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## **Pavements in Public Urban Spaces**

**Contribution for solutions design and analysis**

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## **Abstract**

The goal of this final year project is to develop a guide of good practices on local streets pavements and surfaces, based in needs of space uses and characteristics of materials.

This guide, organized as a catalogue, will present the relevant characteristics of pavement and surface materials used in urban streets.

For each scale of urban streets were defined plants and cuts “generics”, and were identified needs, depending on traffic/integration, working as a guide of good practices of street arrangement.

There will be presented complementary measures for paving and surfaces, helping to understand materials in a global sense, including consequences of use, application, drain and re-use.

In this comparative analysis it was used ponderative model developed under this work.

For the validation of the theoretical formulation it was developed a case study, at Parque das Nações in Lisboa, where is discussed the applied materials in paving and their adequacy and the conformity with the theoretical analysis.

The crossing of information between the needs of urban spaces and the characteristics of the materials, by a ponderative way revealed to be a simple and effective way, to identify the use purpose of each material. The results of this study are presented in this work.

## **Keywords**

Materials, Pavement, Ponderative Analyse, Street, Urban Street Arrangement, Urban Space

# 1. Introduction

The Pavement is a primordial factor in use and in users behaviour conditioning, for these reasons, it has a high potential in the valorisation of the urban spaces.

Pavement is the structure, constituted by one or more materials, located above or under natural soil, with the purpose of allowing the circulation of different traffics in adequate conditions.

One of the first kinds of pavement was the roman roads, fruit of great engineering work made with various layers that still nowadays can be seen.

In Portugal the most famous kind of pavement is the “Calçada Portuguesa”, that constituting a traditional form of covering, was raised to artistic phenomenon by artists workers whom, had flooded with seas of stones our main squares and arteries.

In the urban space where, due to the increase of functions and constants, the goal is to conciliate transport, leisure and accessibility in commercial, as residential and services zones, it is essential to associate the factors of security, comfort, maintenance and investment costs; in this context the pavement gains a special relief.

The purpose of this work is to provide a support tool in the choice of pavement materials for urban public spaces of local character (local Streets, Local Delivering streets and ways), urban spaces with different requirements but with the common desired levels of perception, comfort and security.

Taking in attention this purpose, it was considered important in a first part to make a theoretical study of materials and urban spaces, and in a second part, a practical study that will validate the information previously collected.

A case study in a place of recognized merit in Lisbon, with a great diversity of streets and pavement solutions; the chosen place was “Parque das Nações”.

First is elaborated a description of urban spaces since the biggest scale (the urban net) till the different spaces that constitute the street, analyzing is diverse users and levels of integration. This information focuses mainly street scale, describing the needs and characteristics of spaces that compose them.

After the description of urban space, it is pertinent to identify the relevant characteristics of pavement materials, each one of them as a specific form of classification. The most common materials in urban space are presented and classified in accordance with the presented methodology.

Following the description of urban space and paving materials, it is possible to cross the information and calculate the scope of application of pavement materials. For these porpoise are elaborated functions able to relate the pavement material data and urban space needs.

In the end of this work it should be possible to get a widened vision of pavement in urban space, and to get a support tool in the space arrangement, as well as in the choice of materials for diverse solutions.

## 2. Urban Space

Urban space is the sum of different spaces, dedicated and adapted to different users (Pedestrian, Motorized Vehicles, Bicycles, etc.). There are two main different urban streets, the “Regulars” that serve buildings and have many kinds of traffic, road, pedestrian, etc; and ways inside gardens and plazas that do not serve buildings and only have pedestrian traffic, each one them with specific characteristics. The regular streets are described in Table 2.1, and the gardens and plazas ways are described in Table 2.2.

### **Diverse Street spaces description:**

**Sidewalk** – space dedicated to pedestrian circulation, must have pedestrian connotation for one better legibility of space. The pedestrian space is divided in sections, two or three bands consonant the width of sidewalk is inferior or superior to 2m. The different sections have different functions and specific characteristics, such as represented in Figure 2.1

The description of the sections is the following one:

- **Service section (Section 1)** – the Band more close to the road, is used for the location of urban furniture, hatchways, illumination, etc. This band, makes the transition between the sidewalk and the way, is a space of transition. In this band an easy opening of ditches is essential.

