CLASSIFICATION AND VERIFICATION MODELING OF PEDESTRIAN CROSSING

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Abstract: The requirements demanded for pedestrian crossings, as the meeting point of pedestrian and vehicle traffic, are becoming more and more numerous and to guarantee that they are understandable, employable and feasible for all people in safe and convenient conditions, and in the most natural and autonomous manner (LEY 51, 2003).

Natural stone is a highly demanded material used for covering and surface finishing of public external spaces. However, complying with the increasingly demanding requirements for pedestrian crossings, makes using natural stone much more difficult due to the inherent limitations that this material presents: from the labour-intensive mechanical procedures required to modify its shape, (as it cannot be moulded), to the inability to change its properties by chemical addition.

This situation has been the premise of this investigation, with the objective of establishing a verification model of the functionalities of the pedestrian crossing, in general, and in particular, a verification model which can be used for a pedestrian crossing built with natural stone.

The result is a model that can be used for the verification of the functionalities of a pedestrian crossing. In the process of building this model, the functionalities had to be classified in order to systematize the own verification method by which this classification can be considered as a secondary result of the investigation, even though it was not the main object.

After realizing this investigation it can be confirmed that the functionality of a pedestrian crossing depends on almost a hundred parameters which must be checked or measured, in turn proving that this design and construction process is indeed complex.

Keywords: Accessibility, Pedestrian Crossing, Classification, Verification.

Introduction

The Moscow Declaration emerged from the First Ministerial Worldwide Conference of the United Nations about Road Safety, which took place at the end of 2009, which proposed eleven general action lines for road safety treatment. In particular, line number four says:

 "To develop and to apply policies and general measures for the protection of all people who participate in transit and especially for vulnerable groups"

The protection of those groups, understood as those who, based on the means of transport that they use, (principally cyclists and pedestrians), as well as the physical characteristics of the age group to which they belong, have a greater risk of suffering injuries in case of accident, has become in recent years one of the most important objectives in the international organisms; their safety is considered to be a global public health matter (PARIS, A. et al, 2011).

The present human range, comprised of people with mobility problems, vision, hearing, problems comprehending their own environment and all those people that do not have any of those problems, constitute the reference to design and build new cities, or to transform the ones that exist in the horizon of sustainability. The regulations and the laws, furthermore, demand that they be as such (DEL MORAL, 2010).

All of that brings us to the elaboration of this investigative task, which forms part of a larger study which, under the title of "Design and Technological Conditions of Granada Sierra Elvira Limestone in public streets: pedestrian

crossings"; which is being carried out as an initiative of ONCE (Spanish National Organization of the Blind) Foundation and with the Department of Architectonic Construction of the University of Granada.

Objectives

The object of this research is the pedestrian crossing, understood as the place where both the moving pedestrians and moving vehicles intersect at the same level. Some of these pedestrian crossings have to be surfaced in some of its parts with natural stone. These are not considered crosswalks that are on a distinct level and are neither subterranean nor elevated, because these particular crosswalks present other problems.

The objectives that are considered in the project are the following:

a) The classification of the different pedestrian crossing types is a task required prior to determining the method of verification. One must take into account the different forms in which they can be modified, as the parameters are distinct in the type of pedestrian crossings that we find.

b) The obtainment of a verification method of the functionality of the pedestrian crossing made with natural stone.

Classification of pedestrian crossings

Methodology for the classification

Classification, considered as an activity of reason, can be defined as the division of types, according to the etymological origin of this word, of a diverse and compound group, by means of separation of what is different and the grouping of the similar (SIERRA, 1999).

The main rules for this classification are the following. It must be complete and exhaustive without excluding any element of the whole; each class is mutually exclusive, meaning that no part may be categorized in two

different classes; the criteria for classification must be unique and consistent in all cases of the same classification.

Normally, the application of these rules takes us to a simple hierarchical classification, where the successive establishment of categories and subcategories takes us to the final grouping of the elements in their own classes and subclasses. However, when we tackle the definition of the elements that must serve to classify different types of pedestrian crossings, we find elements, that after making the division, are common as distinctive elements and therefore do not allow a clear grouping by similarities, unless we are redundant in the subclasses that we establish.

