along the route. It is recommendable to simultaneously use conditions of danger (alerting flooring and cross flooring), attention (stop flooring) and advance (guide flooring). The information must be readable by all users, in accordance with **Universal Design**.
NON-SLIP	This allows using the flooring with comfort and safety, avoiding slipping by the pedestrian when stepping on the flooring, whether the user stands still or moves, with dry or wet flooring. In accordance with the ANSI A117.1-1998[1], ADAAG 4.29.2 and ASTM C1028 recommendations, we adopted the static coefficient of friction and its value shall be above 0.6 for horizontal surfaces and above 0.8 for inclined surfaces.
TACTILE CONTRAST	This serves to identify the flooring and read the information by touch. The signalling information is read by contact of the feet or walking sticks. The information contained in the flooring can be provided through profiles in the surface, making the difference in texture noticeable between standard flooring of the public walk and the designed path.
SOUND CONTRAST	This serves to identify the flooring and read the information through sound signals. The walking stick or foot contact extracts different sounds from the signalling flooring and the walkway. Materials that have a high coefficient of restitution provide a greater sound contrast. Example: **porcelain tile**.
VISUAL CONTRAST	This allows identifying the flooring and reading its information by visible signals. Individuals with poor sight use the dark versus light visual contrast between the signalling strip and the walkway. The red colour is recommendable for the alerting and cross flooring, because it has a longer wavelength[3] and can be held longer by human sight, during the movement of pedestrians or drivers of vehicles.
DIMENSION	The signalling strip must be dimensioned such that the pedestrian can identify it without any problems as he walks. In accordance with the extent of human gait, the act of dimensioning the single or grouped pieces shall form a signalling strip at least 40 cm wide (ISO/TC173).
DURABILITY	It must provide useful life with regard to the replacement of pieces damaged by use or ageing. Special attention to frost and impact resistance is required for the integrity of the profiles. Materials resistant to wear by deep friction (mm^3) with high bending strength are recommended (N/mm^2) for a longer service life of the flooring.

Table 3 – MECLAPA materialization stage: CFA formal properties[11].

The graphic computation enables interpreting the attributed flooring surface treatment values, and also allows defining the nominal height of the profiles for the preparation of the moulds. Finally, it allows defining the milling approach for the physical prototype in the green mass that will serve as a negative for the preparation of mould in a polymer matrix. Initially we prepared samples of green mass for each type of CFA, which were milled in dimensions of 0.5x33x33 cm in a CNC machine. We then deposited liquid resin on the surface of the samples, which after drying yielded the mould for pressing the prototypes, as shown in Figure 9.

When the resin mould was finished, we made the samples with a porcelain tile body, characterising a pre-industrial production. In order to make the physical prototypes we used 800 kg of commercial porcelain body in the form of spray-dried powder, of which 400 kg was red and 400 kg was yellow. We pressed the pieces measuring 380 0.5x40x40 cm at kgf/cm^2 with a SACMI model PH 555 industrial press, with a cavity and punch of 40x40 cm. The porcelain tile samples were then fired in a roller kiln and subsequently rectified to measure 33x33 cm, which characterises the preparation of the prototypes.

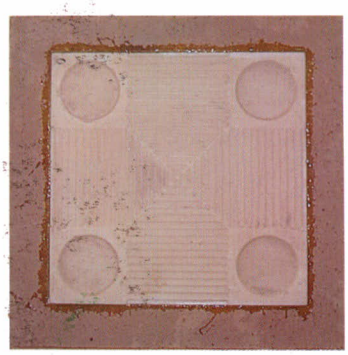

Figure 9. Acrylic resin mould for pressing the flooring.

2.3. APPLICATION

The proposed MECLAPA flooring application stage is in accordance with the paging system and the principles of Universal Design. It serves essentially for tests and evaluation and is characterised as the end of the materialisation stage. The application of the flooring for accessibility can be judged as a project only in theoretical form and must be assessed in its true form in actual conditions, i.e., with the pieces installed in a pilot area for performance assessment.