- **Free section (section 2)** - the second band is destined to the circulation of people, must have at least a width of 1,2m to allow an easy circulation to all kind of pedestrians, and must be free of obstacles. To increase the legibility for blind users it should have tactile signalization on the pavement. A comfortable displacement compels that the inclination must be less than 5 % longitudinally and 2% transversally. This section should have pedestrian connotation and provide a comfortable circulation, through a regular surface, firm and adherent.

- **Access Section (Section 3)** - Existing in sidewalks of great width, is destined to make the transition between the sidewalk and buildings, can be used for commerce support spaces (esplanades, advertising, vegetation, etc.). It should have a pedestrian connotation and the possibility of opening of ditches is valued. This band has the functions of transition and permanence.

**Road** - reserved for the circulation of motorized vehicles. Consonant the scale of the street varies its necessities, the lesser the transport function the minor the comfort and belong feeling necessity. As other urban spaces the material must allow the access to inferior infrastructures.

**Parking /Bus stops** - Spaces reserved for parking or loads/discharges of road vehicles must be structural resistant to the vehicles that use the space and resistant to freed chemistries.

**Cycleway** - Dedicated to the circulation of Bicycles, segregated from the remaining traffics, must have a regular covering that provides a comfortable circulation; situated normally in gardens or streets with big traffic conflicts, guaranteeing the security of users.

**Gardens/Plazas Ways** - Spaces independent from the transport net, exclusive to pedestrian traffic are divided in the same sections that sidewalks with the exception of Section 3 that does not exist, because these ways do not serve buildings. Independence of the urban space allows the use of materials with all types of connotation, because it does not confuse users. The easiness of opening of ditches loses impact; as the ways do not serve buildings have few subsoil infrastructures.

[1] [2]

**Table 2. 1 Deliverer Street, Total Traffic, [1] [2]**

Deliverer Street, Total Traffic				
Use	Segregated		Legend	
Traffic	Total			
Street	Unlevelled			
Road	Comfort	Yes	e	g
	Connotation	Road		
	Hatchways	Yes		
	Parking	Yes		
	Bus stop	Possible		
Sidewalk	Composition	Section 1	a	
		Section 2	b	
		Section 3	c	
	Comfort	Yes		
	Easy Hole opening	Yes		
	Connotation	Pedestrian		
	Urban Furniture	Yes	d	
	Vegetation	Yes	d	
	Hatchways	Yes	e	
Accessibility	Ramps	Yes	f	
	Guiding Pavement	Yes	j	
	Alert Pavement	Yes	i	
Drainage	Impermeable Pavement	Double drainage	h	
Moderation	Raised Crosswalks	Possible		
	Sidewalk Extension	Yes		

**Table 2. 2 Pedestrian Ways for Plazas and Gardens, [1] [2]**

Ways in gardens or Plazas			
Traffic	Pedestrian		Legend
Street	Levelled		
Way	Composition	Section 1	a
		Section 2	b
	Comfort	Yes	
	Easy Hole Opening	N/a	
	Connotation	Any	
	Urban Furniture	Yes	c
	Hatchways	Possible	d
Accessibility	Alert Pavement	Yes	
	Guiding Pavement	Yes	e
Drainage	Impermeable Pavement	Yes	f
	Permeable Pavement	Yes	f

**Pedestrian ways for Gardens and Plazas**



**Figure 2. 1 Sidewalk sections scheme, Adapted [2]**

### 3. Materials

The description of pavement materials was effectuated with a standardized analysis described in Table 3.1; the classification used goes from 1 to 3 where 3 is the maximum grade. The first step is a descriptive analysis that identifies the composition, being followed by a quantitative evaluation that classifies is structural, functional, aesthetic and economic behaviours.

The pavement materials analysed for this work are described in Table 3. 2, being identified the references for each material.

Table 3. 3 was elaborated to favour a better understanding of different pavement materials, that compels all the data from different materials, theoretical acquired and validated in the case study, for an efficient interpretation; the legend is presented in Table 3. 4.