This brings us not to suggest an outline of a simple gradual or hierarchical classification, but instead a faceted or multi-hierarchical classification (HASSAN, MARTIN, & MARTIN, 2003). Faceted classifications are used to organize groups of things with enough homogeneity so that they can be described by a definite number of attributes or properties (categories and facets) and their values (pertaining to categories).

The difference between both systems of classification can be explained graphically in the following figures.

Figure 1. Organizational diagram of the simple hierarchical classification and of the faceted classification. Source: own development from HASSAN, MARTIN, & MARTIN, 2003)
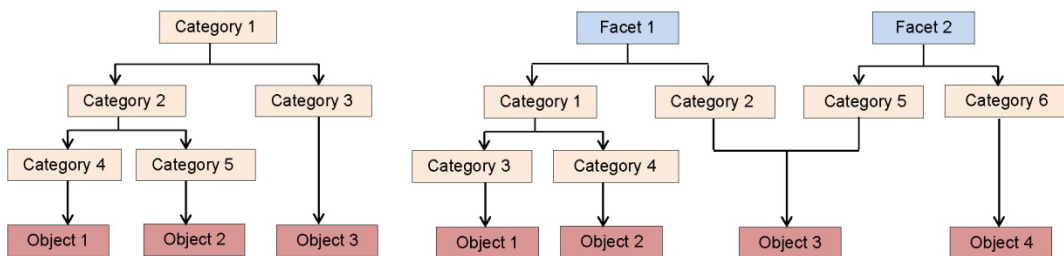
Simple hierarchical classification   Multihierarchical or faceted classification

The faceted classification is different from the simple hierarchical in that the objects are characterized through multiple dimensions or facets; each one of them has its own category group.

Classification of pedestrian crossings

In the case of pedestrian crossings, four groups of facets are found that allow us to characterize them from four different points of view:

A. *The relationship between the pavement and the road.*

    A.1. Pavement and road at the same level

    A.2. Elevated pavement

        A 2.1. In the event of an elevated pavement and to meet requirements for ease of access and movement, the level of the pavement and road must be the same. This can be resolved in three ways:

            A 2.1.1. Build a pedestrian crossing on one level with a dropped kerb with an incline designed to match the elevation of the crosswalk and the pavement.

            A 2.1.2. Build a crossing on two levels: lower the entire pavement to the street level, in which case it is necessary to implement two inclined planes

            A 2.1.3. Build a pedestrian crossing of three inclined levels that converge toward the pedestrian crossing in the street.

    A.3. Raising the road to the same level as the sidewalk in order to provide a pedestrian crossing on the raised platform of the road.

B. *The presence of traffic lights.*

    B.1. Pedestrian crossings without traffic lights or "zebra crossing".

    B.2. Pedestrian crossings with traffic lights

C. The presence of a traffic island.

    C.1. Pedestrian crossing without traffic islands.

    C.2. Pedestrian crossing with traffic island.

        C.2.1 Traffic island placed at the same level as the road.

        C.2.2 Raised traffic island in relation to the road with access ramps.

D. The existence of a cycle lane.

When referring to pedestrian crossings, there are two manners to address the relationship between the pedestrian crossing and the cycle lane.

    D.1. Pedestrian crossing for the cycle lane: the cycle lane is integrated in the street.

    D.2. Pedestrian crossing for cycle track: the cycle track runs along the pavement, and the pedestrian crossing is set back in respect to the road.

Variants

In each of the three solutions of pedestrian dropped kerbs, formal distinctions are established according to if it is a pedestrian crossing in the pavement or if it is on the corner.

According to the dimensional parameters to which pedestrian crossing design must adhere, variants of type are found. By this we mean the solutions according to if it has been designed in conformance with the criteria of the new Ministerial Order of Urbanized Areas (ORDEN VIV/561, 2010), or if has been designed previous to that date and/or if it has been designed under criteria of different autonomic regulations.

It can also have variants of the pedestrian crossing according to the covering material of the footway; concrete, clay or natural stone.