2.3.1. Paging system

The **paging system** is a process of study and application of flooring for accessibility with a coherent layout, a regular tile installation and good state of conservation. It is a project tool and execution for correct application of the flooring in order to create accessible spaces, as a result of its relation with surroundings, by offering comfort and safety to the users. Through the paging system we better understand the condition of signalling established by the formal properties and the coherence that must exist between the types used on the pedestrian routes. The paging system is shown in Figure 10.

The paging system for urban environments considers the relation between vehicles and pedestrians, zones of great danger for pedestrians, and this accessibility must be controlled. In these situations, in open air zones and areas with public facilities, we must apply the alerting flooring. In the pedestrian strip free of obstacles and with free circulation we have used the guide flooring. In the zones with directing points[12] in the pedestrian route we must indicate them with cross flooring. Some examples of situations of the paging system are shown in Figure 11 and Figure 12.

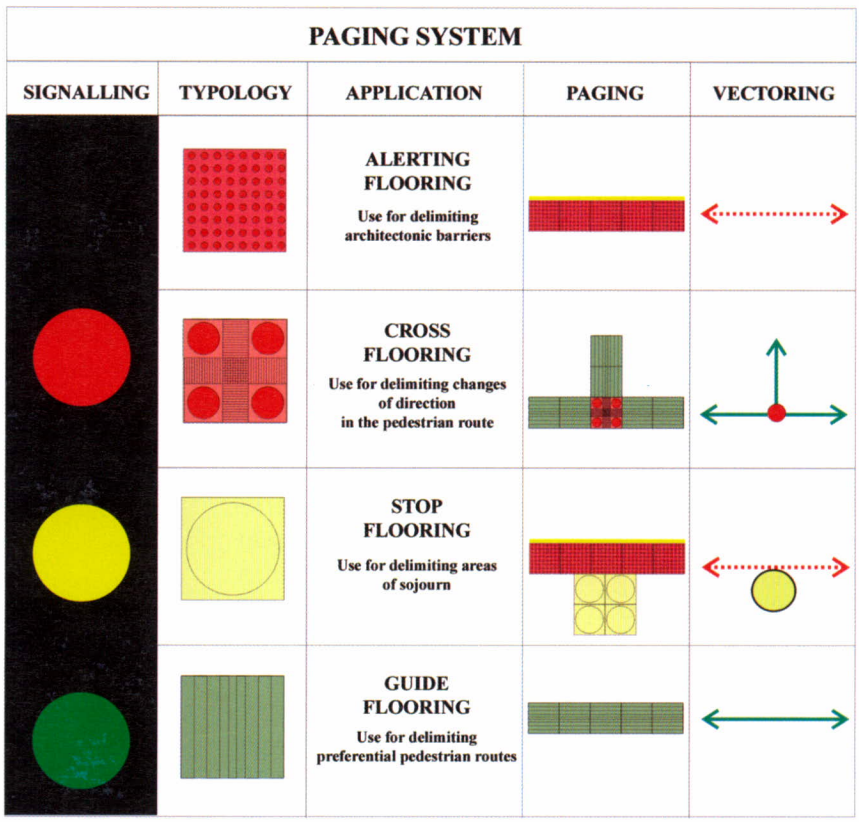

Figure 10. MECLAPA application stage: CFA paging system[11].