[3] [4]

**Table 3. 1 Characteristics of Pavement Materials**

Characteristics of Pavement Materials			
Composition	Structural and functional	Aesthetic	Economical
Composition	Functional characteristics	Nobility	Price
Continuity	Chemistry Resistance	Potential	Construction Easiness
Materials	Bearing Resistance	Connotation	Mise en oeuvre
Specifications	Drainage		Cleaning
			Hole Digging
			Durability
			Workability

**Table 3. 2 Most Common materials in Urban Space**

Most common materials in Urban space		
Material	Pavement	Reference
Concrete	Slab	[3] [4] [5]
	Flag	[4] [6] [7]
	Block	[4] [6] [8]
Bituminous	Bituminous Mixture	[3] [4]
	Surface Treatment	[3] [4] [5]
Natural Stone	Gravel	[4] [6]
	Flag	[4] [9]
	Block	[4] [6]
	Hydraulically Bounded Small Stones	[4]
	Portuguese Blocks	[4] [6] [10] [11]
Selected Soil	Sand	[3] [5]
Hydraulic Pavement	Stone Wastes	[4]
Ceramic	Tiles	[4] [6]
	Flag	[4] [6]
	Porcelanic Flag	[6] [12] [13]
Wood	Boards and Blocks	[6] [14] [15]
Rubber Pavement	Anti-Impact	[14] [16] [17] [18]



**Table 3. 3 Final Characteristics of materials table**

Final Characteristics of materials table																	
Pavements	Structural and Functional					Aesthetic			Economical								
	Road Comfort	Pedestrian Comfort	Bearing Capacity	Drainage	Oils and Fuels	Weather Conditions	Connotation	Nobility	Potential	Workability	Easiness of construction	Mise en oeuvre	Cleaning	Hole Digging	Durability	Price (€/m <sup>2</sup> )	
Concrete	Slab	3	3	3	i	3	3	d	2	2	3	1	1	3	1	3	38
	Flag	3	3	3	d	3	3	d	2	3	3	2	2	2	3	3	18
	Block	3	3	3	d	3	3	d	2	3	3	2	3	2	3	3	18
Bituminous	Bituminous Mixture	3	3	3	i	1	3	r	2	1	2	3	2	3	2	3	25
	Surface Treatment	3	3	1	i	1	3	r	1	1	2	3	2	3	2	3	11
Natural Stone	Gravel	1	2	1	p	3	3	p	2	2	1	3	3	1	3	2	8
	Flag	3	3	3	i	3	2	p	3	3	1	2	3	3	3	3	60
	Block	2	2	3	i	3	3	d	2	3	1	2	3	2	3	3	35
	Hydraulically Bounded Small Stones	1	2	2	i	3	3	p	3	2	1	1	1	2	1	2	
	Portuguese Blocks	2	3	3	i	3	3	p	3	3	1	2	3	2	3	3	33
Hydraulic Pavement	Stone Wastes	3	3	2	i	1	3	p	3	2	2	1	1	3	1	3	23
Selected Soil	Sand	3	3	1	d	3	2	p	2	1	1	3	3	2	3	2	15
Ceramic	Tiles	1	2	3	i	1	2	p	3	3	3	2	3	2	3	3	13
	Flag	3	3	3	i	1	2	p	3	3	3	2	2	3	1	3	23
	Porcelanic Flag	3	3	3	i	3	3	p	3	3	3	2	2	3	1	3	28
Wood	Boards and Blocks	1	3	2	p	1	2	p	3	3	1	2	3	3	3	2	70
Rubber Pavement	Anti-Impact	1	2	1	d	3	2	p	2	3	3	3	3	3	3	3	53

**Table 3. 4 Table 4.1 Legend**

Table 4.1 Legend								
Grade		Connotation		Drainage		Price (€/m <sup>2</sup> )		Case Study
3	Good	r	Road	i	Impermeable	Cheap	<20	Validated
2	Average	p	Pedestrian	p	Permeable	Average	20<p<40	Not Validated
1	Bad	d	Both	d	Both	Expensive	p>40	

## 4. Ponderative Model

Once identified the needs of various streets scales, and the characteristics of diverse materials, it is possible to cross information and recognize the scope of application of each material.