In any case, it has been considered that they are variants of a main type that do not give way to a new type, but a different form of carrying out the defined type.

Method development to check the functionalities of a pedestrian crossing made with natural stone.

Method objectives

The pedestrian crossing is a complex element in the field of urban public spaces. It is not only because it is the space that pedestrians share with the drivers in their vehicle, each one of them with their own distinct interests. It is also because the variety of situations and conditions that can be found in the group that we generally call "pedestrians"; each of them with their own needs and rights. This complexity of the element and the variety of urban situations present when a new pedestrian crossing is implemented create the need of a verification protocol of the functionalities that the element has to answer as a quality control tool of the final result.

In the design of this protocol, special emphasis has been placed in the implementation of the principles of the Universal Design (CDU-NCSU, 1997). This represents an important effort due to the complex nature of the elements and the parameters that have to be taken into account.

Method implementation.

The methodology used to introduce the verification procedure of the functionality of the pedestrian crossing can be broken down in the following processes:

1. To identify all elements of the pedestrian crossing that will be verified.

2. To define the parameters which characterize the identified elements.

3. To quantify the parameter values which will be used as are reference for its verification.

4. To measure the value of the parameter that it is being verified.

5. To compare the measured value with the reference value, to determine if it is adequate or not.

6. Finally, the adequacy levels of the pedestrian crossing values will be verified against the parameter reference values will be presented with expressions of type A/B, being:

   a) The number of parameters of the pedestrian crossing where verification is positive.
   b) The complete number of parameters verified.

The proposed procedure, that in general terms, can be considered the protocol that has to be taken in all the verification procedures and raises a series of questions that are necessary to address.

In step number 1, the exhaustive and indiscriminate elements that can be found in a pedestrian crossing result in a long inventory that can be cumbersome to manage. To simplify this step and to systematize the process, the elements should be organised in groups according to the classification described in the previous section. To do so, it is necessary to introduce a first verification list that we will call "Zero List" and it will become the master list, where the general data of the pedestrian crossing will be stored to allow classification according to the different types. Afterwards, it is possible to choose exclusively the lists that are necessary for the verification.

For example, if after checking the Zero List of general facts and classifications, we ascertain that we have a pedestrian crossing over a raised platform, without traffic light control and without a traffic island, but with a cycle lane, we can exclude several verification list elements that will not appear in this case: verification of dropped kerbs, traffic lights, traffic islands and cycle lane conditions.

The Zero List has a second function, that of verification of the general design criteria of the pedestrian crossing. In the selected example, we mentioned that the pedestrian crossing does not have traffic lights nor traffic islands, so it is not necessary to verify those elements. However, we could find an error in the design, such as that the pedestrian traffic of the crossing might be raised and the distance between the two pavements could be greater, and this, in turn, could require the installation of traffic lights

and the design of an intermediate traffic island. The use of the Zero List during the verification process should point us to these circumstances.

A verification process of the chosen functionality types should not make the process repetitive or question it, as that is not its objective, but to check that the chosen type was the right option among all the suitable potential types, so as to avoid serious design mistakes and, most of all, to detect possible changes in the conditions that were used to formulate or estimate what are termed "great initial determining conditions".

For that reason, during the verification process a verification of the threshold values for pedestrian and wheeled traffic is suggested in order to analyze the uniformity of the design of the footway, its place in the environment and to define the desirable function of the pedestrian crossing in its location, with the purpose of eventually determining the yes/no satisfaction of the functions that have been assigned (IVP-MADRID, 2000).

In steps nº2 and nº3, we find a varied casuistry. The parameter to be checked in step nº2 as the quantification of the reference parameter adopted in step nº3 can be established by different foundations. There are two types of foundation:

a) Legal foundation, which we identify with "L". These come from a norm that has legal oversight, so they are of obliged execution.

b) Practical foundations, which we identify with "P". Specifications from guidelines are included in this group, as the UNE norms. These are not of obliged execution, as the ones that are in the handbooks or sectorial studies. They do not have legal oversight, so they are not of obliged execution. However, they are supported by studies or practice. These are what we call "good professional practices".