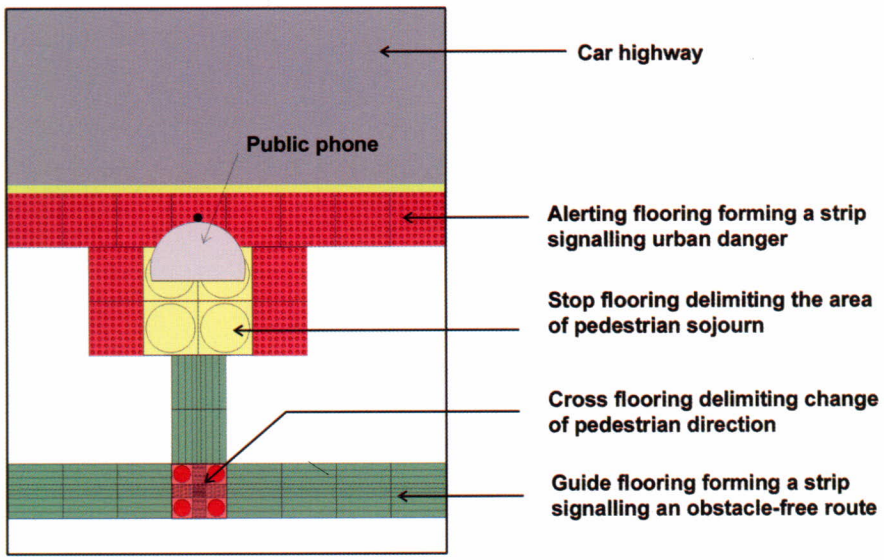

Figure 11. MECLAPA application stage: paging system for the location of a public telephone in urban surroundings[11].

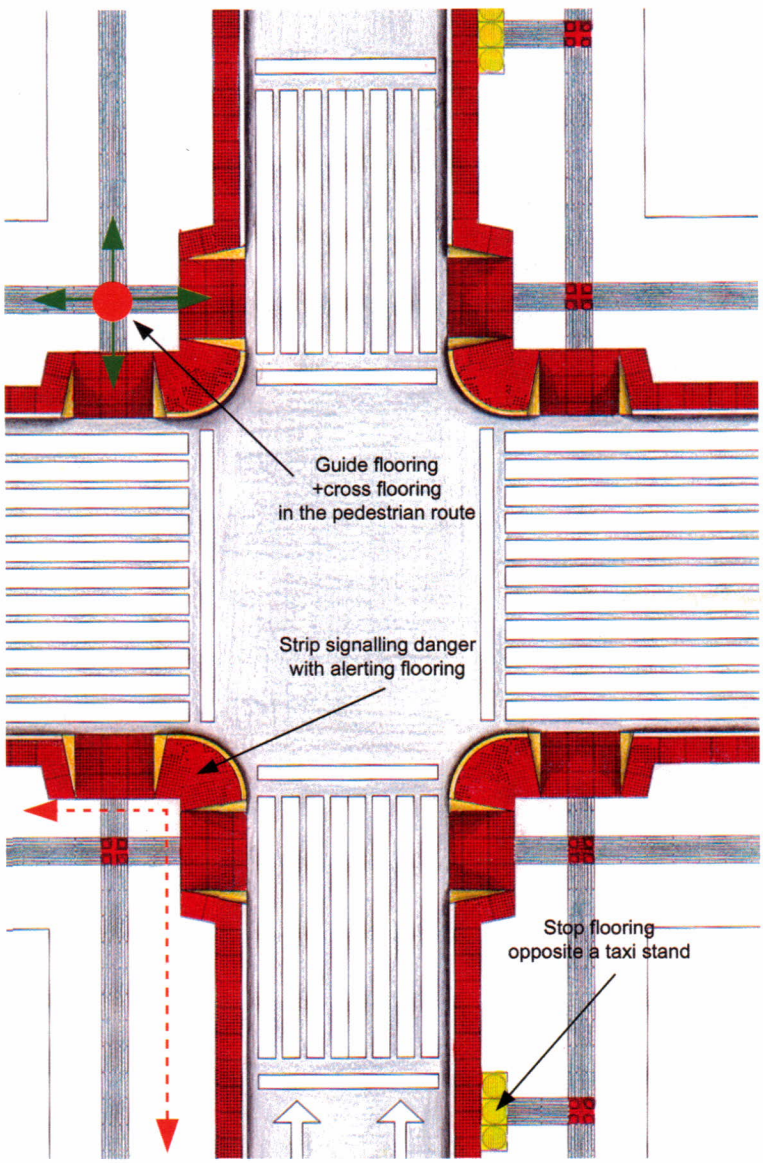

Figure 12. Example of CFA application in urban surroundings, according to the Paging System[11].