For a better understanding of materials scope, the spaces with the same characteristics had been grouped, road, sidewalks, and ways. Each one of these groups is divided in different sections that compose them. The adequacy of each material to the different spaces is achieved by the correspondence of the characteristics of materials and the necessities of the sections, using a generic weighed analysis with the methodology indicated in Function 5.1.

$$Clas. = \sum p_i \times Var._i \quad (4.1)$$

Where:

- *Clas.*- scope of application classification grade
- $p_i$ - weight
- *Var.<sub>i</sub>*- characteristics considered relevant grade

## 5. Scope of Application

The results from crossing the validated materials data, and the needs of urban spaces, by the use of a Ponderative Model, are presented in the next Tables, respectively Table 5. 1 Road space, Table 5. 3 Sidewalk space, and Table 5. 4 Way space. For a better understanding the tables legend is presented in Table 5. 2.

**Table 5. 1 Scope of Application for Roads**

Scope of Application for Roads								
	Pavements	Surface Treatments	Arrangement	Delivery street	Local Street	Parking	Bus Stop	Traffic Moderation
Concrete	Slab	Grooves/Incrusted gravel		2	2	3	3	1
		Moulded/Special Figures			2	3	3	2
	Flag	Grooves /Incrusted gravel	Broken Bond	3	3	3	3	1
		Moulded/Special Figures	Broken Bond		3	3	3	2
	Block	Grooves /Incrusted gravel	Herringbone	3	3	3	3	1
			Stretcher Bond		2	3	3	2
		Moulded/Special Figures	Herringbone		3	3	3	2
			Stretcher Bond		2	3	3	2
Bituminous	Bituminous mixture	Flat		3	3	1	1	1
		Incrusted Gravel		3	3	1	1	1
Natural Stone	Flag	Bush-hammered	Broken Bond		3	3	3	2
		Flamed	Broken Bond		3	3	3	2
	Block	Bush-hammered/Flamed	Stretcher Bond		3	3	1	3
			45° Joints	3	3	3	3	2
	Portuguese Blocks	Polished	Irregular		3	3	3	3
Hydraulically Bounded Small Stones				1	3	1	3	
Hydraulic Pavement	Rocks Waste				2	1	1	2
Ceramic	Tiles	Flat	Herringbone		2	1	1	3
	Flag	Flat	Broken Bond		2	1	1	2
	Porcelanic Flag	Flat	Broken bond		2	3	3	2

**Table 5. 2 Scope of application tables legend**

Scope of application tables legend	
Grade	
3	Good
2	Average
1	Bad
	Not Advised

**Table 5. 3 Scope of Application for Sidewalks**

Scope of Application for Sidewalks								
	Pavements	Surface Treatments	Arrangement	Section 1	Section 2	Section 3	Guiding/Alert Pavement	Ramp
Concrete	Slab	Incrusted gravel		1	2	2	1	2
		Moulded/Special Figures		1	2	2	3	2
	Flag	Incrusted gravel	Stack Bond	3	3	3	1	3
		Moulded/Special Figures	Stack Bond	3	3	3	3	3
	Blocks	Incrusted gravel	Parquet	3	3	3	1	3
			Stretcher Bond	3	3	3	1	3
		Moulded/Special Figures	Parquet	3	3	3	3	3
		Stretcher Bond	3	3	3	3	3	
Natural Stone	Flags	Bush-hammered/Flamed	Stack Bond	3	3	3		3
		Polished/Honed	Stack Bond	3	3	3		3
	Blocks	Bush-hammered/Flamed	Stretcher Bond	3	2	3		2
	Portuguese Blocks	Polished	Irregular	3	3	3		3
	Hydraulically Bounded Small Stones			1	2	2		2
Hydraulic Pavement	Rock Wastes			1	2	2		2
Ceramic	Tiles	Flat	Stretcher Bond	3	2	3		2
		Flat	Parquet	3	2	3		2
		Security	Stretcher Bond				3	
		Security	Parquet				3	
	Flag	Flat	Stack Bond	1	2	2		3
		Security	Stack Bond				3	
	Porcelanic Flag	Flat	Stack Bond	1	2	2		3
Security		Stack Bond				3		