For the same parameter to be studied, we can find foundations of different nature in nº2 and nº3. Thus is the case of the "nonslip" parameter of pavements. As a parameter, it is described in all the legal norms that the pavement must be nonslip (step nº2) and so it is based in the legal fundament "L". However, this legal requirement is not measured

quantitatively so the determination of reference values (step nº3) is done in basis of practical fundaments "P".

Step nº4, depending on the nature of the parameter to be evaluated quantitatively or qualitatively, an actual observation of the situation could be required, by conducting some field measurements or researching any documentation to find the desired information.

In step nº5 the reference values are compared to the ones obtained from the pedestrian crossing that is under verification, using a binary number of "0/1", "0" when the verification is negative because the measured valued is not adequate for the reference´s value and "1" when the verification is positive. This way of expressing the results makes the partial sums by groups of verified elements easier, as well as the final global result. There are two more options:

- When it has not been possible to qualify or quantify the parameter that should to be verified. In this case, it will be defined as an "N".
- When the verification of the parameter in the list is not applicable. This option has not been possible to eliminate.

Finally, step nº6 of obtaining results from the verification requires the separation of them into two groups; "AL/BL", for the verified parameters that come from legal requirements "L", and "AP/BP" for the verified parameters that come from good practices "P". In both cases they will be accompanied by all the "N" that have been produced in the verification process, with a final expression, that is not an operable math formula, of the following type:

<div align="center">

AL/BL - NL and AP/BP - NP, where:

</div>

A= number of parameters where verification has been positive or marked with "1", legal "L" or good practices "P".

B= number of parameters that should be verified, according to the chosen verification lists, legal "L" or of good practices "P".

N= number of parameters that could have not been verified, legal "L" or good practices "P".

The final expression is read in the following way:

There have been "A" parameters that have a positive verification, from a total of "B" parameters that have been verified, with "N" parameters that have not been able to be verified.

The following mathematical formula must be:

$$A + N = B$$

A final SUMMARY LIST gives us a global vision of the global verification results, with the following expression:

$$\Sigma(AL)i \ / \ \Sigma(BL)i - \Sigma(NL)i \qquad \Sigma(Ap)i \ / \ \Sigma(BP)i - \Sigma(NP)i$$

Results

The definition of the different types of the pedestrian crossing has generated a classification that helps in their theoretical and practical understanding, as it includes a visual aid catalog that includes most of the situations described in the text. In the appendices of the present article, a sample of the graphics that comprise the catalogue is presented.

By developing a verification model of the pedestrian crossing we have obtained a method that systematically organizes the elements and the parameters that regulate them.

From the application of the verification lists we can point out:

- The zero list is composed of 9 items of selection from the verification lists, where 2 to 4 lists will be used depending on the facets that concern the pedestrian crossing along with 9 checking items from the general conditions of the pedestrian crossing.
- For the verification only two, three or four of the elaborated lists will be used, depending on the type of the pedestrian crossing that will be checked, so that the number of elements to be evaluated ranges from 34 to 37, that are also defined as a whole by a number of parameters that range between 77 and 92.

Conclusion

The complexity of the pedestrian crossing as an element in urban areas has been highlighted, where a high number of elements are involved, which in turn are also regulated by numerous parameters and are difficult to manage in the designing, building and service life span of the pedestrian crossing.

The classification and the verification procedure proposed in this investigation are useful tools to help in the management of those processes.

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APPENDIX

APPENDIX 1.Graphic documentation of the different pedestrian crossing types

It has been considered appropriate to document the different pedestrian crossing types proposed, formulated on the basis of the described criteria, with graphic aids. Although the graphic representation of a concept has the advantage of providing an immediate comprehension of the idea, it has the risk of losing some of the generalities that need to be conveyed, as these details and characteristics of the represented elements must be specified: shape, colours and textures which induce thinking in terms of specific construction systems and materials.

Figure 2 and 3 present samples of the elaborated graphics to illustrate the different pedestrian crossing classifications that have been conducted.