2.3.2. *Principles of Universal Design*

Based on the principles of Universal Design[10] we have developed a relation between the user and the environment, favourable for the creation of accessible spaces. The application of the CFA in terms of eighteen principles is intended to encourage accessibility for the greatest number of persons. The seven principles of Universal Design are set out in Table 4.

Principles of Universal Design	Ceramic Flooring for Accessibility
EQUITABLE USE	The ceramic floor tile is usable by people with different abilities. The meaning of the signals must be identical for all users: whenever possible the meaning must be the same and equivalent if identity is not possible. For example, the cross flooring with braille for those with a visual handicap. The flooring should not allow segregation or stigmatisation of the users. It enables individuality, safety and protection in an equitable form and is attractive for all users. .
FLEXIBLE USE	Ceramic flooring respects and fulfils individual preferences and abilities. There are different forms of the application (contact with the feet, walking sticks, and wheelchair). It facilitates the position and acuity of the user.
SIMPLE AND INTUITIVE USE	Understanding the language of ceramic flooring is very simple; it does not depend on the level of concentration or the linguistic abilities of the user. In contrast, it fulfils the expectations and intuition of the user. It organises the information according to its importance: danger, attention and advance. It displays effective and fast responses during and after executing a task.
READILY PERCEIVABLE INFORMATION	The ceramic flooring communicates the information of the signals that the user needs and does not depend on environment conditions or the sensorial abilities of the individual. It offers different forms of communication (visual, sound, tactile) to assure presentation of essential information. It favours the reading of essential information.
TOLERANCE TO ERROR	The ceramic flooring minimises the risks and negative consequences of possible accidental or non-intentional actions. It organises the paths that might contain errors and risks: alerting flooring at the kerb, stop flooring for area of permanence, guide flooring for safe areas. The risk and error warnings are associated with the alerting and cross flooring. They emphasise safety against human mistakes. They stimulate unconscious acts in tasks that demand watchfulness.
REDUCED PHYSICAL EFFORT	Ceramic flooring offers comfort and efficiency with minimum effort. It allows the user to hold a neutral corporal position. The user does not become tired when using it. It reduces repetitive actions. It reduces the duration of physical efforts.
DIMENSION AND SPACE FOR APPROXIMATION AND USE	The dimension and paging space of the flooring are consistent with access, reach, operation and use, independently of the size of the body of users, their posture or mobility. They assure reaching all the components in a comfortable way for all the users, whether seated or standing. They are equipped for differences in the size of feet, walking sticks and human gait.

Table 4. Principles of Universal Design for CFA[11].

The principles of Universal Design are applied in the conception, materialisation and application stags of Ceramic Flooring for Accessibility. Figure 13 shows the list of eighteen principles with the application of the ceramic flooring in the "Urban Transport Terminal of Florianópolis", based on the paging system.