**Table 5. 4 Scope of Application for Ways**

Scope of Application for Ways								
	Pavements	Surface Treatments	Arrangement	Section 1	Section 2	Guiding/Alert Pavement	Kinder Gardens	Cycleway
Concrete	Slab	Incrusted gravel		1	2	1		3
		Moulded/Special Figures		1	2	3		3
	Flag	Incrusted gravel	Stack Bond	3	3	1		3
		Moulded/Special Figures	Stack Bond	3	3	3		3
	Block	Incrusted gravel	Parquet	3	3	1		3
			Stretcher Bond	3	3	1		3
		Moulded/Special Figures	Parquet	3	3	3		3
			Stretcher Bond	3	3	3		3
Bituminous	Surface Treatment	Flat		1	2			3
		Incrusted gravel		1	2			3
Natural Stone	Flag	Bush-hammered/Flamed	Stack Bond	2	3			3
		Polished/Honed	Stack Bond	2	3			3
	Blocks	Bush-hammered/Flamed	Stretcher Bond	2	2			2
	Portuguese Blocks	Polished	Irregular	2	3			3
	Hydraulically Bounded Small Stones			2	2			2
	Gravel			3	2			2
Hydraulic Pavement	Rock wastes			2	3			3
Selected Soil	Sand			3	3			3
Ceramic	Tiles	Flat	Stretcher Bond and Parquet	2	2			2
		Security	Stretcher Bond and Parquet			3		
	Flag	Flat	Stack Bond	2	3			3
	Flag	Security	Stack Bond			3		
	Porcelanic Flag	Flat	Stack Bond	2	3			3
Security		Stack Bond			3			
Wood	Boards and Blocks		Stretcher Bond and Transverse	3	3			2
Rubber	Flag		Stack Bond	3	2	3	3	2

## 6. Discussion

During this work execution some limitations emerged, such as the lack of technique equipments to validate all the materials characteristics, or the impossibility of performing them, for example the easiness of opening ditches.

In benefit of the work structure and organization (limited in its extension) much of the collected data was excused in benefit of synthesis. This procedure can justify the fact of some data had been taken as acquired.

Further more, some of the adopted criteria of classification due to its subjectivity, is not totally supported by technique characteristics, an example of this fact is nobility and connotation. To correct this situation it would be necessary to make inquiries to the population. This action was attempted without success, due to time limitation in favour of an easier but at the same time more vulnerable to errors, personal analysis.

The case study did not enclose all the theoretically studied pavement solutions, this implicates that much of the collected data was not validated. In the functions for calculating materials scope, the attribution of ponderative weights and the choice of relevant variables would benefit with a practical validation, which can eventually justify alterations in these parameters.

Being aware of this context and limitations, it was possible to elaborate a work which intends to contribute for a better knowledge of needs in urban spaces, and pavement materials characteristics.

## 7. Conclusion

This work deals with the basic needs of urban spaces and pavement materials characteristics.

In the process of crossing information, it was not used a very rigid approach with a lot of variables, allowing the possibility for changes according to the needs or resources. The followed approach was a more generic one, where only the relevant characteristics were considered, giving the possibility to add variables in the functions, depending on it is final purpose.

This work was able to provide a simplified description of the most common pavement materials in urban streets and a working support on street arrangement, which is confirmed by an extended similarity between streets analyzed in the case study, and theoretically elaborated. This work was able to create a catalogue of paving works good practices for in local streets.

It was regrettably confirmed that the great distinction between theoretically streets and the ones verified in the case study was the total absence of horizontal signalling in the pedestrian space.. Difference that could be easily corrected increasing circulation safety for blind users, allowing the democratisation of space.

In future works developments, it will be interesting: to validate the material scope of application functions; to validate the materials not considered by the case study; and to verify how the presented classification is not too simplified, taking into account the necessary differentiation of the materials.

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