Figure 2. Details of the traffic island at the same level as the driveway (see previous figure C.2.1). Access to the central sidewalk via dropped kerb.
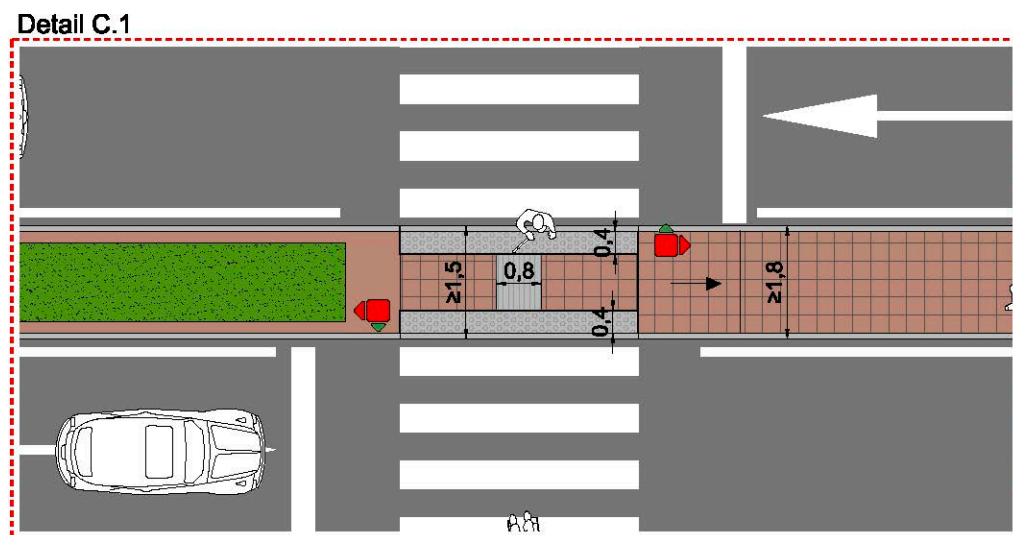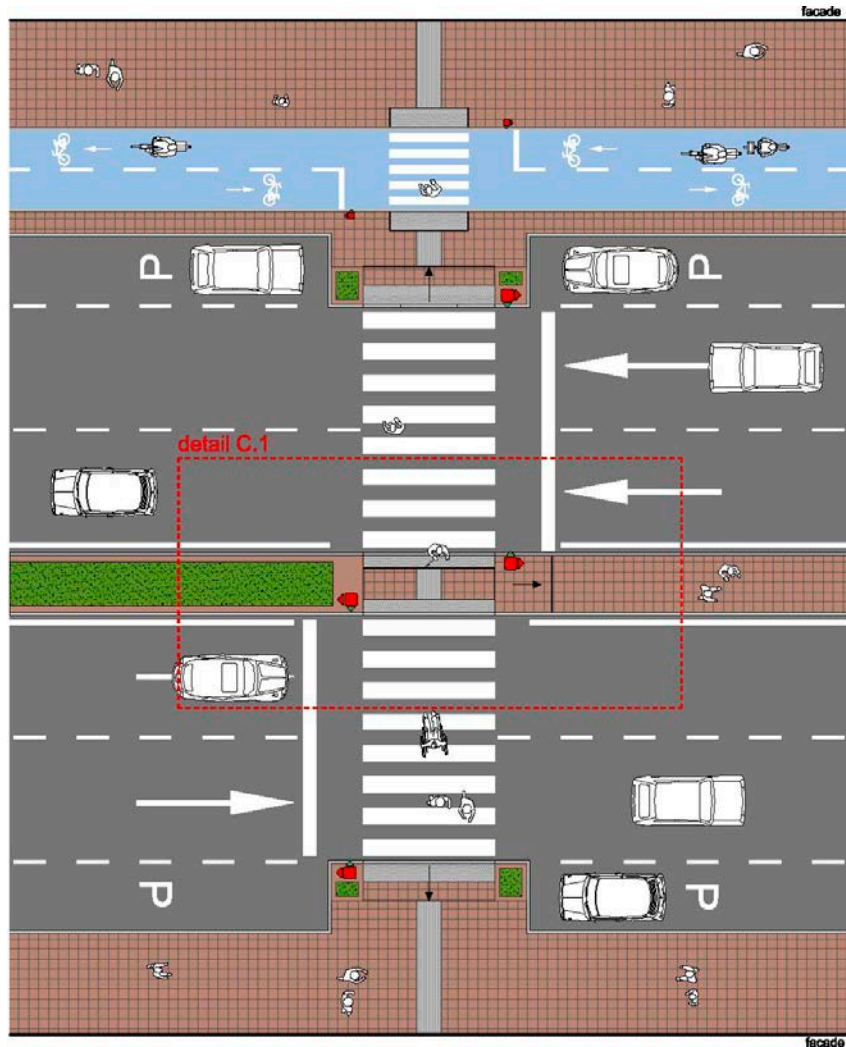
Figure 3. Pedestrian crossing with traffic light B.2 and single-level crossing, A.2.1.1