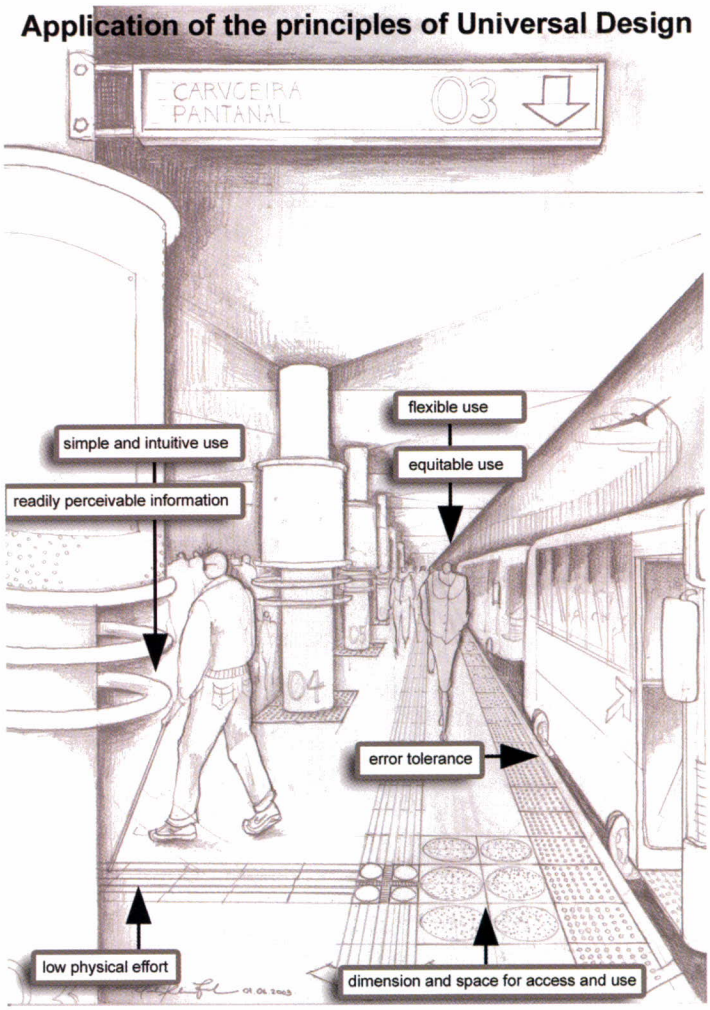

Figure 13. MECLAPA application stage – simulation at the urban transport terminal of Florianópolis[11].

3. RESULTS AND DISCUSSION

After the efforts devoted to solving the problems of accessibility of handicapped persons and enabling the greatest number of persons to benefit from the increased accessibility, the Ceramic Flooring for Accessibility - CFA was developed. Table 5, Figure 14, Figure 15, Figure 16 and Figure 17 show the CFA prototypes in porcelain tile, resulting from the MECLAPA materialisation stage.

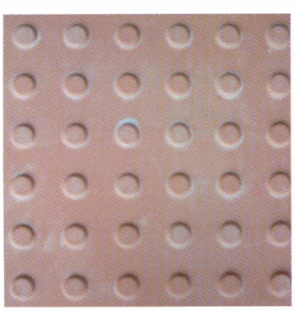

Figure 14. Alerting CFA.

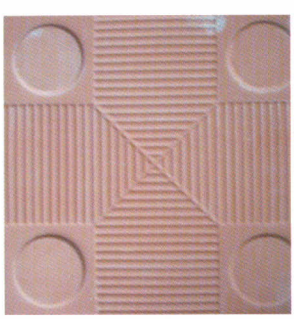

Figure 15. Cross CFA

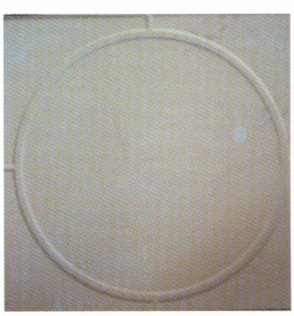

Figure 16. Stop CFA

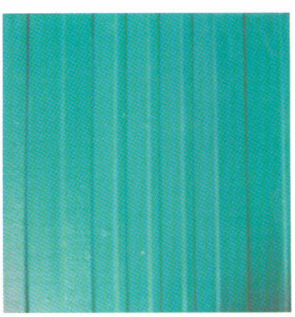

Figure 17. Guide CFA.

Table 5 – Illustrations of the Ceramic Flooring for Accessibility – CFA – developed in porcelain tile[11].

CFAs are ceramic tiles fitted with tactile, sound and visual devices that signal access conditions and order the architectural barriers in the path of pedestrians, with a projected service life that will favour accessibility for all the users based on the application of the Principles of Universal Design[11]. Their use in pedestrian walkways can essentially favour accessibility for bearers of handicaps through surrounding conditions that compensate their mobility, sensorial or cognitive limitations, increasing their opportunities for full social participation.

The discussion of the reality of the handicapped persons in society reflects the social importance of the research. Based on these discussions, ceramic floor tiles were developed that promote increased accessibility in the paths of pedestrians, thus promoting social integration.

The technical and scientific importance of the research, specifically for Materials Science and Engineering, consists in relating the social and environmental needs of handicapped persons to the structure, properties, processing and performance of ceramic materials. In Architecture and Town Planning, it serves as an instrument for use and evaluation of the correct application of the flooring for accessibility in given urban settings. Design contributes understanding of the ceramic tile design process and the projected service life of the product. In sum, the interdisciplinary approach of the research shows the possibility of treating complex social problems –i.e., disabilities– in areas of knowledge with different perspective, which are however scientifically related in their search for a common solution.

The economic importance of this work is reflected in the wide range of end products, particularly the **Line of Ceramic Flooring for Accessibility**. New types of **Porcelain tile**, whose technical dissemination is widespread in Brazil, with uses destined for human health based on real demand with urban applicability on a city scale, are the strong points that are likely to drive the industrial manufacture of these technological products. The ceramic sector will then have increased economical support in the future commercialisation of CFAs.

4. CONCLUSION

The present study enables concluding that Universal Design applied to ceramic flooring for accessibility - CFA - contributes in attending to a greater number of people with regard to their special mobility, cognitive and sensorial needs. In this way, CFAs contribute to the process of social integration, increasing the opportunities of bearers of handicaps, and thus enabling full access to their citizenship.

On the other hand, the principles of Universal Design applied to ceramic tiles in the industrial field can contribute to disseminating the idea of accessibility in this type of flooring, which will stimulate the development of products with superior technical characteristics to the products currently available in the market relating to comfort and safety.

5. ACKNOWLEDGEMENT

- The authors thank "Universidade Federal de Santa Catarina" for the structure for research.

- They also thank "Conselho Nacional de Pesquisa – CNPq", for the financial support,
- "Financiadora de Estudos y Projetos – FINEP", for the contribution of the "Núcleo de Design",
- and the companies "Esmalglass do Brasil" and "Portobello Revestimentos Cerâmicos" for their support.

REFERENCES

[1] AMERICAN NATIONAL STANDARD. Accessible and usable buildings and facilities. ICC/ANSI A117.1-1998. Falls Church, VA: International Code Council, 1998.

[2] AMERICANS WITH DISABILITIES ACT (ADA). Accessibility Guidelines for Buildings and Facilities. 1991. Captura eletrônica: http://www.access-board.gov/adaag.

[3] CALLISTER JR, W. D. Materials science and engineering: an introduction. Wiley: New York, 1999. 5th ed.

[4] DISCHINGER,M. ZURBA,N.K. Acessibilidade no Centro de Florianópolis: análise e recomendações sobre a área urbana central. PMF/IPUF: Florianópolis, 1998.

[5] HANDY,S; NIEMEIER, D.A. Measuring accessibility: an exploration of issues and alternatives. Environment and Planning A, vol. 29, p. 1175-1194, 1997.

[6] HOULDT, J. Theories and Methodologies of Design. Chalmers: Sweden, 1994.

[7] IBGE – Instituto Brasileiro de Geografia e Estatística. Censo Populacional 2000. Captura eletrônica: www.ibge.gov.br

[8] MANZINI,E. VEZZOLI,C. O desenvolvimento de produtos sustentáveis. Editora da USP: São Paulo, 2003.

[9] ONU – Programa de Ação Mundial para Pessoas Portadoras de Deficiência. Tradução: Thereza Christina F. Stummer. Captura eletrônica: www.cedipod.org.br

[10] STORY, M.F; MUELLER, J.L; MACE, R.L. The Universal Design File: Designing for People of All Ages and Abilities. NC State University, The Center for Universal Design, 1998.

[11] ZURBA, N.K. Metodologia do Processo de Design e de Classificação de Revestimentos para Acessibilidade aplicada em Pisos Cerâmicos de Porcelanato. Dissertação de Mestrado em Ciência e Engenharia de Materiais. Centro Tecnológico. Departamento de Engenharia Mecânica e de Materiais. UFSC: Florianópolis, 2003.

[12] ZURBA,N.K; DISCHINGER,M. Acessibilidade no Espaço Público Urbano. ENEPEA – IV Encontro Nacional de Ensino de Paisagismo em Escolas de Arquitetura e Urbanismo no Brasil. Paisagem e Ambiente: Tendências Contemporâneas. UFSC: Florianópolis, 1998.