Traffic island at road level C.2.1.

Cycle track on pavement, cycle track over the pavement D.2. Pedestrian crossing by cycle lane in unique platform (similar situation to the "pavement and street at the same level" A.1)

APPENDIX 2. Verification list

The following is a proposal of Zero List along with an example of an elaborated verification list.

ZERO LIST Selection of verification 'list 0 = Not applicable to do the list 1 = list to be verified			List N°	Check with 0 ó 1
FACET 1: PAVEMENT/ROAD				
At the same level			1	
Raised Pavement	The pavement lowered to the road: ramp	Single level ramp	2	
		Lowered pavement: two plane ramp	3	
		Triple level ramp	4	
	The pavement is raised to the road: raised platform		5	
FACET 2: TRAFFIC LIGHTS				
With traffic lights			6	
FACET 3: TRAFFIC ISLAND				
With traffic island	At the same level of the road		7	
	At the same level of the pavement		8	
FACET 4: CYCLE LANE				
Pedestrian crossing for the cycle lane: the cycle lane is integrated on the street. This type does not require a specific list because its verification is done according to the relation between the pavement and road, analyzed in facet 1				

ZERO LIST Selection of verification 'list 0 = Not applicable to do the list 1 = list to be verified	List Nº	Check with 0 ó 1
Pedestrian crossing to pavement-cycle lane: the cycle track runs along the pavement away from the street	9	

ZERO LIST General Parameters 0 = The verification is negative. 1 = The verification is positive. N = The verification could not be made.	Check 0, 1 ó N
Pedestrian crossing situated in the natural way of the pedestrian	
Forced crossing by the pedestrian crossing	
Uniformity in the construction and design	
Suitable visibility conditions	
Traffic lights are required	
Traffic island is required	

FACET 1: PAVEMENT/ROAD		NAME OF THE AUTONOMOUS COMMUNITY				List 4	
Raised pavement - Lower the pavement to the road - three-plane ramp							
ELEMENTS / parameters		Value of reference			Measured value	Verification	Comment
		L		P		AL / AP	
		According to O/VIV	Previous to O/VIV				
UNOBSTRUCTED MEASUREMENTS	1. Width	≥1,80 m (1.5 m exceptionally in consolidated urban areas)	≥ 1,50 m, if there is no unique platform. It can be 90 cm in some cases (S/Rgto2009) ≥1,20 m (S/D72/92)				
	2. Height	≥2,20 m	≥ 2,20 m (S/Rgto2009)				
CURB	3. Height		≤ 12 cm (S/Rgto2009) ≤ 14 cm (S/D72/92)				
	4. Type of pavement	Hard, stable, no loose parts or protrusions	Without loose elements pieces, without flanges between them, without an excess of brightness (S/RGTO2009) Changing colour and texture in the corners, bus stops and obstacles (S/D72/92)				
PAVEMENT IN GENERAL (low gradient streets)	5. Sliding safety	Nonslip	Nonslip	To check that at least one of the following parameters: Rd≥35; R11 ó R10/V4; it has superficial irregularities ≥1 mm			